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VOICE FREQUENCY DIALLING OVER TRUNK LINES IN SOUTH AUSTRALIA

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With the gradual conversion of metropolitan and later the larger country telephone networks to automatic operation it was natural that the need for facilities to enable telephonists in manual exchanges outside these areas to dial direct into the automatic networks, would be felt. This gave rise to what are known as direct dialling trunk circuits, on most of which the country telephonist dials into the automatic network in the one direction and the trunk telephonist in the automatic area rings out manually in the other direction.

In the first circuits of this nature ordinary loop dialling was used, the distances being relatively short. This arrangement required relatively simple changes in the existing equipment and apart from increased leakage on these open wire trunk lines, as compared with the ordinary subscribers or junction loops, there was no difference in the operating adjustments, etc. As the system developed it became desirable to dial over longer distances and it was soon found that the limit for loop dialling was passed, making it necessary to use cailho or simplex methods of dialling, which involved the use of the 2-line wires in parallel with a ground return. Still further development necessitated the extension of direct dialling to groups of trunk circuits which were already fitted with phantom circuits or superimposed telegraphs, and it became necessary, therefore, to use the dialling circuits as composite legs using the well-known method in which the four wires of the phantom group provide four D.C. signalling legs as well as three talking circuits. In this case, of course, also, the earth was relied upon as a return conductor.

The use of the earth as a return conductor is subject to considerable disadvantages in practice, for reasons which are fairly well known, possibly the worst feature of the system being the difficulty due to leakage with open wire construction in wet weather. The limits for successful dialling using the composite method of earth return were soon reached and it became obvious that further extension of the principle of direct dialling would involve the use of new circuit features if reliable dialling results were to be given.

Gradual installation of voice frequency repeaters at intermediate stations, and later the use of carrier systems, made it obvious that the future dialling and signalling system would necessarily have to make use of currents which lie in the voice frequency band, that is, between, say, 200 and 2600 cycles per second, instead of the low frequencies and direct currents previously used. The use of signalling systems using voice frequencies meant that signals would go wherever the voice would go, and be subject to the same effects as regards attenuation, amplification, etc.

The first efforts at voice frequency signalling made use of 1,000 cycles per second as the signalling frequency, and as this frequency is in a portion of the band where interference from the voice frequency is inclined to be severe, the receivers were designed to work on a 1,000 cycle tone interrupted at 16 cycles per second, and, in addition, a time delay feature was incorporated, the whole circuit design aiming at making the receiver immune from false operation by voice, the theory being that the voice, although it might contain 1,000 cycle components, could scarcely be expected to contain components of 1,000 cycles per second, interrupted at 16 cycles per second for long enough to release the slow acting relays.

In some countries, on the other hand, 500 cycles per second was chosen instead of 1000 cycles per second, and this was interrupted at 16 cycles per second also. Both the above systems have sufficed for manual ringing between two towns, but are not usable for transmitting dialling impulses, and as a matter of fact, are far from satisfactory even for manual ringing. The adjustments on ordinary voice frequency ringers have always been inclined to be critical, the ringer either operating falsely on voice or failing to operate on legitimate signals.

More recent developments with voice frequency circuits abroad have included features designed to make the receivers immune from interruption by voice, this result being secured by various ingenious devices, and there is now no great difficulty in setting up reliable signalling systems in which bursts of tone of varying durations are transmitted over the line to carry out the essential signalling needs. The tone frequency as mentioned above, lies anywhere between 200 and 2600 cycles per second and the level of the tone transmitted is quite comparable with the levels of ordinary speech passing over the same circuit.

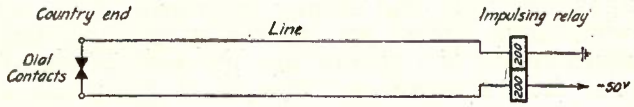

Fig. 1.—Ordinary Loop Dialling.

The tone, therefore, can be handled by intermediate repeaters or by carrier systems just as is the voice band due to the subscriber's speech. This achievement has made it possible to extend the range for direct dialling on trunk lines to an unlimited distance, and to cater for a wide range of signalling requirements. The choice of the frequency to be used for dialling is by no means a simple one, many separate factors having to be considered before deciding on the frequency or frequencies to be used. In some cases the traffic needs can be met by the use of a single frequency only, with others it is necessary to use two separate frequencies, sometimes even four frequencies to provide the necessary combination of signals required.

The use of direct dialling on trunk lines in South Australia received a good deal of attention in recent years following on the conversion of the metropolitan network to automatic working. It was apparent at the outset that very little use could be made of loop, cailho or composite dialling, because the conditions in South Australia were unique in regard to the extensive use that had been made of superimposed circuits for telegraph and phantom working. Practically every pair of wires had a phantom or a telegraph circuit superimposed on it, making it very difficult, if not impossible, to secure any large number of direct current dialling circuits from these wires. The extensive use of voice frequency repeaters and carrier systems provided the final objection to the use of direct current methods so that it was decided to pursue the use of voice frequency dialling as soon as possible. The necessity for the extension of the principle of direct dialling was also brought forcibly to mind by the fact that the existing trunk switchboard was practically full, and it was impossible to extend the switchboard in its present location, and it was equally difficult to secure the new building which would have been necessary. Direct dialling offered the possibility of postponing considerably the time when the trunk switchboard itself would need to be replaced. In addition, the use of direct dialling from country towns speeded up the handling of traffic flowing into the city very considerably as it completely eliminated the incoming telephonist on all such calls and it minimized holding time on the trunk line because the country telephonist would receive instantaneous ringing signals or busy signals as the case might be, and was able to make successive calls very quickly when required, the clearing being automatic as soon as the country end was unplugged.

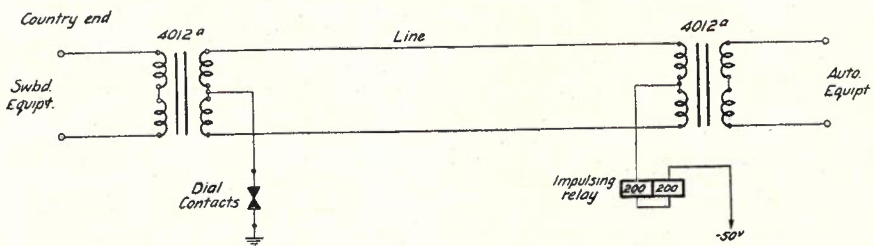

Fig. 2.—Simplex or Cailho Dialling.

The majority of the circuits required to be fitted with voice frequency dialling, were likely to be physical trunks for some years to come, and there was therefore a good deal to be said for the use of a frequency which was as high as possible, to minimize the effects of crosstalk into adjacent circuits. The human ear is not uniformly sensitive to all frequencies, being most responsive to frequencies round about the middle of the band, so that by the use of say 2200 cycles per second a higher level of tone could be transmitted for a given amount of disturbance in adjacent circuits. The use of this higher frequency also had the advantage that immunity from false operation by voice was given for all ordinary cases because of the fact that the energy contained in speech lies mostly below 1200 cycles per second, the higher frequencies contributing very greatly to the articulation, but not appreciably to the volume.

The use of 2,500 cycles per second for voice frequency signalling has been discussed by Philips, the use of this frequency being advocated because of the fact that interference by voice is extremely slight compared with the interference that would exist at, say, 1000 cycles or lower. Experience in South Australia has shown that 2500 cycles per second is rather high for some carrier systems, as it is approaching the limit of the pass band and attenuation is likely to be introduced due to various filters. It is found that the use of 2200 cycles per second proves a very satisfactory compromise between immunity from voice operation and desirable transmission properties over carrier systems. The voice frequency receiver tuned to accept 2200 cycles per second will exhibit very little tendency to operate when loud speech is impressed on the input within the range of speech volumes ordinarily encountered, but exceptional cases have been experienced where loud shouting in telephones can cause interference to the receivers due, apparently, to the fact that the carbon transmitters are seriously overloaded and the resulting harmonic distortion produces components of appreciable energy in the vicinity of 2200 cycles per second.

To provide complete immunity from operation by voice even for the most extreme cases, use has been made in South Australia of a well-known guard circuit principle, which makes use of the theory that speech will invariably contain at least two frequencies simultaneously. The receiver is therefore tuned to accept 2200 cycles per second and to operate the necessary relay, but if any other frequency is present, in addition to the 2200 cycles per second, the guard circuit will operate on this other frequency and will block the receiver, preventing the operation of a relay even though the 2200 cycles tone is present in sufficient amplitude. It is found, in practice, that although speech may contain many components sufficiently close to 2200 cycles to operate the relay, there will always be sufficient amplitude of other frequencies present to operate the guard circuit and prevent false operation.

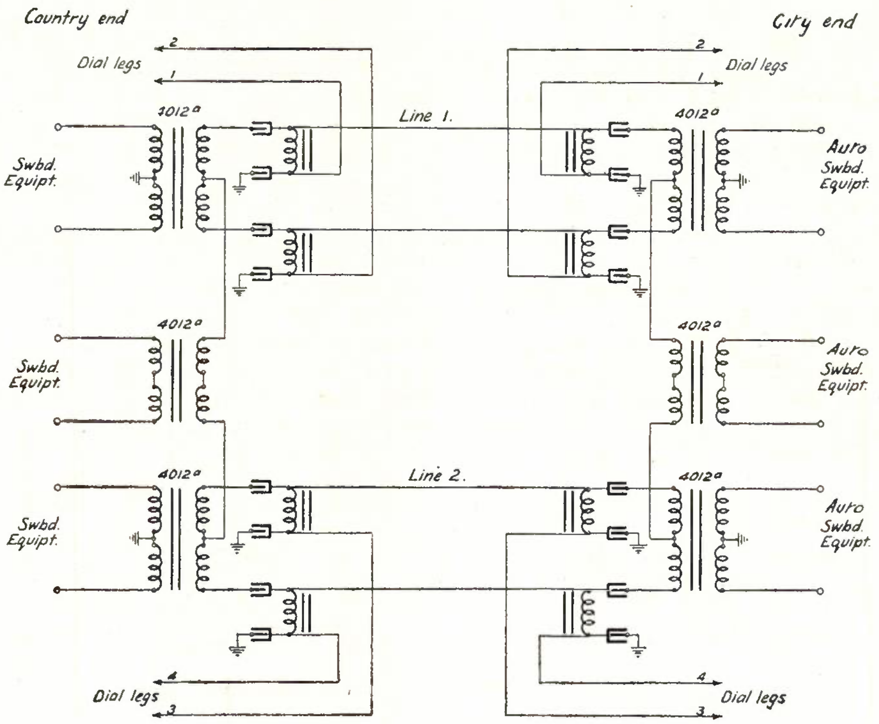

Fig. 3.—Composite Dialling.

The actual application of this guard circuit principle varies with different manufacturers. A typical example is the delivery of voice frequency ringers from Standard Telephones and Cables, on Schedule C.1855. In these receivers the signalling tone of 1000 cycles per second operates the signalling relay, but if any frequency above or below 1000 cycles per second is present, the guard circuit will operate and prevent the signal relay from functioning. The guard circuit takes the form of a special high speed guard relay which operates almost continuously on speech and whose contacts prevent the normal operation of the chain of signalling relays. On receipt of a pure tone of 1000 cycles per second this guard relay does not operate, allowing the normal signalling relays to function.

Receivers in use have been designed with the object of cutting the cost to a minimum and eliminating as many special parts as possible. For this reason the guard circuit feature has been included in the form of a "feed-back" circuit, as this is considered preferable to the inclusion of a special high speed relay which is necessarily costly and rather difficult to adjust. The guard circuit functions to feed-back a biassing voltage to the grid of the first tube to completely block the amplification of the tube if any frequency is present other than 2200 cycles per second.

The complete receiver circuit is shown in Fig. 9. The input circuit is high impedance to minimize transmission loss due to the receiver, which is bridged across the line concerned. The first tube is a 6F7 containing a triode and pentode in the one envelope. The normal bias on these sections is such that ordinary Class A amplification is secured. The output of the 6F7 drives the beam tetrode tube 6Y6G which is biassed to cut off.

The grid circuit of the 6Y6G contains a simple parallel resonant circuit tuned to 2200 cycles per second. The selectivity is adequate for the purpose and on receipt of a tone of 2200 cycles per second the plate current of the 6Y6G rises from zero to approximately 32 milliamps. The gain of the complete receiver is such that with the lowest level likely to be encountered at the receiving end from the distant sending end, the plate current reaches 32 milliamps. Should the line or carrier attenuation decrease or should any other factor change in such a direction that the received level increases, the plate current of the 6Y6G tube does not rise above 32 milliamps appreciably. This automatic gain control is secured very simply by reducing the screen grid potential of the 6Y6G tube to a suitable low value, below the plate voltage, and it is found that this low potential on the screen grid, together with the use of a suitable value of grid leak as shown, will limit the plate current to 32 milliamps over a very wide range of input voltage. This device has given very satisfactory results in service over many months and has eliminated the need for lining up the dialling circuits to cater for changing attenuation. The 6Y6G tube is particularly suitable for the application shown, where the plate voltage is 130. This automatic limiting of the output current depends on the flow of grid current through the grid leak connected to the 6Y6G tube. The circuit arrangement and the choice of valves adopted in South Australia were chosen to provide 30 milliamps, approximately, to enable an ordinary impulsing relay 200/200 ohms of the automatic exchange standard variety to be used directly in the plate circuit, to avoid the use of the special high speed impulsing relays of low inertia and inductance, which are used in some other systems abroad. It was considered that the use of a standard impulsing relay was well worth while if it could possibly be utilized because of the obvious advantages from the point of view of familiarity with standard adjustments, etc., which this relay would confer. Experience has shown that over a very wide range of line or carrier conditions, the "weight of impulse" delivered from the contacts of this impulsing relay lies within the normal limits without any adjustments to the dialling system.

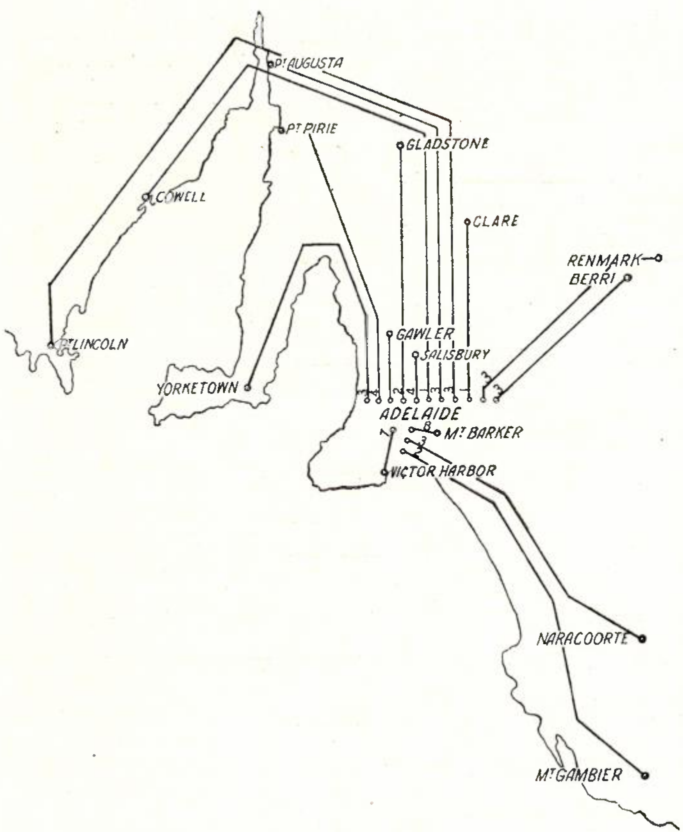

Fig. 4.—Voice Frequency Dialling Circuits, South Australia, as at 30-1-1940.

The circuit as shown, but without a guard feature, is immune from operation by voice for all ordinary conditions but to guard against the abnormal conditions that might occur on isolated cases the guard circuit shown is included. It will be noticed that at the bottom end of the parallel tuned circuit is a small condenser. If a pure tone of 2200 cycles per second is received the impedance of the parallel tuned circuit is very high and the resultant current through it, and therefore, through the condenser at the bottom end of the circuit, is extremely small. In consequence the voltage developed across this condenser is very small. Connected across the condenser mentioned is a full wave metal rectifier, which will consequently not be energized if only 2200 cycles per second is received. If, however, other frequencies are present across the input to the receiver, particularly the lower frequencies below 2200 which are likely to contain most of the energy in speech, there will be an appreciable current through the parallel tuned circuit because its impedance will be much lower to these frequencies and consequently an appreciable voltage will now exist across the series condenser. The metal rectifier will therefore be energized and appreciable direct current voltage will be produced at the output of the metal rectifier and will pass through the simple filter system shown to the grid of the first tube. The gain of this tube will then be reduced much below its normal figure and the net result is that the output from the 6F7 available to drive the 6Y6G tube will be insufficient to operate the relay in the plate circuit. The higher the amplitude of the unwanted frequencies, the higher will be the amount of feed-back supplied, so that, in practice, it is practically impossible to cause false operation of the relay by unwanted frequencies. The filter system shown at the output of the metal rectifiers is designed to provide a definite hangover time to keep the 6F7 tube blocked for a brief interval after the presence of an unwanted frequency. This feature makes the system very safe from interference by unwanted frequencies, particularly of the large amplitude steep wave front variety such as clicks, etc., produced, say, from the automatic exchange loop circuit which is connected through to the trunk line during dialling. Surges due to below the signal frequency where the voltage drop will be greater the lower the frequency. If, on the other hand, it is desired to operate the receiver with a signalling frequency of 600 cycles per second or 750 cycles per second, it is possible that unwanted frequencies of higher values will be present and the reactance of a simple condenser may not be sufficiently high to provide sufficient guard voltage. It is evident that the guard condenser can be replaced by a series resonant circuit, resonant at the desired signalling frequency. The guard voltage will then be developed across this combination at frequencies both below and above the wanted frequency. Ex-

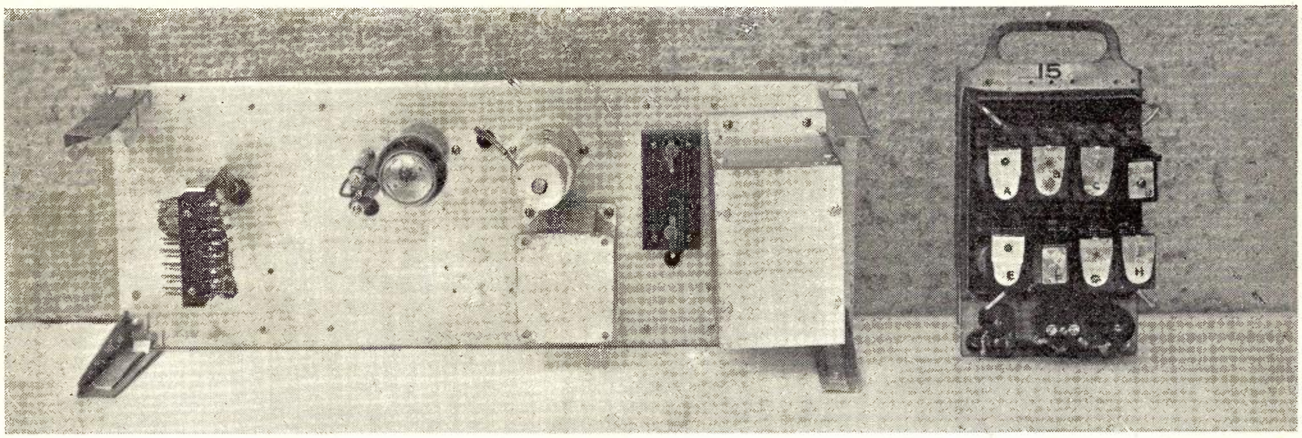

Fig. 5.—Dialling Receiver and Relay Set.

the making and breaking of direct current dialling loops may be very high indeed and one of the greatest difficulties in some voice frequency dialling circuits is to make the receivers immune from false operation due to these loud clicks, etc.

For the reasons mentioned earlier in the article the frequency used in South Australia to date, has been 2200 cycles per second because with the majority of the circuits of the ordinary physical variety it was considered that 2200 cycles per second would be likely to give the least interference from one trunk line to another due to the well-known effects mentioned whereby the ear is relatively insensitive to these higher frequencies. It is evident that cases will arise where the use of 2200 cycles per second would not meet all requirements, and it has been found that the use of the circuit arrangement shown enables the system to be worked with any frequency desired. The only change required in order to use another frequency is to re-tune the parallel resonant circuit to the desired frequency and to change the value of the series guard condenser to another value suitable for the frequency to be used. With the use of 2200 cycles per second a simple series condenser to provide the guard voltage is all that is required, because it is evident that the unwanted frequencies will all be perience has shown that there is no difficulty in dialling and having the receiver completely immune from interruption by voice, while tuned to 600, 750 or 1000 cycles per second and using only a simple series condenser for the guard feature, it being necessary merely to change the value of the condenser for each frequency selected for dialling.

Before the introduction of voice frequency dialling the method of operation on trunk lines was for the country telephonist to plug in and ring manually to Adelaide. When the Adelaide telephonist answered, no supervisory signals were transmitted back, the system depending on the country telephonist remaining on the line until the Adelaide telephonist answered. Similarly, when the city subscriber answered after being rung by the Adelaide telephonist, no supervisory signal was transmitted back to the country end.

On an outgoing call the arrangement was for the Adelaide telephonist to plug in and ring manually and again, when the country telephonist answered, and later, when the country subscriber answered, no supervisory signal was transmitted back to Adelaide. Similarly, when conversations ended, no supervisory signals were transmitted from one end of the trunk line to the other in either direction. As this simple system appeared to meet traffic needs adequately it was considered desirable for at least the experimental period, to dispense with special supervisory signals in the voice frequency system other than the

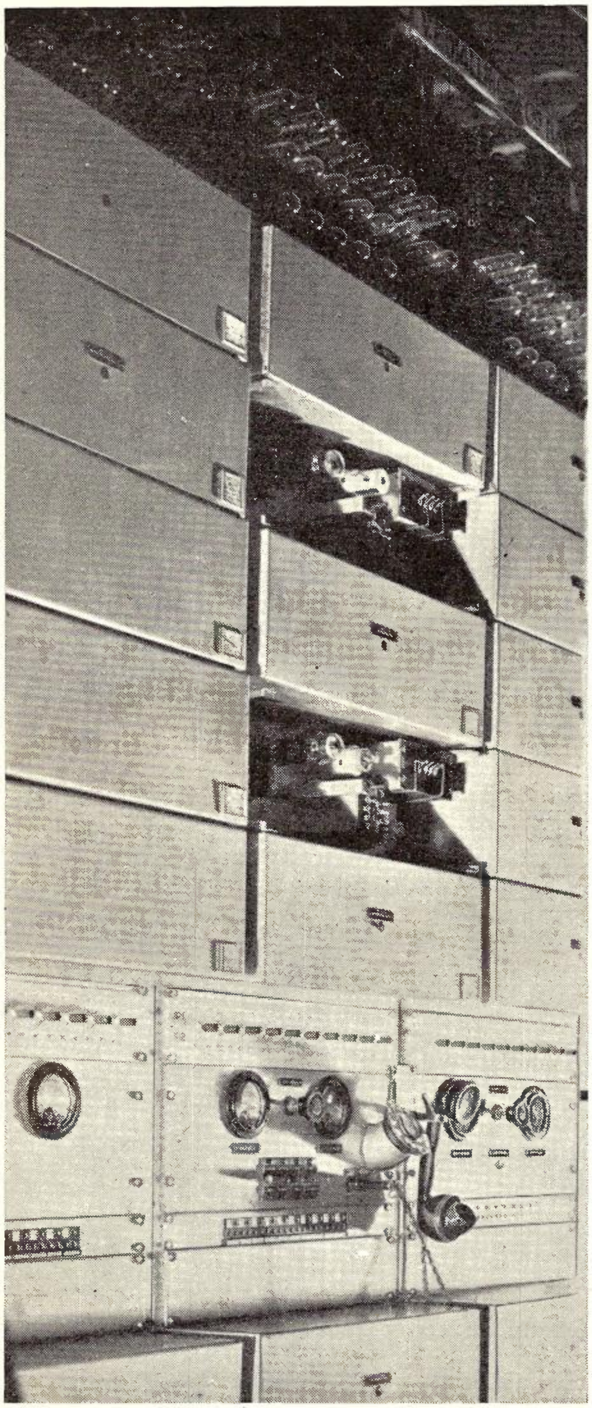

Fig. 6.—Rack Assembly—Front view showing Dialling Receivers, Bias and Test Panels.

usual automatic exchange tones, which, of course, are transmitted over the system.

The existing trunk exchange at Adelaide is a sleeve control type of switchboard in which all the relays for calling and clearing, etc., on the trunk line, are concentrated in a line relay set mounted on an automatic switch base mounting plate on a jack-in basis. It so happened that the mounting plate had accommodation for eight relays, but only five were in use. It was, therefore, decided to make use of these mounting plates and the circuit design was therefore subject to quite a good deal of investigation to arrive at a circuit arrangement which would require not more than eight relays. This limitation rather handicapped the designers, but had the obvious advantages of using existing equipment, saving capital expense and, above all, saving time in obtaining supplies.

The relay group contains eight relays and provides for the country telephonist to plug in and throw the dial key, automatically seize the circuit to the automatic exchange at Adelaide, to receive the dialled impulses consisting of a spurt of tone for each break of the dial, to set up the required conditions for repeating the impulses into the automatic exchange faithfully and to transmit back to the country telephonist the usual dial tone, ringing or busy tones, etc. It provides, also, for the mere withdrawal of the plug at the country end automatically freeing the automatic exchange equipment and setting the equipment back to normal, ready for the next call.

In the outgoing direction the relays provide for the manual trunk telephonist to plug into the multiple jack, and if the line is not already in use the talking circuit is diverted to the tip and ring of the trunk multiple jack, enabling the trunk telephonist to listen on the trunk line or carrier system and to ring over the trunk line by operating the ringing key. The ringing relay, which operates from the sleeve of the trunk cord circuit, feeds any desired frequency over the line depending on the particular line concerned. In some cases it transmits 1000 cycles interrupted at 16, which is received at the country end on a standard 1000 cycle ringer panel. Another relay in the group provides control of a 3 db. pad which is normally in circuit (in accordance with the well-known pad switching scheme) and is switched out of circuit whenever the circuit is switched through to a long trunk line beyond Adelaide, the discrimination being entirely automatic. The pad is not removed from the circuit on calls to automatic exchanges because the present transmission losses in the Adelaide network are such that the removal of the pad is not necessary. Provision is made for the pad to be removed automatically when the called party answers, should such a feature be required later. A reverse current relay which operates on reversal of battery from the automatic exchange is provided for this and other purposes.

At the country end the usual arrangement is to employ an existing 1000 cycle ringer panel to receive outgoing rings from Adelaide. For dialling to the city, an oscillator of 2200 cycles per second is provided and where several operating positions are involved requiring the provision of facilities for several lines being dialled on simultaneously, a splitting amplifier is provided to supply an independent source of tone for each operator. The circuit arrangement is such that the telephonist plugs into the trunk jack, listens each break of the dial a burst of tone is transmitted to line.

The detailed circuit operation is shown in the appendix. The towns at which the equipment and circuits described have been installed are shown in Fig. 4. The route distances range from Adelaide - Salisbury, 12 miles, to Adelaide - Mt. Gambier, 300 miles, and Adelaide-Port Lincoln, 420 miles. On each circuit dialling by means

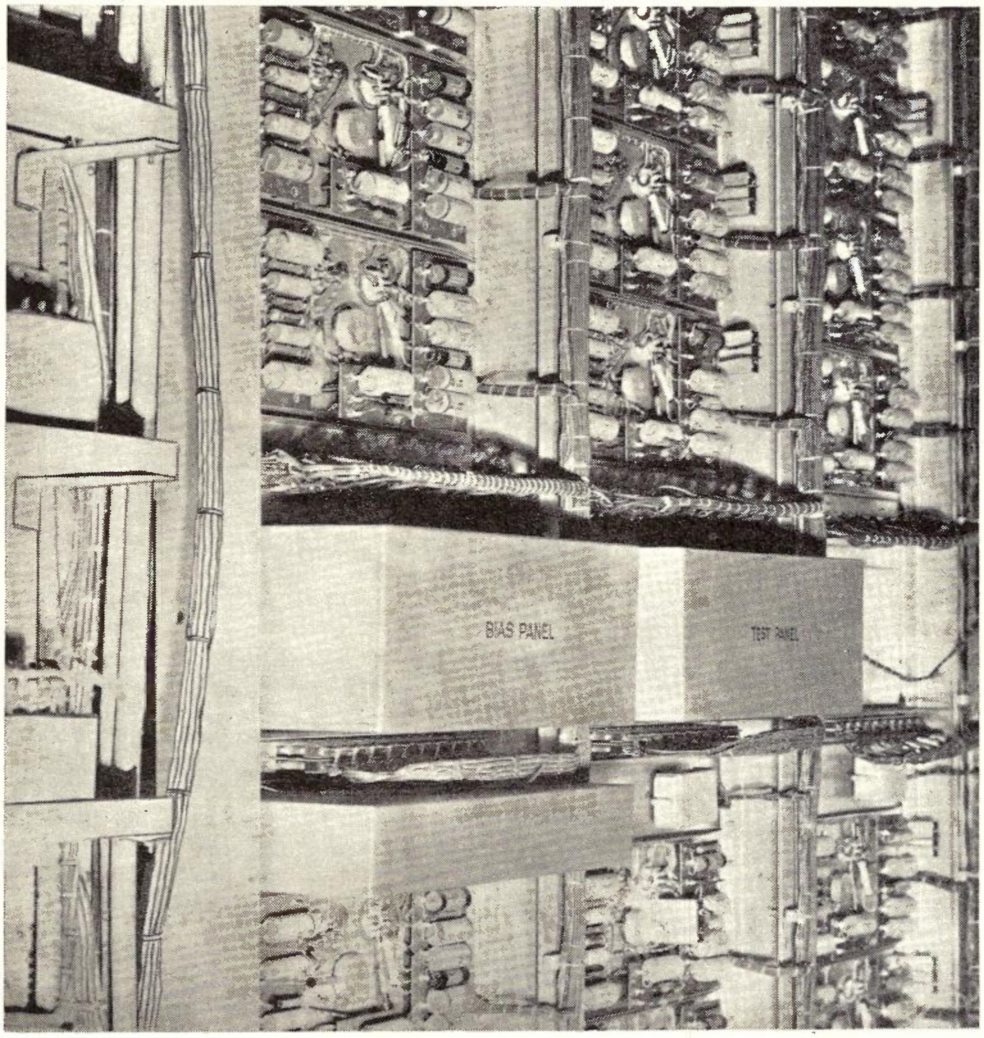

Fig. 7.—Assembled Racks. Rear view showing some of the Dialling Receivers, Bias and Test Panels.

first to make sure that the circuit is free, and then throws the dial key. The operation of the dial key causes relays to operate which transmit to Adelaide a long burst of tone, the timing of this interval being determined by the charging time of a large capacity condenser, and is of the order of 2 to 3 seconds. A guard lamp adjacent to the dial key lights while this seizing burst is being transmitted to warn the operator not to dial too soon. Usually the interval mentioned is not appreciable to the operator. The operator next dials in the normal way and for other than voice frequency would be impossible for various reasons. The circuits working over carrier channels are as follows:—

Port Augusta	CT4	Carrier	System
Berri	CT4	,,	,,
Renmark	SOS	,,	,,
Mount Gambier	C2F	,,	,,
Port Lincoln	SOS	,,	,,
Yorketown	SOT	,,	,,
Naracoorte	SOS	,,	,,
Port Pirie	T1	,,	,,
Gladstone	T5	,,	,,

It has been found convenient in practice to use ordinary copper oxide voltmeters at the sending end to adjust the sending level and also at the receiving end to read the incoming voltage across the end of the system. The receiver, as installed, will give a constant output of approximately 32 milliamps with an input voltage across the end of the line (terminated in the normal condition) from 0.4 volts upwards. There is no difficulty in obtaining this figure, and the receiver gain is adequate to work with a much lower input level if required in the future.

At the Adelaide end the receivers have been mounted on 19 in. plates of sheet steel assembled on 10 ft. 6 in. racks and mounted adjacent to the relay sets which, as mentioned above, are on a "jack in" basis. The mounting details are shown in Figs. 5, 6 and 7. The components used are all Australian made. The input transformer is a Type I.T. 18 from Transmission Equipment Pty. Limited. The tuning inductance in the 2200 cycle tuned circuit is a special iron-cored coil from Transmission Equipment Pty. Limited, the inductance being 0.45 henries, and having a high Q value for the frequencies concerned. The remaining components are radio type resistances and condensers, valve sockets, etc., as mentioned above, none of the relays in the circuit are special, the relay in the plate circuit of the 6Y6G tube being a standard impulsing relay with pin type armature.

A simple test circuit is provided at the Adelaide end to enable routine tests to be applied to receivers and relay sets and a standard weight of impulse and speed of dial test set is provided alongside the relay sets for the same purpose.

At the country end, one side of the dial key is used as a test key on each line. When this side of the key is depressed a steady burst of tone is transmitted to line. This feature is very useful in making tests and adjustments on systems. At the Adelaide end a plate current key enables the current in the 6F7 tube and in the 6Y6G tube to be checked quickly.

The selectivity of the tuned circuit is not unduly sharp, the guard circuit providing the additional immunity required from false operation by voice, etc. The use of 2200 cycles per second and a fairly broad tuned circuit means that the system is not dependent on the maintenance of an exact oscillator frequency at the country end and what is probably of greater importance, is not dependent on the maintenance of an extremely high degree of precision in synchronism in carrier channels. With ordinary carrier systems there is a tendency for the synchronism to drift somewhat due to power supply fluctuations, etc., and if the dialling system is one which requires the carrier system to be maintained within very close limits, a certain amount of difficulty from the maintenance point of view might be expected. The arrangement used is such, at present, that the received frequency can be 100 cycles above or below the correct figure with no change in the weight of impulse, and dialling is possible with very wide departures from the correct frequency. Normal departures from synchronism do not amount to anything like the above limits, so that no difficulty is experienced in this regard. The frequencies of the country end oscillators are checked readily at Adelaide by means of a Cathode Ray Oscillograph, the incoming frequency being compared with a local oscillator for the purpose.

It was found that the ordinary dial tone from automatic exchanges is rather vague in character, being a nominal 33 cycles per second, and this was not transmitted efficiently over the ordinary carrier systems so that the country end telephonist had difficulty in hearing dial tone and was not sure that the correct sequence of relay operation had taken place. The dial tone for the particular switches set aside to work with the voice frequency circuits have been fed for trial with 1000/16 tone in place of the 33 cycle dial tone. This tone is derived from the ordinary 1000 cycle ringing machines. An extremely small amplitude is used but it is so distinctive that no difficulty is experienced in identifying it at the country end. As the voice frequency receiver is bridged across the line during the transmission of these various tones, there is a possibility that the guard circuit will operate and render the receiver inoperative while a tone is passing. This might conceivably prevent the country telephonist from releasing the circuit if she encounters, say, a number unobtainable tone or busy tone. It is found that the amplitude of these tones required to give positive identification at the country end is far below the level required to make the guard circuit function. This is due to the well-known properties of the metal rectifier whose output for small amplitudes is very small, but whose output increases rapidly with increasing amplitude of energizing current. The receiver as used, is therefore not troubled by the standard tones used, but is quite safe from false operation by the loudest voice.

APPENDIX:—Detailed Circuit Description:— Call to Automatic Exchange

Country End—See Figure 8

Country telephonist plugs into trunk line jack and challenges line. Terminating network is removed at inner springs.

Extra springs on the jack made and feed earth to prepare circuit for relay S.

The telephonist throws the Dial Key.

The dial key main springs place the impulsing springs of the dial across the ringer 2,200 cycle supply which is short-circuited to prevent premature tone transmission.

One set of outer springs of the dial key prepares starting circuit for 16 cycle relay in ringer. This relay circuit has been modified to operate from 24-volt D.C. instead of from 16 cycle A.C.

The other set of outer springs of dial key completes circuit for relay S which operates.

Contacts S1.2 lock up relay S.

Contact S7 changes from S6 to S8.

chain and disconnects the 2,200 cycle current supply from the line.

Adelaide End—See Figure 9

The long seizing burst enters the dialling receiver and after amplification causes plate current to flow through impulsing relay D.

Contact D12 changes from D11 to 13 and

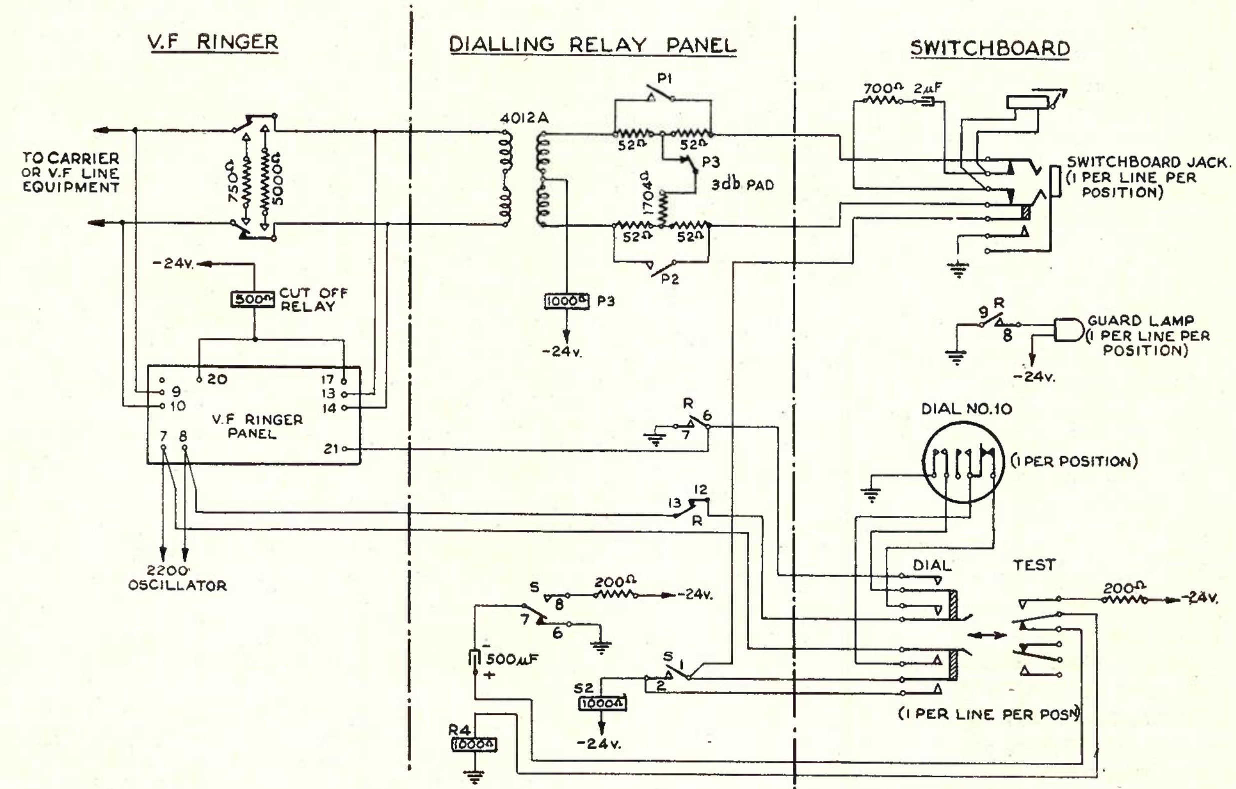

Fig. 8.—V.F. Dialling and Signalling, Country End, using S.T.C. Ringer.

Relay R4 operates for the charging time of 500 μF condenser; approximately 2½ secs.

Contacts R6.7 make and feed earth to 16 cycle relay in ringer.

Contacts R8.9 light warning lamp. Dialling must not be commenced until lamp goes out.

Contacts R12.13 break the dial impulsing contact short-circuit across 2,200 cycle supply.

Contacts of 16 cycle relay in ringer, start a chain of relays in V.F. ringer panel, the last of which changes the line from the ringer to 2,200 cycle supply and feeds a long seizing burst of approximately 2½ secs. duration, to line.

When the 500 μF condenser is charged relay R releases but relay S remains operated.

Warning lamp is extinguished at contacts R8.9.

Contacts R.12.13 allow dial contacts to short circuit the 2,200 cycle current and the seizing burst to line ceases.

Relay 16 cycle, in ringer restores the relay

feeds earth through the 3,000-ohm resistance to relay E in shunt with 500 μF condenser.

The large charging current into 500 μF condenser causes such a large voltage drop across 3,000-ohm resistance that relay E will not operate.

After approximately 1½ secs. the condenser is fully charged, and relay E operates. This time delay prevents false seizing of circuit due to line disturbances, etc.

Contact E7 changes from E6 to 8 to prepare holding circuits for relay E through G 200 ohm.

Contacts E11.12.13 and E1.2.3 change line from trunk to auto connection.

Relay C operates from earth at D.12.13.

Contact C4 changes from C3 to 2 and contact C14 changes from C13 to 12 and connects 600-ohm dialling loop to the automatic circuit but the loop to the automatic selector circuit is not completed at this stage.

When seizing burst ceases relay D releases.

Contact D12 falls back to D11 and relay C releases slowly.

Relay E locks up through D11.12 G 200 ohm and E7.8 Relay E is slow releasing and will not drop out on dialling trains.

Relay G operates on 200-ohm winding.

Contact G2 changes from G1 to G3 to prepare holding circuit for G through G1300 ohm when D12 makes with D13.

channels. The 1,000/16 cycle tone is adjusted to a very low level and does not operate any signalling equipment).

Country End

Country telephonist commences to dial and moves the dial off normal.

Earth from off normal dial springs operates 16 cycle relay and relay chain in ringer which

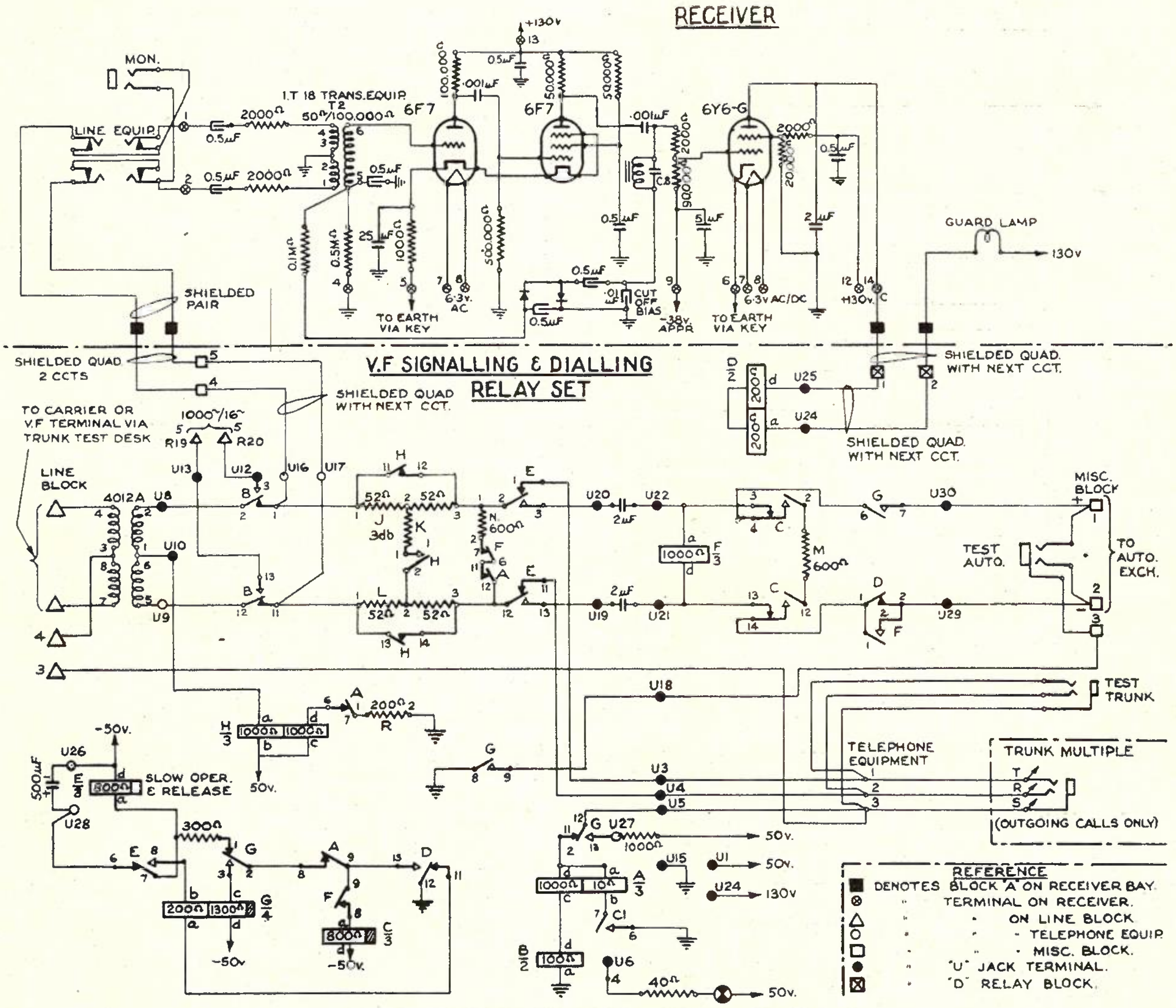

Fig. 9.—V.F. Dialling Receiver and Relay Set—Adelaide End.

Contacts G12.13 place battery through 1,000 ohm on the trunk switchboard multiple sleeve to mark the circuit engaged.

Contacts G6.7 complete the loop to Auto Exchange and engage the switch which is an ordinary group selector.

Contacts G8.9 feed a holding earth over the private wire to the selector.

Dial tone of a frequency of 1,000 cycle/16 cycle should now be heard at the Country Station (this dial tone is different from the ordinary 33 cycle dial tone because the latter is not transmitted efficiently over carrier

connects the line to the 2,200 cycle supply across which the impulsing contacts are short circuited. This occurs at the commencement of each impulse train.

As the dial returns to normal the impulsing contacts make and break to feed out spurts of 2,200 cycle tone to line. After each train of impulses the off normal contacts in the dial open and relays in ringer restore. This permits the operator to hear supervisory signals, if present, between impulsing trains.

At the conclusion of dialling the operator restores the dialling key.

The relay chain in the ringer has connected the line normal to the ringer and switchboard.

Relay S remains locked up during the conversation and negative battery is connected to the 500 μF condenser through 200-ohm resistance, S7.8.

Ringing signal or the appropriate supervisory signal should now be heard.

When line is extended at the country end to another long distance trunk and pad switching facilities are provided, relay P operates and removes 3db pad.

Adelaide End

The 2,200 cycle spurts from the country end are converted to D.C. impulses by relay D.

Contacts D12.13 operate relay C on the first impulse and also feed a holding pulse to relay G 1,300 winding.

Contact C2.4, C12.14, change over to 600-ohm loop to automatic exchange to improve dialling. Relay C is slow-releasing and will hold to cover each complete impulse train. On the restoration of relay C the loop is held by relay F, which is a polarized relay and operates when the called subscriber answers.

Contacts D1.2 feed impulses to the automatic exchange. With 35 mA's flowing through relay D the weight of the impulses is approximately normal with usual adjustment of relay D.

On the completion of dialling, supervisory tones are sent to the country end.

When the called subscriber answers the consequent battery reversal operates the relay F.

Contacts F1.2 mask the impulsing contacts D1.2 as a further safeguard against false operation during conversation.

Contacts F8.9 open the circuit of relay C to prevent interruptions to conversations due to false operation of relay D.

Contacts F6.7 remove the 600-ohm termination.

The 3 db pad is normally in circuit and remains in for automatic conversations.

At the Conclusion ofthe Conversation

Telephonist withdraws plug and S relay releases.

Contact S7 restores to S8 and 500 μF condenser now discharges through relay R.

Contacts S1 and S2 open.

Relay R operates for the discharge time of condenser, approximately 2½ secs.

Contacts R8.9 light guard lamp to warn telephonist against replugging the line until lamp is extinguished.

Contacts R6.7 operate relay chain in ringer to connect line to 2,200 cycle supply.

Contacts R12.13 open but as dial key is restored, serve no purpose at this stage.

Releasing burst of 2,200 cycle current is fed to line for approximately 2½ seconds.

When condenser is nearly discharged relay R restores.

Guard lamp is extinguished at contacts R8.9.

Contacts R6.7 restore the chain of relays in the ringer.

Ringer and switchboard circuits are now restored to normal.

Adelaide End

The releasing burst of 2,200 cycle current operates relay D for approximately 2½ seconds.

Contact D12 removes holding earth from relay G 200 ohm and relay E.

If the automatic subscriber has hung up, relay F releases.

Contacts D12.13 operate relay C which connects 600 ohm loop to automatic exchange at C2.4 and C12.14.

Contacts D11.12 are open long enough for relay E to restore.

Contacts D12.13 hold relay G through 1,300-ohm winding.

Contacts E7.8 open the locking circuit for relay E. Contacts E1.2.3 and E11.12.13 restore line to trunk connections.

When relay D restores contacts D12.13 open and relay G releases.

Contacts G8.9 remove holding earth from the automatic exchange switch, which releases.

Contacts G12.13 open and remove engaged test from the trunk switchboard multiple sleeve.

Contacts G1.2 restore and circuit is now normal.

Outgoing Call from Adelaide Trunk Switchboard

Telephonist tests line and if free, plugs in.

Relay A operates from 24 volt battery on the telephonist's cord circuit sleeve. Relay B is a marginal relay and will not operate on 24 volts.

Contacts A8.9 open the holding circuit of relays E and G to prevent false operation.

Contacts A11.12 remove the 600-ohm termination.

Contacts A6.7 open relay H and the 3 db pad is switched out. Relay H is normally operated and the 3 db pad switched in.

When telephonist throws the speaking key, split earth from telephonist's circuit operates other winding of relay H and 3 db pad is reinserted.

Telephonist depresses the ringing key.

50-volts potential is fed to sleeve circuit and relay B operates.

Contacts B2.3 and B12.13 feed ringing current to line whilst ring key is depressed.

If the trunk line is now connected to another long trunk line, relay H does not operate and 3 db is out during conversation. In the case of a short line, a split earth operates H and cuts the pad in.

Country End

Incoming ringing current operates ringer relays which in turn drop the indicator.

Telephonist plugs in and as for this condition there is no occasion to throw the dial key, no relay operation occurs.

If pad switching facilities are provided and the line is connected to a long trunk, relay P operates.

Contacts P1.2.3 switch out the 3 db pad.

At Conclusion of Conversation

Adelaide End

Telephonist removes plug and relay A restores.

Contacts A8.9 restore the holding circuit for relays G and E to normal.

Contacts A11.12 restore the 600-ohm termination across the line.

Contacts A6.7 restore and relay H operates, reinserting the 3 db pad.

Country End

If at the end of the conversation the country telephonist wishes to attract the attention of the Adelaide telephonist, she may do so by depressing the test key side of the dial key.

Relay R operates.

Contacts R12.13 operate chain of relays in ringer.

Burst of 2,200 cycle current is fed to line whilst test key is held.

Adelaide End

Relay D operates.

Contacts D12.13 operate relay C. Contact A8.9 are open, so relays E and G will not operate.

Contacts C6.7 feed 20 ohm earth to light cord circuit supervisory lamp.

The "Test" side of the "Dial" Key provides a means for transmitting test current from the country end for testing purposes and sending level adjustments.

It also provides a means for re-setting the seizing and releasing sequence should this be upset.

(The seize and release sequence can be upset in practice, for example, if a channel fails during conversation, so that the releasing burst is ineffective.)

A Mobile Recording Unit for the Australian Broadcasting Commission

H. W. Hyett

The advantages of having broadcast pick-up equipment available in a transportable form, so that events of interest which occur at locations remote from the studios can be brought to the listening public, have long been realised and equipment of this type has been available since the very early days of broadcasting. It was necessary to connect this equipment to the studios by land lines, so that unless a telephone line was within a reasonably short distance of a location from which it was desired to broadcast considerable expense and delay were often incurred in getting the programme matter on the air. Even when a telephone line was available at the exact location, delays often occurred in having it connected through to the studios. In order to overcome these disabilities in broadcasting from locations which were difficult to reach from the telephone network, small portable ultra-high frequency transmitting and receiving sets were eventually developed and these were used to provide the link between the pick-up point and the nearest available telephone line. This type of equipment, which has been supplied to all States, performs quite satisfactorily and has been used to a considerable extent in the National Broadcasting Service for the broadcast of items such as the Great Public Schools' Regatta in New South Wales, descriptions of the Fleet Manœuvres in Jervis Bay, etc.

As the art of broadcasting was further developed different types of equipment for recording programmes in the studios were tried, but the results obtained did not compare favourably with those from a direct broadcast, as the equipment at this time was rather crude. Several of the larger manufacturing companies in the United States realised the possibilities of equipment of this type and concentrated on the development of suitable machines. During the last few years comparatively cheap equipment for the recording of sound on discs of a type which is suitable for instantaneous reproduction has been available, and equipment of this type is now considered to be an essential part of the studio plant.

Broadcasting organisations are, in most countries, quickly realising the possibilities of mobile units which contain as many as possible of the facilities hitherto found only in studios. The first mobile recording studio to be acquired by the Australian Broadcasting Commission was designed and constructed by the Postmaster-General's Department and was placed in service in May, 1939. The unit was constructed in the Departmental Workshops in Melbourne for the Sydney office of the Australian Broadcasting Commission and was driven to Sydney via the Prince's Highway, many recordings of interest being made during the journey.

Before the design of the A.B.C. unit was commenced, as many details as possible were obtained regarding the equipment and experience of other broadcasting organisations and this information, in conjunction with the requirements of the A.B.C., determined the form the equipment would take.

The vehicle consists of a 30-cwt. Bedford chassis, on which a special body has been constructed in accordance with a specification prepared by this Department. The inside dimen-

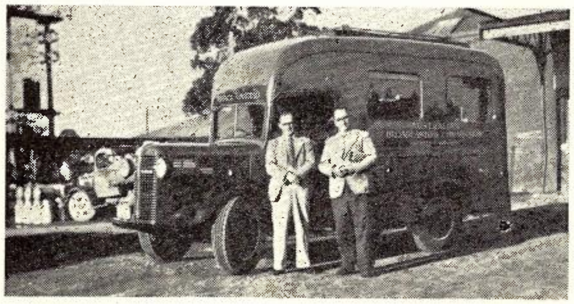

Fig. 1.—MOBILE STUDIO AT DROUIN, VIC., BUTTER FACTORY.

sions of the body are 9 ft. x 5 ft. 6 ins. x 6 ft. 1 in. high, which necessitated an overall height of about 8 ft. 6 ins. The tare weight of the vehicle is about 41 cwt., making a total weight, with the equipment installed, of about 56 cwt. The finish of the unit is in chrome green with the lettering "A.B.C. Mobile Studio" on each side, "A.B.C. Mobile Studio" on the rear door, and "A.B.C." in the outline of the map of Australia on the sloping front above the windscreen. Two fixed windows are provided on each side of the van and another of the adjustable type in the rear door, a sliding glass panel being provided in the bulk-head in the rear of the driving position. A small additional door is also provided at the rear through which access is obtained to the microphone, power and telephone cables. A lead-lined battery compartment is provided on the near side immediately behind the driving cabin, access to which can only be obtained from outside the van. An exhaust fan is fitted above the rear door and when this is not in use it is concealed by a metal cover. The roof is specially strengthened and built in the form of a platform 8 ft. long by 4 ft. wide, and is capable of supporting several persons. Guard rails which fold down over the platform while the unit is travelling have been provided. The platform is reached by means of an iron ladder fitted at the rear of the vehicle.

In designing the electrical equipment provision was made for the unit to be operated either from commercial AC power supply or from a local supply housed within the unit. The amplifier equipment and recording machines are of a standard type suitable for operation from a 230 volt 50 cycle supply. The local supply is derived from a 32 volt 120 ampere hour lead-acid secondary battery, which is mounted in the lead-lined compartment and a 0.5 K.V.A. motor alternator set is used to convert to 230 volts 50 cycles. This machine is equipped with starting, voltage and frequency controls, the voltage and frequency of the output being indicated on meters mounted on the bulk-head above the machine. As the motors on the recording machines are of the synchronous type, it is essential that the frequency of the supply be maintained at 50 cycles in order to prevent variation in the speed of the turntables. The motor alternator set is not required to deliver anything like its maximum output and once the frequency has been correctly adjusted very little further adjustment is necessary, provided the load is not varied. This limitation prevents the switching on or off of one of the recording machines while a recording is in progress on the other.

It was necessary to take special care with the location and mounting of the motor alternator set to ensure that no vibration reached the recording machine. On account of the weight of the set, which is about 5 cwt., consideration had also to be given to the distribution of the loading on the vehicle. The machine was, therefore, placed in a transverse position at the forward end of the body immediately behind the driver and was mounted on rubber blocks. No rigid connection was permitted between the set and the van structure, flexible conduit being used on the cabling. For the 32-volt battery D.P. Kathanode Traction type cells were chosen on account of their special features which had specific application to the class of work they would be required to perform in this unit. The plates of the cells are of the Faure or "pasted" type, the most important characteristics of which are their high capacity to weight ratio and low internal resistance. Special precautions have also been taken to prevent disintegration of the positive plates, due to overcharging, high rates of charge and discharge or excessive vibration, by wrapping the positive plates in a kind of felt made from spun glass fibres which holds the paste in position, but at the same time permits free passage of the electrolyte and gases. The rated capacity of the cells is 112 ampere hours, this being at the five-hour rate, and whilst the normal charging rate is 10 amps the makers claim that the rate may be increased to 20 amps without damaging the cell.

The interior lighting is of 32-volt equipment and may be connected either directly across the 32-volt battery or alternatively to the 230 volt 50 cycle supply through a step-down transformer. A hot cathode mercury vapour rectifier is provided for charging the 32-volt battery from the commercial AC power.

Provision is made for the equipment to operate from commercial voltages between the limits of 200 and 250 by means of an adjustable auto-transformer fitted with hand-wheel control and an iron-clad changeover switch is used to change from the commercial supply to the output of the motor alternator. Separate fuses are connected in all circuits and all power wiring consists of twisted pairs run in flexible conduit.

The transmission wiring is run in copper conduit and is maintained at as great a distance as possible from the power circuits. Special care was taken to ensure that these two classes of circuits did not parallel one another at any point.

The transmission wiring itself was divided into two groups, one for the high level circuits and one for the low, and separate conduits were used for each group. It was considered desirable to take every precaution against crosstalk owing to the large gains involved and the confined space in which the equipment was located, and when the final tests were made absolute stability was obtained at the condition of maximum gain.

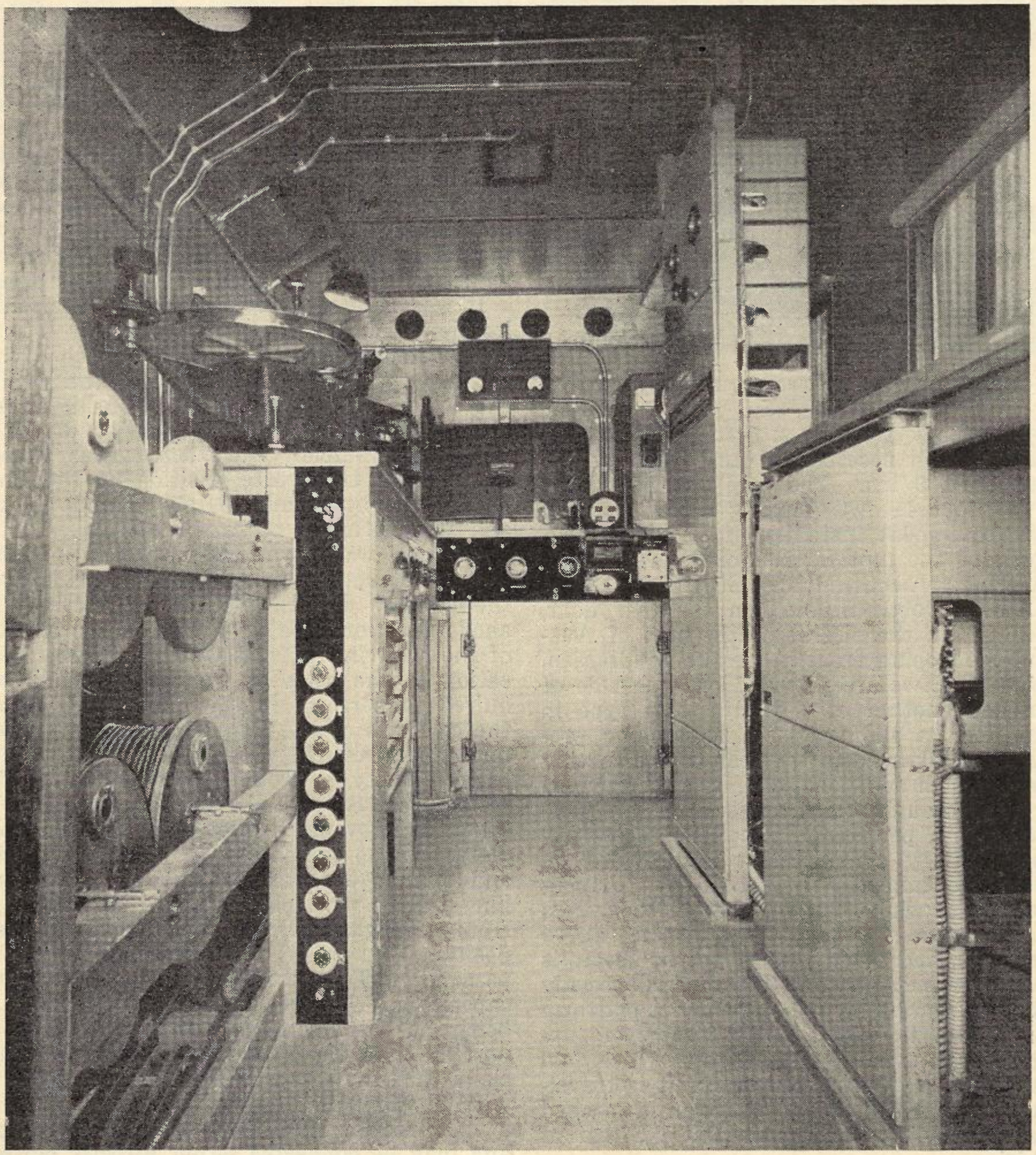

Fig. 2.—Interior of Van. The cable reels, with cranks removed, and the steadying jacks can be seen in the left foreground. The commercial supply and fuse panels are hidden from view by the amplifier rack. Provision for storage of materials has been made underneath the recording table.

Recording Machines. A pair of "Presto" stationary recording machines similar to those provided in the studios are mounted on rubber blocks on the recording table, which is located on the near side of the van as far forward as possible. These machines can be operated at turntable speeds of either 33-1/3 r.p.m. or 78 r.p.m. by throwing a small change speed lever into either one of two positions, the drive from the motors being applied to the inside of the turntable flanges via rubber idler wheels. To provide for the two speeds a double steel pulley is fitted to the motor shaft so that a rubber idler wheel may be engaged between the smaller or larger diameter, according to whether a speed of 33-1/3 or 78 r.p.m. is desired. A feature of this type of drive is that the turntable speed depends only on the diameter of the motor pulley and the inside diameter of the turntable and is independent of the diameter of the rubber wheels.

The cutting head is moved across the disc by means of a buttress thread feed screw, the drive to which is taken from the centre turntable, so that any given feed screw will always cut the same number of lines per inch irrespective of the turntable speed. It is usual to provide a feed screw which will cut 112 lines per inch inside to out for 33-1/3 r.p.m. recordings and one which will cut 96 lines per inch outside to in for 78 r.p.m. recordings.

The machines are fitted with Presto Type BA1 cutting heads, which have an excellent high frequency response. At the frequencies below 250 cycles these heads record a groove of constant amplitude, whilst above this frequency the velocity of the recording stylus is constant. Standard gramophone reproducing equipment is, therefore, suitable for the reproduction of the recordings made on these machines.

A microscope capable of magnification of 32 diameters is fitted to each machine for the inspection of the grooves, disc surfaces, cutting styli, etc., and the depth of the cut and the cutting angle of the stylus are readily adjustable.

Levelling screws and spirit levels are included on the machines so that the turntables may be correctly aligned before recording is commenced. Locking mechanisms are also provided on all movable parts, such as motors, turntables, pick-ups, etc., so that there is no possibility of these components being damaged whilst the unit is in motion. A reproducing pick-up is also mounted on each machine for playback purposes.

Amplifier Rack. The amplifying rack, which is also floated on rubber blocks, carries a pre-amplifier and a recording amplifier, also miscellaneous equipment such as gramophone record equaliser and loud-speaker level control. The power converter which supplies power to both amplifiers is mounted on a separate rack well away from the remainder of the equipment, as it was found that the large fields surrounding this unit caused power hum to be introduced into other parts of the equipment. These two racks are mounted on the near side of the van and, as access is obtained to the various components from the rear, it was necessary to allow sufficient space behind the racks to permit a mechanic to work in comfort.

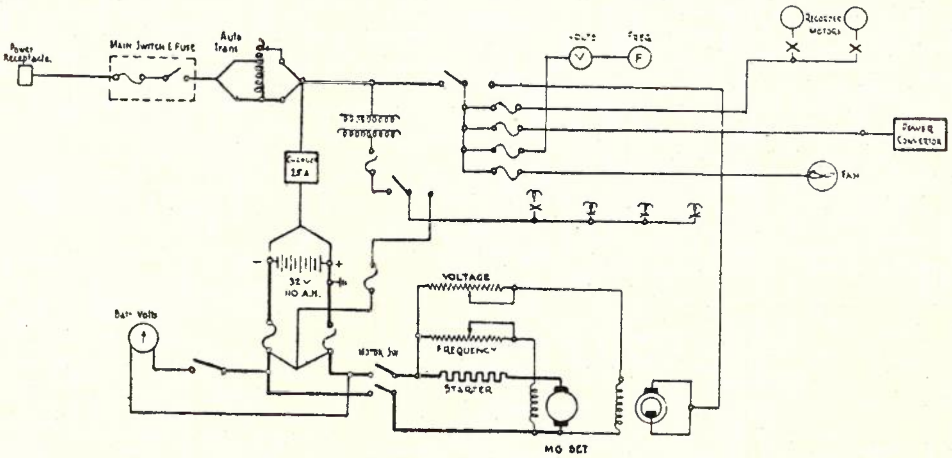

Fig. 3.—A.B.C. Mobile Recording Van—Power Circuit.

The preamplifier is a two-stage transformer coupled unit having a 200 ohm input and a 600 ohm output. A 606 type tube operating as a triode is used in each stage, giving a gain of about 50 decibels and a power capability of 100 milliwatts.

The recording amplifier is a three-stage amplifier push-pull throughout, having an overall gain of 60 decibels. The final stage in this amplifier consists of two pairs of 2A3 type tubes in push-pull, these providing two separate 600 ohm outputs. The power capability of each pair of tubes is 10 watts with a harmonic distortion value of 5 per cent., or 5 watts with a harmonic distortion value of 1.8 per cent. As the maximum level at which the cutting heads operate is + 20 decibels on 6 milliwatts (0.6 watts), it will be seen that ample power reserve is available. Under normal operating conditions one of the outputs is used for driving the cutting heads, whilst the other provides a monitoring channel to which the monitoring loud speaker is connected. Headphone monitoring is also provided directly across the cutting heads. A bridging network which reduces the level to 6 milliwatts is normally connected across the monitoring output and this circuit is used when it is desired to transmit the programme matter via a telephone line to the studios or elsewhere.

It is obviously desirable to locate all controls and the level indicator on the recording table, so that it will be unnecessary for the operator to turn away whilst a recording is in progress. The control panel, is therefore, located on a sloping fronted cabinet placed between the two recording machines. This panel carries the main gain control and level indicator, the cutting head and playback changeover switches and the monitoring loud speaker on and off switch. Immediately below the front edge of the recording table a 4-channel mixer panel has been mounted by means of which the four microphone circuits and the playback pick-ups are controlled. Three of the microphone circuits are capable of extension to points remote from the van by means of long shielded cords which are carried on specially constructed reels mounted inside the small rear door. A fourth reel carries a length of power cable which is used to connect commercial power supply to the unit when it is available. A microphone point has also been provided in the driver's cabin, the circuit from which is connected directly to one of the four faders.

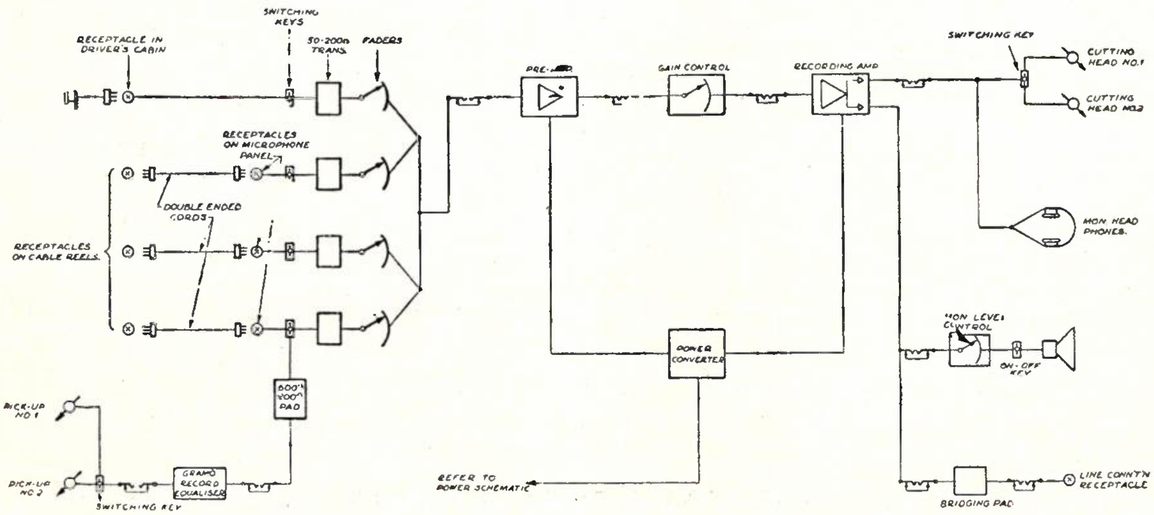

Fig. 4.—A.B.C. Mobile Recording Van—Block Schematic.

The signal is picked up by the microphone, passed to the appropriate fader and thence to the preamplifier, where the level is raised to a value of about 30 decibels below 6 milliwatts. The main gain control is connected between the preamplifier and the recording amplifier in a 600 ohm circuit, and it is at this point that the level is adjusted so that the average peaks at the output of the recording amplifier do not exceed + 20 decibels on 6 milliwatts. After passing through the recording amplifier the signals are fed from one of the two amplifier outlets to either one of the recording heads, depending on the position of the switch and from the other outlet to the monitoring loud speaker. The latter is not used when the microphone is being used in the driver's cabin, as the sound insulation is not sufficient to prevent acoustic feed back from the loud speaker into the microphone. In this circumstance the monitoring headphones may be used as a check on the operation of the equipment.

After a recording has been completed it is often desirable to make a check for general satisfactoriness by playing-back right away and the playback pick-up on each machine is provided for this purpose. The same amplifying equipment is used for both recording and playback, but a low frequency equaliser, which restores the frequencies below 250 cycles to normal, is connected in the playback circuit. It is also possible to re-record from a disc on one turntable to a blank on the other with this arrangement.

The recording technique is similar to that of recording in the studios, but owing to the unit being operated in the field its operation actually combines the functions of the pick-up operator with those of a recording operator. This means that two operators are usually required.

Since the unit has been handed over to the Australian Broadcasting Commission it has been in almost daily use and the only complaints which have been received have been concerning the lack of space for the staff while travelling. Therefore, considering that the unit is the first of its kind in this country and that the variety of uses to which it would be put was not fully realised during its development, its performance is very satisfactory. Should a second unit be required the experience gained with the existing equipment will enable a unit to be constructed which will fulfil all requirements.

A TELEPHONE EFFICIENCY TESTER

P. J. Killey and G. N. Smith, B.Sc.

The idea of testing the transmission efficiency of telephone instruments entirely by instrumental methods is not new but has been tried and utilized in several countries in different ways and a considerable amount of developmental work has been carried out by the British Post Office, which has been using telephone efficiency testers for some years. In these times when attention is concentrated so much on the performance and testing of transmission equipment, it seems opportune to reconsider the transmission performance of the telephone instrument itself.

It is well-known that if the "effective" transmission efficiency of telephones can be increased by say three decibels, the boundaries of exchanges can be extended or the gauge of subscribers' underground cables can be reduced, and the saving which accrues from such an improvement represents a considerable sum of money. A telephone network designed to give a particular grade of transmission depends, among other things, on the telephones having a certain minimum transmission efficiency. It is, therefore, important that every telephone which is purchased should attain a certain specified performance, and it is equally important that every instrument in service should be maintained up to this standard.

The effectiveness of a telephone conversation depends not only on the volume of the transmission, but also on its quality. Since the problem of providing sufficient volume has been largely overcome by the loading of cables and the use of amplifiers, developmental work on transmitters and receivers is being concentrated on improvements in quality. Although many tests in addition to volume efficiency are necessary to determine the "effective" transmission efficiency of a type of transmitter or receiver, all of these tests are not necessary for the bulk testing of apparatus. Provided an accurate means of testing the volume efficiency is available, this test is usually sufficient to ensure that an individual instrument is a normal sample of its type.

Owing to the large number of telephones to be dealt with in any city, it is essential that any testing scheme must be speedy, simply manipulated and sufficiently accurate. In the past, telephones reconditioned in workshops have been tested by speaking over a length of artificial line and although the use of the human voice and ear has some advantages, no great accuracy can be obtained unless the "voice-ear" balancing method is employed. This method of testing volume efficiency is used in laboratories where "Standard" telephones are maintained for reference purposes. However, as a comparison of any two instruments occupies three operators for approximately three-quarters of an hour, the method is obviously unsuited for bulk testing.

The efficiency of telephone lines and line equipment for the transmission of voice frequency currents is usually assessed by tests at a single mean frequency (say 1,000 cycles/sec.) or a series of tests at various frequencies. Such frequency measurements are unsatisfactory for the testing of electro-acoustic telephone apparatus principally on account of the peaked frequency response resulting from diaphragm and air chamber resonances in the transmitters and receivers.

The Telephone Efficiency Tester, Type R1A (usually abbreviated T.E.T.) has been developed in the Department's Research Laboratories to provide a more accurate means of testing the transmission efficiency of new or re-conditioned telephone instruments. The essential components of this instrumental tester are a special oscillator, a loud-speaker, a volume indicator, an artificial ear and an amplifier, which, when connected in various combinations, perform the functions carried out by the voice and ear in speaking tests. The apparatus is panel mounted and assembled on a rack 6 ft. 11 ins. high, as shown in Fig. 1.

Oscillator: The oscillator (known as a rhythmic oscillator) delivers an output having a sawtooth wave form and varying in frequency from 500 to 1800 cycles per second approximately 10 times per second. These frequencies cover the range which contributes most to speech volume and also cover the fundamental resonances of transmitters and receivers. The rhythmic oscillations are produced by means of two neon tube oscillators. One which oscillates at 10 cycles per second controls the frequency of the other and sweeps it over its range from 500 to 1800 cycles per second. The output of the oscillator passes through a low pass filter which has a cut off frequency of 1800 cycles per second. This filter, in addition to eliminating harmonics of the sawtooth wave, allows accurate adjustment of the oscillator by setting the upper frequency limit to the filter cut off frequency. This adjustment is obtained after operating a switch which decreases the speed at which the oscillator sweeps over its frequency range from 10 times per second to once every seven seconds. At this slow speed an A.C. meter connected across the output of the filter shows whether the oscillator frequency passes or does not reach the filter cut off frequency of 1800 cycles per second and allows it to be adjusted until it just passes this frequency.

Volume Indicator: The volume indicator consists of an amplifier and full wave copper oxide

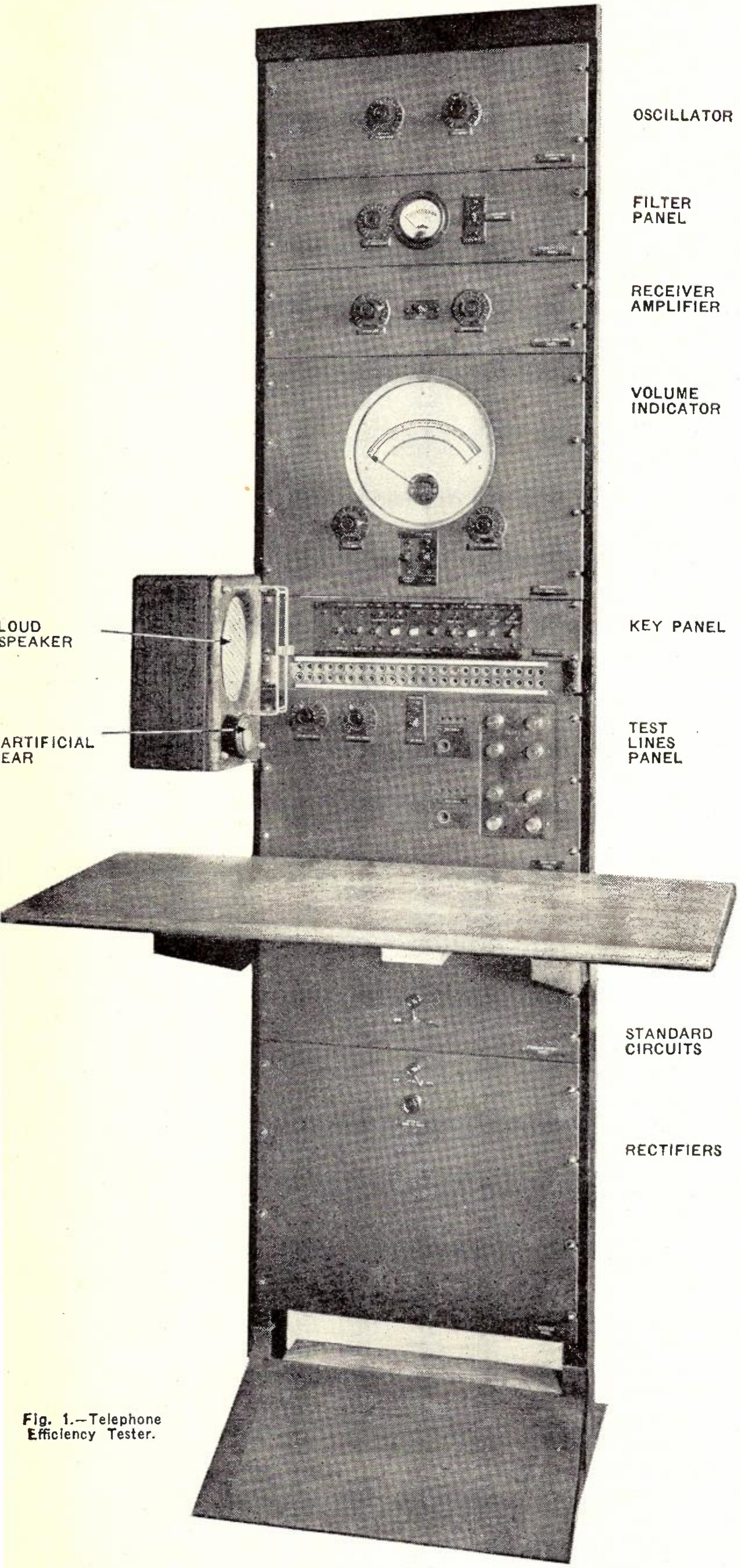

Fig. 1.—Telephone Efficiency Tester.

rectifier. The rectified current operates a D.C. milliammeter which has an 8 in. scale. This meter, which can be seen in Fig. 1, is calibrated in decibels above and below "Standard." A + and — 5 db key decreases or increases the gain of the amplifier by 5 db thus allowing the majority of readings to be taken near midscale. The full wave rectification avoids errors which can occur with a half wave rectifier if the current to be measured is asymmetrical.

Artificial Ear: The artificial ear, which is used for converting the acoustic output of receivers to electrical energy suitable for measurement on the volume indicator, is constructed from an improved type of handset receiver (B.P.O. No. 2P) modified to provide for acoustic coupling with the receiver under test. This coupling is designed so that the load on the receiver approximates to that of a human ear and consequently the receiver is tested under normal load conditions. Although the response of the artificial ear does not contain any appreciable resonances in the frequency range of the T.E.T. it increases with increase in frequency and consequently an equalizer is provided in the receiver amplifier which amplifies the output of the artificial ear.

Facilities: The T.E.T. has facilities for conducting the following tests:—

Sending efficiency of transmitters and complete telephones (C.B., Auto. or L.B.);

Receiving efficiency of receivers and complete telephones (C.B., Auto. or L.B.);

Sidetone of telephones;

Sending and receiving efficiencies of induction coils and bellsets;

D.C. resistance of transmitters and complete telephones;

Insulation resistance of telephones and components.

Sending Efficiency: The sending efficiency of a transmitter or of a telephone is measured by placing the transmitter at a fixed distance in front of the loudspeaker which delivers a tone from the rhythmic oscillator. The electrical output of the telephone and associated exchange circuit (provided for C.B. or Auto. instruments) is measured on the volume indicator. The circuit arrangement for this test is shown in Fig. 2.

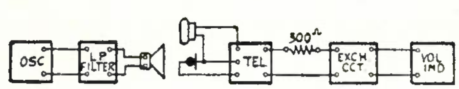

FIG. 2 SENDING EFFICIENCY TEST

Receiving Efficiency: Receiving efficiency is measured by applying the output of the oscillator via a 25 db pad and the exchange circuit, to the line terminals of the telephone. The receiver is then held against the artificial ear, which, as mentioned previously, converts the output of the receiver to electrical energy which is measured on the volume indicator after amplification to a suitable level by the receiver amplifier. Fig. 3 shows the circuit arrangement for this test.

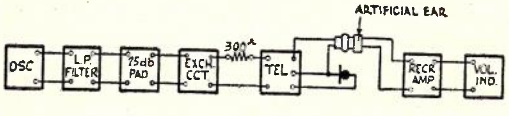

FIG. 3. RECEIVING EFFICIENCY TEST

Sidetone: With the introduction of anti-sidetone circuits it has become necessary to provide a means of testing telephones for correct sidetone reduction as normal volume efficiencies do not necessarily indicate normal sidetone characteristics.

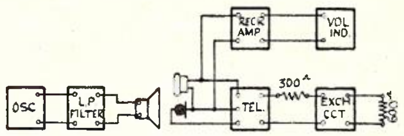

FIG. 4 SIDETONE TEST

The sidetone testing circuit is shown in Fig. 4. The transmitter is held in front of the loudspeaker as for testing sending efficiency and the output of the exchange circuit terminates in an impedance of 600 ohms. The receiver amplifier, which is connected across the receiver to measure the sidetone voltage, has a high impedance input when used for this test. The output of the amplifier is measured on the volume indicator.

The sidetone of a telephone depends principally on the following:—

(1) The type of telephone circuit;
(2) The impedance of the line;
(3) The efficiency of the transmitter;
(4) The efficiency of the receiver.

In the sidetone test of the T.E.T. it is desired to test the telephone circuit, including the induction coil and condensers, but excluding the effects of line impedance and transmitter and receiver efficiencies. The line impedance is fixed and the efficiency of the receiver is eliminated, as the sidetone voltage developed across it, is measured instead of the acoustic output. The sidetone measuring circuit is calibrated so that a telephone known to have normal sidetone will give a sidetone reading equal to the reading it gives for sending efficiency. The operation of a key, following the sending efficiency test, converts the circuit to the sidetone testing condition and if the telephone has normal sidetone its sidetone reading will agree with the reading previously obtained for its sending efficiency. By this means the sidetone test is made independent of the transmitter efficiency.

Bellsets: The sending and receiving efficiency of bellsets of any particular type should not vary between samples by more than approximately 0.5 db. It is therefore desirable to be able to measure their efficiencies within very close limits —particularly as short-circuited turns in the induction coil cause a transmission loss which may be large or small depending on the number of turns short circuited. Although a bellset could be associated with a transmitter and receiver and tested as a complete telephone, this method would not give accurate results since the efficiency of the transmitter would probably vary during the course of the tests.

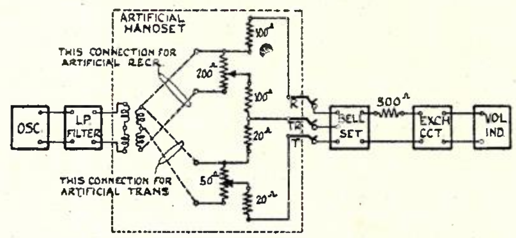

FIG. 5. USE OF ARTIFICIAL HANDSET FOR TESTING BELLSETS

Artificial Handset: Bellsets are tested by means of the artificial handset as shown in Fig. 5. It consists of a transformer and a network of resistances through which the oscillator output is applied to the transmitter terminals of the bellset for testing sending efficiency, and, to the receiver terminals, for receiving efficiency. The network provides impedance terminations approximating those of a receiver and a transmitter. The output from the line terminals is measured on the volume indicator. It will be noticed that the receiving efficiency is tested by sending current from the receiver terminals to the line terminals whereas the transmission is in the opposite direction in practice. However, the accuracy is not affected by this reversed method of testing. Induction coils can be tested in a similar manner after association with a condenser or other components which are used in their normal circuit.

Resistance Tests: The D.C. resistance of a telephone or transmitter may be measured while the normal line current is flowing and under speaking conditions (i.e., while the transmitter is held in front of the loudspeaker). This is arranged by means of a key which connects the meter of the volume indicator as a voltmeter across the terminals of the telephone or transmitter which is being tested. The meter is provided with a scale calibrated in ohms to give a direct reading and it is wired via the contacts of the exchange circuit supervisory relay to prevent it from being connected and overloaded when a telephone or a transmitter is not connected. Provision is made for measuring the insulation resistance of apparatus at a potential of 200 volts.

Calibration: The Department's "Standard Grade of Local Line Transmission" (usually abbreviated "S.L.T.") is as shown in Fig. 6. It is the grade of transmission (sending and receiving) given by the "Standard" Telephone 566 C.B., 300 ohm non-reactive local lines and 22 V exchange circuit as shown. The T.E.T. is calibrated by measuring the efficiency of a set of "Standard" Telephones connected as shown in

Fig. 6, and then adjusting the gain of the volume indicator so that a telephone with efficiency equal to "Standard" would give a reading of that value. A set of six Working Standards which have been calibrated against the Department's Reference Standards are provided with the T.E.T. for the purpose of calibrating. All telephones (C.B., Auto. and L.B.) with the various types of transmitter and receiver in use are tested against the same calibration and are required to be so many db above or below "Standard," depending on their type.

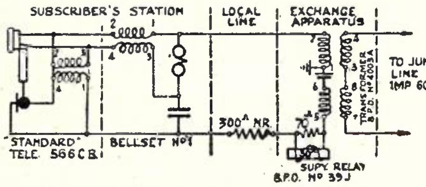

FIG. 6. STANDARD GRADE OF LOCAL LINE TRANSMISSION (S.L.T)

C.B. and Auto. instruments are connected to the same local line and exchange circuit as used for the calibration with the "Standard" telephones. Their efficiency is therefore compared directly with that of the "Standards" and is relative to the efficiency of a "Standard" Telephone 566 C.B.

As L.B. telephones do not require an exchange battery supply, the C.B. exchange circuit and 300 N.R. line are not included in the circuit when they are under test. Since they are tested against the same C.B. calibration and neither an exchange circuit nor a local line is included, the test is a comparison of their efficiency with that of "S.L.T." (the complete circuit of Fig. 6).

Stability Check: Normally the T.E.T. is calibrated at the commencement of each day's testing. A "Stability Check" key allows subsequent checking of the stability of the oscillator and volume indicator at intervals during the day. The operation of this key connects the output of the oscillator via a transformer and potentiometer to the volume indicator and immediately following the calibration this potentiometer is adjusted so that the volume indicator reads midscale. Any alteration of the characteristics of the oscillator or volume indicator would be indicated by an alteration in the "Stability Check" reading.

Test Lines: Since the T.E.T. is required to test various components (transmitters, receivers, etc.) and several types of complete telephones, a rapid means of connecting the apparatus and of converting the T.E.T. circuits to those required for the particular type of test are necessary. The telephone or component which is to be tested is connected to two or more, as required, of four terminals designated "Test Lines." These terminals are specially designed for ease in connection of either the eyelets of a cord, or ordinary wires, and are connected in multiple with jacks for use when testing plug-ended equipment. The Test Line terminals provided in duplicate can be switched to patching jacks which may be connected to dial testing or other equipment used for tests which are not provided for in the T.E.T. If such testing apparatus is situated close to the T.E.T., a telephone may be completely tested while it is connected to the Test Line Terminals. Duplicate Test Lines allow a second operator to carry out dial tests while the next telephone is tested for transmission.

Switching Keys: Keys are provided for changing over the circuit to "Sending Efficiency," "Receiving Efficiency," "Sidetone," etc., and for connecting the Test Lines to the appropriate circuit for the apparatus under test. For example, when testing a C.B. receiver, the rest of the apparatus in a C.B. telephone in addition to the local line and exchange circuit are required and are provided by the operation of the "Receiver C.B." key. Similarly, the operation of the "Telephone L.B." key would connect the test line terminals 1 and 2, used for the telephone line, direct to the volume indicator for sending efficiency or 25 db. pad for receiving efficiency and apply 2.7 volts to terminals 3 and 4 for connection to the battery terminals of the telephone.

Power Supply: The T.E.T. is operated direct from the A.C. power supply except for the transmitter current of local battery telephones which is provided by a 4 V accumulator associated with a network (in the T.E.T.) to give 2.7 V which has been determined as an average voltage for two dry cells. D.C. for plate supply of valves, 22 V exchange circuit and relay operation is obtained by copper oxide rectifiers. The D.C. plate supply includes a voltage stabilizer to ensure steady operation.

The T.E.T. provides a means of measuring volume efficiency within very close limits and consequently allows the detection of faults which would not be apparent by ordinary speaking tests. In addition to its principal use for conducting acceptance tests or testing reconditioned apparatus, it provides a ready means of adjusting receivers, etc., for maximum efficiency, selecting transmitter insets having resistance suitable for L.B. working or comparing various circuit arrangements. As it does not take into account fidelity of reproduction, it should not be used for assessing the relative "effective" transmission efficiencies of two different types of transmitters or receivers. If two types have similar frequency response, their difference in efficiency as measured on the T.E.T. is usually similar to that obtained by voice-ear balancing tests, but may be different in the case of two instruments having substantially different frequency characteristics. Consequently the T.E.T. efficiency requirements for the various types of telephone, as shown in the operating instructions, do not necessarily represent the voice-ear volume efficiencies of those telephones.

THE NEW MELBOURNE TRUNK EXCHANGE

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INTERSTATE POSITIONS.

The Interstate positions differ from others as regards the arrangement of the connecting circuits. This is due to the method of handling interstate calls, the method being termed "back to back"—each position during the day period being allocated certain trunks, which remain associated with the position for as long as necessary. Each position can control up to four trunk lines, although under normal conditions the usual allocation will be two. At the distant end, Sydney, Adelaide or Hobart, the trunk lines will be associated also with certain positions. The telephonists at each terminal of the trunk line will be constantly in touch and the calls in each direction will be worked off in their order of priority. The method of working will be clearer if an example is quoted. Assume that a Melbourne Interstate telephonist has three tickets for out calls to say Sydney and that the Sydney telephonist has advised that she has two calls for Melbourne, the order of priority being S1, S2, M1, S3 and M2. If two trunk lines are being worked by each telephonist the first two calls S1 and S2 will be set up after which the two telephonists will call their respective subscriber for the third call and the third call will be connected immediately a trunk line becomes available. The subscribers for the fourth and fifth calls will be called also and connected in their turn. This example illustrates the principle of "back to back working," the main intention being to work the calls off as quickly as possible. With the subscribers waiting at each end, the trunk occupancy can reach a high figure, certainly much higher than would be possible by waiting for a free trunk line before calling the subscriber at each end. The method involves some waiting at the telephone on the part of the calling and called subscribers, but this waiting period on the average is not appreciable. Other factors, of course, are present and a good deal depends on the discretion of the telephonists.

This method of working is mainly responsible for the difference between the interstate and the remaining positions. Instead of the connecting circuits consisting of two directly associated halves arranged as described for the demand positions,—see Vol. 2, No. 5, page 301, figure 3,—it has been necessary to provide two groups of partial connecting circuits, one set for trunk lines and the other for subscribers. The first group termed "trunk connecting circuits" will comprise four circuits and the second group termed "local connecting circuits" will comprise five circuits on each interstate position. By means of coupling arrangements any trunk connecting circuit can be associated with any local connecting circuit. Thus a complete connecting circuit is made up of what may be termed two half circuits which normally are dissociated.

The Interstate position arrangements are shown in Figure 4. In the following description the common equipment will be taken first in order to simplify explanation.

Interstate Position Common Apparatus

The following items require no explanation, their functions being the same as corresponding apparatus on the Demand Positions, as already described:—

Calling Lamp Display.
Monitor Call Key.
Sender Changeover Key.
Keystrip Supervisory Lamps.
Routing Position press button.
Connect Answer press button.

The functions of the remaining common apparatus are as follows:—

Tone Cut off Key (TONE CO.) Non-locking.—Tone cut off facilities are required only on local connecting circuits, and then only to disconnect storage tone. This key is thus the equivalent of the tone cut off call key on other suites.

De-couple key (DECOUPLE) Non-locking.—Assuming that a "Trunk" and a "Local Connecting" circuit are coupled, then with the speak key thrown on the former, momentary operation of the common decouple key causes the two circuits to be decoupled.

(**Coupling.**—To couple a local connecting circuit to a trunk connecting circuit, the speak key of the former is thrown, followed by the momentary operation of the couple key associated with the latter circuit.)

Primary or Interstate Routing Press button (PRI OR I/S ROUT'G). This press button serves two functions:

(a) that of "primary routing" being the same as on Demand, Through and Suspense Positions;
(b) The additional function in this case is exercised on traffic set up from local connecting circuits to Interstate trunks (for through working purposes) and it is used to discriminate between an Interstate 2-digit number and a similar Interstate trunk code. This is done by momentarily operating the button **before** keying the 2-digit Interstate trunk code into the Sender.

Check Coupling press button (CHECK COUP'G) Each trunk and local connecting circuit has an individual couple lamp which glows when coupling has been performed. With two complete connections, four couple lamps will thus be glowing. To check which trunk couple and which local couple lamps forms a pair, the telephonist throws the local connecting circuit monitor key of one of the two calls and presses the common check coupling button. The pair of lamps concerned will be extinguished with each depression of the button. The other pair will be those which remain steadily glowing.

Ring press button (RING) With the speak key of a trunk or a local connecting circuit thrown, operation of this button transmits calling signals either to a distant Interstate switchboard, or to minor trunk exchanges, magneto omnibus lines, or recall signals over interstate main trunks. In conjunction with the local connecting circuit speak key, the button is also used for calling the called State on an Interstate through connection.

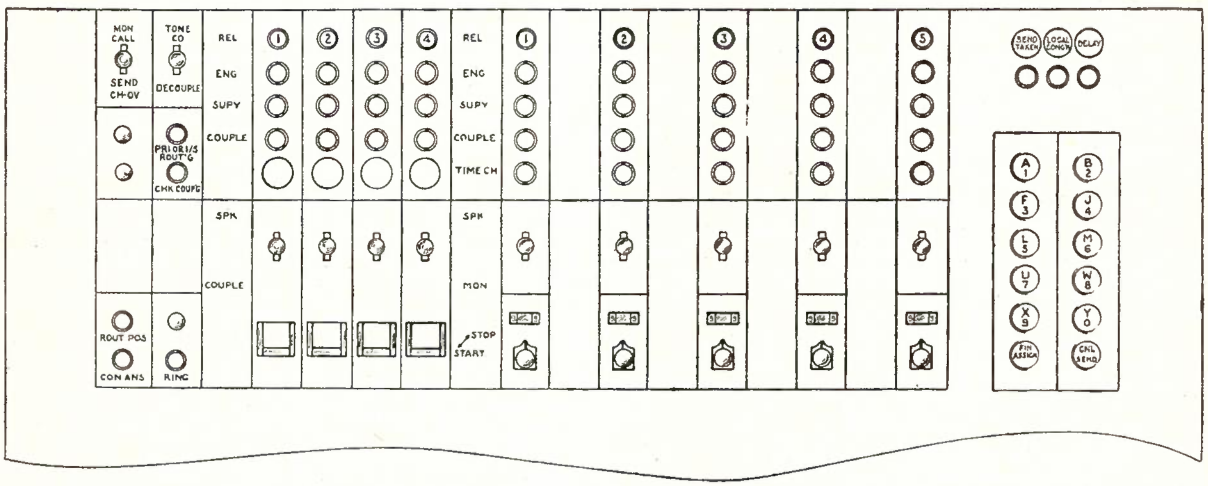

Fig. 4.—Interstate Position—Keyshelf Layout.

Digit Keystrip. This keystrip differs from those on Demand, Through and Suspense Positions in that the alternative function of the finish key is to gain connection to an assigner (for connecting a free Trunk Connecting Circuit to a predetermined Interstate trunk line). The key is marked FIN/ASSIGN.

As the local connecting circuits are the only ones to which senders can be coupled, the other function of the cancel key has been marked "Send". The key is thus marked CNL/SEND.

Interstate trunk assignment is effected by throwing the speak key of a disengaged trunk connecting circuit and momentarily operating the assign key. Within a second or so of the assign key being released, the sender taken lamp will glow, after which the telephonist keys up the code of the required trunk. The assigner uncouples itself automatically as soon as the set-up is complete.

Except for the addition of Interstate connections set up over the local connecting circuit, as already dealt with, all other key-strip and supervisory lamp action is the same as for Demand, Through and Suspense working.

Interstate Position Connecting Circuit Apparatus Trunk Connecting Circuits

Release press button (REL.) Momentary operation completely disconnects an Interstate trunk which had been extended to the trunk connecting circuit either under "day" assignment conditions or after acceptance from the calling lamp Display.

Engaged lamp (ENG). Glows as long as an Interstate trunk is connected to the trunk connecting circuit.

Supervisory lamp (SUPY). With an Interstate trunk line connected to the trunk connecting circuit, this lamp records a calling signal from the distant end. As the signal strictly speaking is of a recall nature, the lamp always flashes; it is extinguished by the telephonist throwing the associated speak key.

Couple lamp (COUPLE). This lamp glows when the circuit is coupled to a local connecting circuit. If the monitor key of the latter circuit is thrown, the couple lamps of the two halves concerned go out with each depression of the coupling identification key.

Speak and Couple key (SPK) Locking. (COUPLE) Non-locking. This is a 3-position lever key. In its speak position it performs two functions; firstly, to enable the telephonist to talk to the distant Interstate telephonist and secondly, to associate the trunk connecting circuit with certain common apparatus on the position. Once coupling has been effected, this key, and that also of the local connecting circuit, can be used to talk to the parties at each end of the connection. (If the telephonist wishes to talk to one party only, she decouples and uses the relevant speak key.)

With the speak key of a local connecting circuit thrown, momentary operation of the trunk speak key into its couple position causes the trunk and local halves concerned to be coupled.

Designation Plate. The function of this plate is to record the number of the Interstate trunk line with which a telephonist is dealing under day working conditions. The numbers having been allocated beforehand, a telephonist, on occupying the position, assigns trunks by keying up the numbers displayed before her.

Local Connecting Circuits

Except as stated below, these circuits function in the same manner as the connecting circuits on other suites. The exceptions are as follows:—

Release press button (REL.). Releases only the **local** part of a connection; that is, the part associated with the local connecting circuit.

Engaged lamp (ENG) and supervisory lamp (SUPY). These are associated only with the local connecting circuit.

Couple lamp (COUPLE). Glows to indicate when coupling has been effected; it can be flashed as already described.

Speak and Monitor key (SPK), MON). Locking each way. The monitor key has an additional function in that it is used, in conjunction with the common check coupling key, to identify trunk and local halves which have been coupled.

Incoming night calls appear on a calling lamp display and telephonists connect them to trunk connecting circuits in the same way as for other suites. Alternatively, call-acceptance conditions can be set up and incoming traffic will be routed directly to the marked connecting circuits.

Telephonists next call the required subscriber over a local connecting circuit, and complete the connection by coupling the trunk and local sides. Where a call is extended through to another State, a coupled trunk and local connecting circuit combination likewise is used.

Assigned trunks remain connected to positions until disconnected by release key action, which might be several hours later. "Local" calls are set up from local connecting circuits and are coupled and de-coupled to trunk circuits as required.

With all Interstate trunks allocated to positions during the day time, it will be seen that, when an Interstate through call has to be completed, no free trunk to the called State will be available to a local connecting circuit. The telephonist handling the call will refer to a monitor who nominates the trunk to be used to the called State. The telephonist then keys up the trunk code over a local connecting circuit and camps on the line. In the meanwhile, the monitor arranges for the release of the trunk line from the position where it is being worked on a "back to back" basis, and when this occurs the telephonist then takes over the trunk. When the through call is completed, the monitor is advised, whereupon she arranges for the trunk to be switched back to its normal day working condition.

A night call to another State is made by assigning a trunk in exactly the same way as for day working conditions, and then ringing out over the line. The local side of the connection is established as already described, and the two sides are then coupled. On the call finishing, **both** sides are fully released.

Interstate trunk numbers consist of two digits in the series 00-99. The actual number of Interstate lines, however, which can be accommodated in this series is less than 100, on account of certain "group search" facilities which have been provided for should Interstate demand working be introduced at a future date.

Each Interstate position has access to all interstate trunk lines as well as to all main and minor trunk lines.

Through Positions

The positions in this suite are generally similar to those in the Demand suite. The main difference—apart from class of traffic handled—is that 10 connecting circuits are provided, and space is available for an additional 4. The general arrangements are shown in figure 5. The connecting circuits are similar to those on the Demand positions and therefore need not be described in detail.

The telephonists on this suite have two main functions:—

(a) To deal with calls incoming from minor trunk lines;

(b) to set up through calls requiring the use of two main trunk lines.

Through calls set up on the through positions remain on the positions and are under the supervision and control of the telephonist for the whole of their duration. This arrangement has been adopted—for the time being at least—to allow the through telephonists to exercise supervision on tandem calls involving main trunk lines.

Country calls for other States are reverted from the Interstate positions. Where a through call cannot be completed because the called trunk line group is in delay, the call is transferred to the Delay positions.

Suspense Positions

The suspense positions each equipped with 6 connecting circuits deal with all tickets on which the completion of calls has been held up for causes other than the required group being in delay. These causes comprise those such as and similar to the called party being absent, not available, and so on.

Incoming calls are not queued but are routed directly to an idle connecting circuit. When an incoming call arrives on a suspense connecting circuit, the associated engaged lamp flashes and a common pilot behind the bulletin frame displays also. The engaged lamp glows steadily when the call is answered, otherwise the connecting circuits are the same as on the Demand and the Through positions. Facilities are incorporated to even the distribution of incoming calls to these positions and also to block access to a position when the telephonist is unable to accept further calls.

Trunk Inquiry Positions

Melbourne metropolitan subscribers desiring to make inquiries regarding trunk calls will do so by calling a special number which will connect them to the Trunk Inquiry Suite. This suite consists of five positions similar in shape and general appearance to other positions in the operating room.

To make it more convenient for night staff to deal with metropolitan trunk inquiries, facilities are provided for calls to be diverted automatically to the Senior Traffic Officer's desk under key control from that desk. In the event of a subscriber then inquiring about the price of a trunk call, the telephonist at the S.T.O. desk can further transfer the connection to the Pricing Position.

A maximum of three calls can be dealt with on a position at a time, the apparatus concerned being as follows:—

Answering Circuits

Engaged lamp. Glows steadily when a call is connected to the circuit. It displays until the Trunk Inquiry telephonist operates the release key on a non-transferred call, or immediately on transfer button operation for a transferred call.

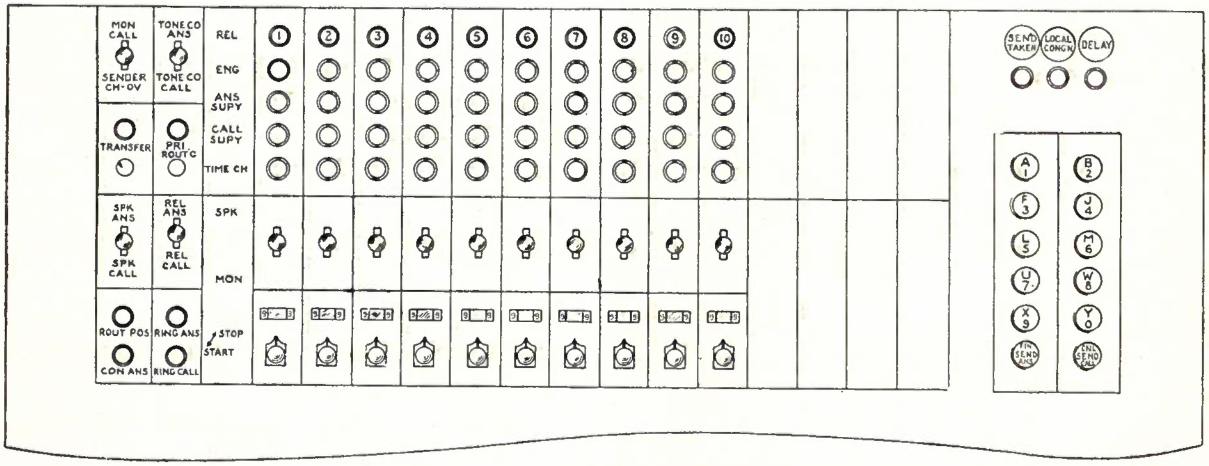

Fig. 5.—Through Position—Keyshelf Layout.

Calls are queued on arrival and appear in calling lamp displays. They are diverted to the connecting circuits in the same manner as for demand and other positions.

Trunk Inquiry telephonists can transfer incoming calls from their positions to either the Senior Traffic Officer or the Pricing Position. When a call has been transferred, the answering circuits again become available for other incoming traffic. Transferred calls in excess of the answering circuits provided on the Senior Traffic Officer's desk and the Pricing positions are held by the automatic equipment, with ringing tone reconnected to the callers, until circuits become free.

Metropolitan subscribers seeking information as to how long it will take to obtain connection to country exchanges can be given this information almost immediately. Each telephonist is provided with a digit keystrip and a set of lamps, and by keying the code of the country exchange, indication is given on lamps as to whether the route is in delay, and if so, the probable delay period as well.

Answer Supervisory lamp. Glows steadily to indicate when the calling subscriber is not on the line.

Speak and Release key. The speak key, which is locking, connects a caller to the position telephone circuit and also establishes conditions preparatory to use of either of the transfer buttons. The release key, which is non-locking, is used to throw the call off the position after it has been dealt with.

Common Apparatus

Transfer Senior Traffic Officer button. With a speak key thrown, momentary operation of this button causes a call to be transferred to the S.T.O. desk.

Transfer Pricing Position button. Same as previous item, but call is transferred to the Pricing Position.

Connect Answer button. Same function as Connect Answer buttons on other suites.

Digit Keystrip and its associated lamps: Register Taken; No Delay; Delay.

The term "Register" used above refers to delay registers, which are taken into use on keystrip operation for ascertaining the condition of Interstate trunks.

The keystrip comprises 12 keys having the same markings as and being interchangeable with the keystrips on Demand, Through and Suspense Positions.

To ascertain the condition of an Interstate trunk, the following takes place:—

Telephonist momentarily operates the FIN/SEND key and waits for the Register Taken lamp to glow, which will happen almost immediately.

She then keys up the code of the wanted group, and if the group is not in delay, the No Delay lamp glows. If in delay, the Delay lamp comes into action, flickering, flashing or steadily glowing to indicate 15, 30 or 45 minutes' delay, respectively.

Telephonist then momentarily operates the CNL/SEND CALL key which extinguishes the lamps and resets the delay register to normal.

Each position is provided with a pneumatic tube inlet valve, an example of its use being the transfer to the Suspense positions of information regarding absentee subscribers.

(To be continued.)

AUTOMATIC TELEPHONE EQUIPMENT RACKS FOR TYPE 2000 EXCHANGES

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One of the major problems in the design of an automatic exchange is the system of trunking to be used, between the subscribers' lines and the exchange selector equipment.

There are at present two main systems of trunking, one being known as the line finder and the other as the preselector method. In the line finder system the subscribers' lines are multipled to the banks of line finders, the wipers of which trunk out to 1st selectors; thus on the origination of a call the calling line is found by a line finder and so is connected to a selector. In the preselector system of trunking each subscriber's line is provided with a uniselector which, on the origination of a call, hunts to find a free 1st selector connected to its banks.

It is evident that in the line finder case the number of individual selecting mechanisms required will be smaller than in the preselector case, because a group of 20 or 25 finders may suffice for a group of 200 subscribers' lines, which would require 200 mechanisms on the preselector system. On the other hand, the line finders, which are two-motion selectors, are more costly items than the subscribers' uniselectors. In a busy exchange more line finders will be needed per group and there thus comes a point at which the economic advantage due to the reduction in the number of selecting mechanisms in the subscribers' line equipment on the line system is no longer pronounced.

Present-day practice has come to regard the two systems of trunking as each having its own separate field, line finders being used for the lighter traffic conditions and preselectors for the heavier.

An appreciation of the foregoing facts has influenced many telephone administrations to adopt the line finder system up to the margin of economy and the preselector system beyond this point. Since the introduction of 2000 type switching equipment, exchanges have been installed in Australia, using line finder equipment almost identical with that standardised by the British Post Office. As a result of experience gained from these installations, the following modifications have been made in exchange equipment on order:—

(1) A combined subscribers' line equipment and primary finder rack.

(2) A final selector rack incorporating a frame to provide intermediate distribution facilities (L.I.D.F.).

The purpose of this article is to describe in some detail the mounting and equipment of these racks.

Subscribers' Line Equipment and Primary Finder Rack

This rack, illustrated in Fig. 1 and described hereunder, has been designed with two main objects in view:—

(1) To have one size of multiple (i.e., 25 sets of banks) in a group of 200 subscribers, instead of the present practice of using varying sizes of multiples dependent on local traffic requirements. This standardisation has the advantage of making it possible to transfer racks without modifications from one exchange to another and to keep in stock a type of rack which can be utilised in any area.

(2) To facilitate installation by providing means for terminating as much exchange cabling as possible on connection strips and to effect a reduction in the amount of cabling between the finder banks and line relays by closer association of these components, as distinct from the practice of mounting line relays on racks separate from their associated line finder equipment.

The rack accommodates two groups of equipment, each consisting of 200 subscribers' line circuits and 25 primary finders with their associated start and control relay sets and allotter uniselectors. Each group of finders occupies two and a half shelves.

Fig. 2 shows the lower portion of the first group of finder equipment on the rack. It will

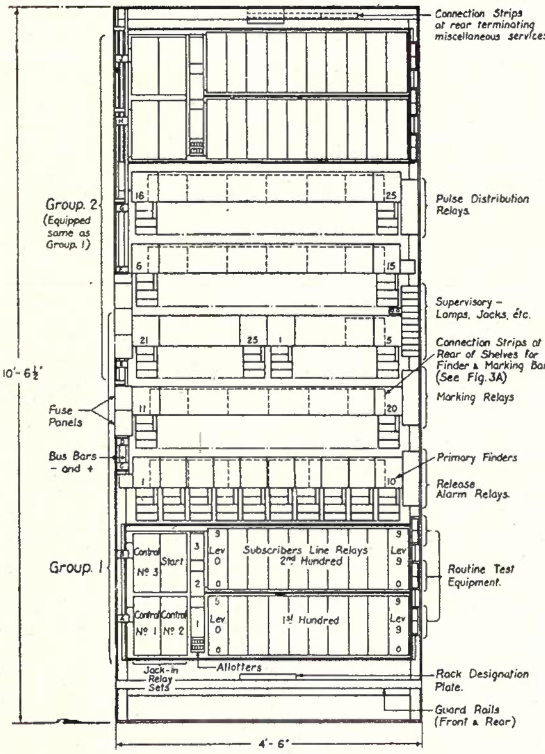

Fig. 1.—Line Equipment and Primary Finder Rack.

be observed that the subscribers' line and cut-off relays are mounted on vertical plates in sets of ten, which are screwed direct on a rigid iron framework. Each relay set is protected from dust by a removable sheet iron cover. The relays employed are the British Post Office Type No. 600, which combine compactness with efficiency.

On the same framework is mounted the line finder start and control equipment, comprising one jack-in primary start relay set and three jack-in primary control relay sets. The allotter uniselectors associated with the control sets are mounted direct on the same framework and are readily accessible to allow withdrawal of mechanism and wiper assembly for adjustment purposes in case of necessity.

The primary finders are of the two-motion jack-in 2000 type, each having four 220 contact banks. The banks of each group of finders are commoned in one continuous multiple which is terminated on connection strips located at the rear of the shelves.

The connection strips are of a moulded type and were specially designed for 2000 type equipment racks. Connections are terminated on one side only, this having proved in practice to facilitate easy location of connections as well as giving maximum accessibility.

The aforementioned strips for a multipled group are arranged to mount behind two primary finder shelves, i.e., the first 100 lines are terminated at the rear of one shelf and the second 100 lines at the rear of another. The arrangement of the tags is illustrated in Fig. 3. On the same connection strips are terminated those leads from the line relays which connect to the primary finder bank contacts, also those which extend to the line I.D.F. situated on the final selector rack.

Each primary finder has a hinged type vertical marking bank, which is wired out to tags on a connection strip serving ten finders on the same shelf. The commoning of the marking bank levels to form a multiple throughout the group is effected by local strapping and inter-commoning between the connection strips associated with the group.

The fuses for the equipment are mounted on moulded panels connected to vertical bus-bars at the left-hand side of the rack. The alarm relays, tone and pulse distribution break jacks, etc., are arranged on mountings at the right-hand side of the rack. Facilities are given for the routine testing of the primary finder levels by means of keys mounted at the right-hand side of the rack opposite the subscribers' relay mountings.

At the rear of the top cross angle of the rack are mounted connection strips terminating traffic recorder leads from the primary finders, also the common alarm, tone and pulse services supplied to the rack from the exchange alarm equipment.

The rear of the rack presents a particularly neat appearance, the shelf jacks, connection strips and shelf cabling being enclosed by sheet iron dust covers, which are readily removable for the inspection of wiring.

Following standard practice, the front guard rail of the rack is provided with a designation plate on which is displayed the title of the rack and its bay location number. To assist further identification of the equipment a label is provided at the end of each shelf bearing the shelf letter and is suitably signwritten to indicate the actual group which the shelf serves.

Final Selector Rack with Local Line Intermediate Distribution Frame (L.I.D.F.)

The rack shown in Fig. 4 is designed to accommodate 60 two-motion 2000 type final selectors having 200 bank outlets with the circuit arranged for either ordinary or private branch exchange service; the former requires 3-220 contact banks and the latter 4-220 contact banks.

The capacity of the rack permits the housing of three separate 200 line groups with a maximum of 20 final selectors per group. Larger groups may, of course, be accommodated, if desired, with a consequent reduction in the number of groups.

A feature of this rack is the provision of a line intermediate distribution frame disposed at the rear of the selector shelves. This enables cross-connecting to be carried out by "jumpers" to even up the load in any group or groups of subscribers or to place any subscriber in a call office or barred trunk group.

Of the many schemes and arrangements which have been evolved from time to time to effect an even distribution of traffic in an automatic exchange, the method now adopted is no doubt the most economical from the point of view of exchange cabling.

Hitherto it has been customary to cable all final selector bank outlets and line equipments to a centralised I.D.F. and it will be appreciated that long runs of cable were the result, whereas

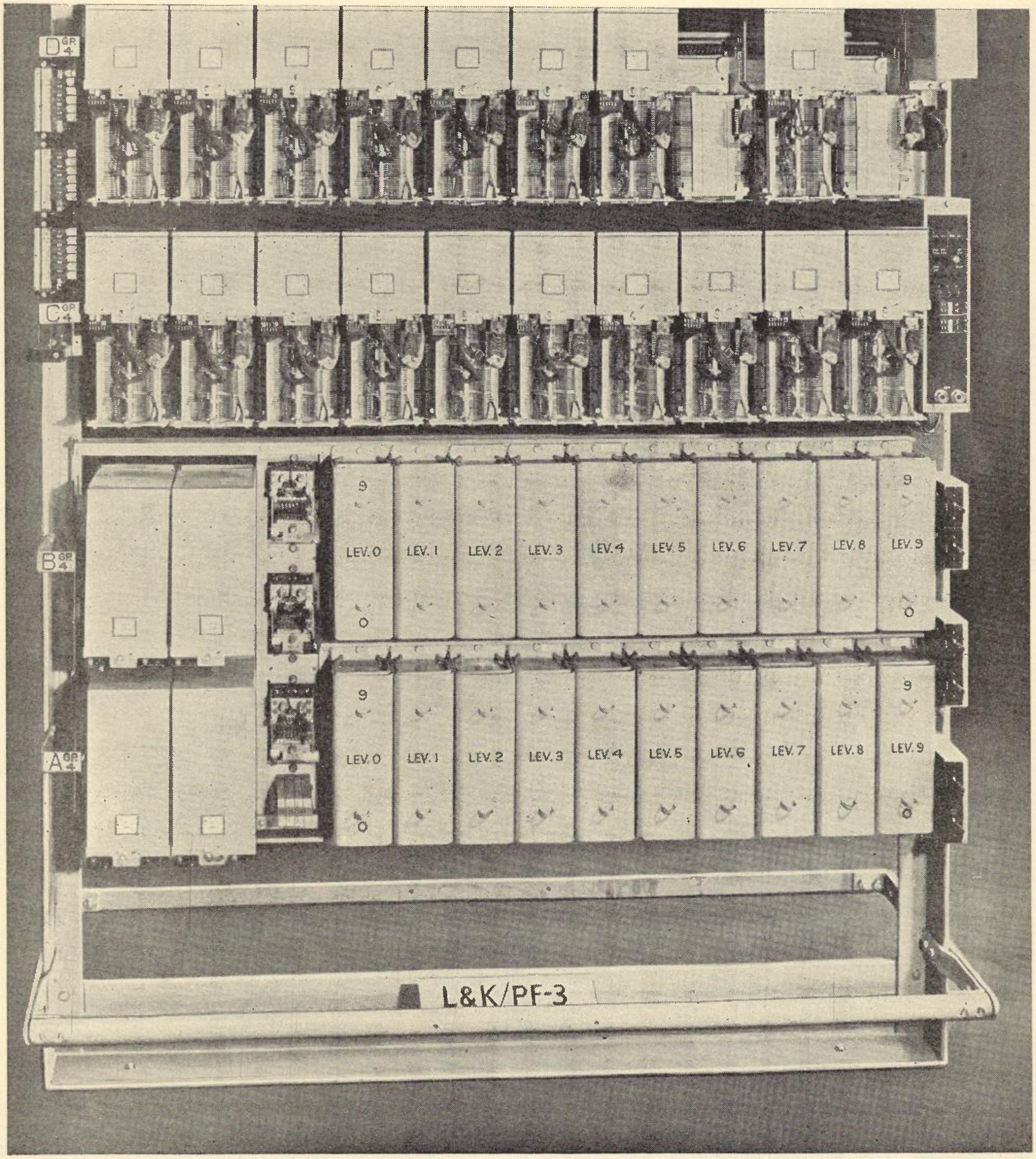

Fig. 2.—Lower portion of P.F. Rack showing First Group.

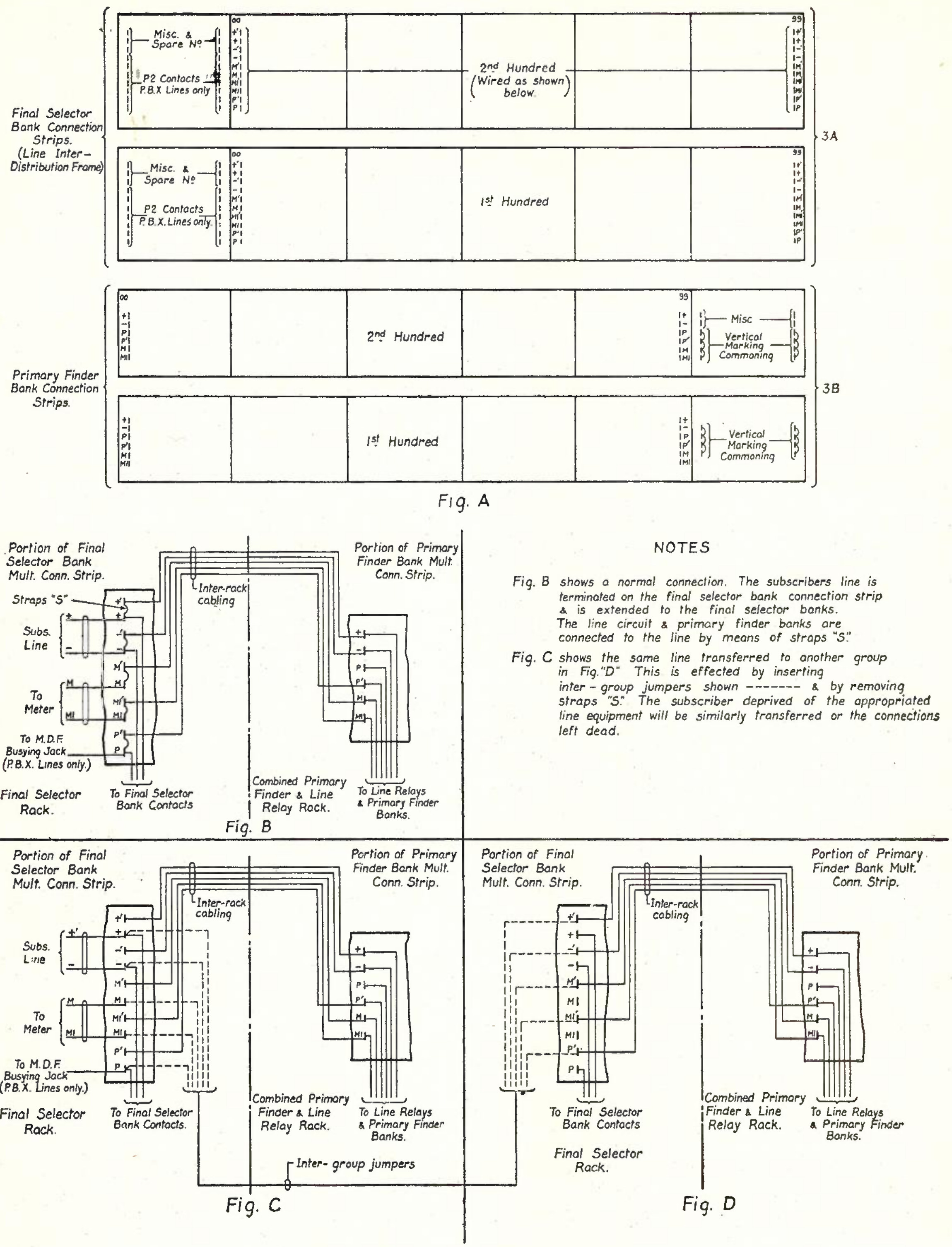

Fig. 3.—Diagram of Connections—L.I.D.F.

the localising of a distribution facility on the final selector racks themselves obviates this disadvantage. The scheme is simply the provision of a duplicate set of tags in the connection strips adjacent to the tags on which the final selector bank multiple outlets are terminated, the duplicate tags being used to terminate the leads from the primary finder banks and line equipment.

The banks of the final selectors are wired, according to pre-determined requirements, in any suitable multiple commensurate with the traffic estimated. The connection strips associated with any one group of final selectors occupy the rear of two of the shelves comprising the multiple, the strips for the first hundred lines being mounted at the rear of one of the shelves and those for the second hundred lines at the rear of the shelf immediately above. The connection strips are of the single-sided moulded type previously described and each have 10 rows of 20 tags set between two rows of fanning holes. The disposition of the strips on the shelves and the allocation of the circuits on the tags, also the general cabling scheme, will be seen in Fig. 3.

As previously mentioned in the description of the line relay and primary finder rack, each

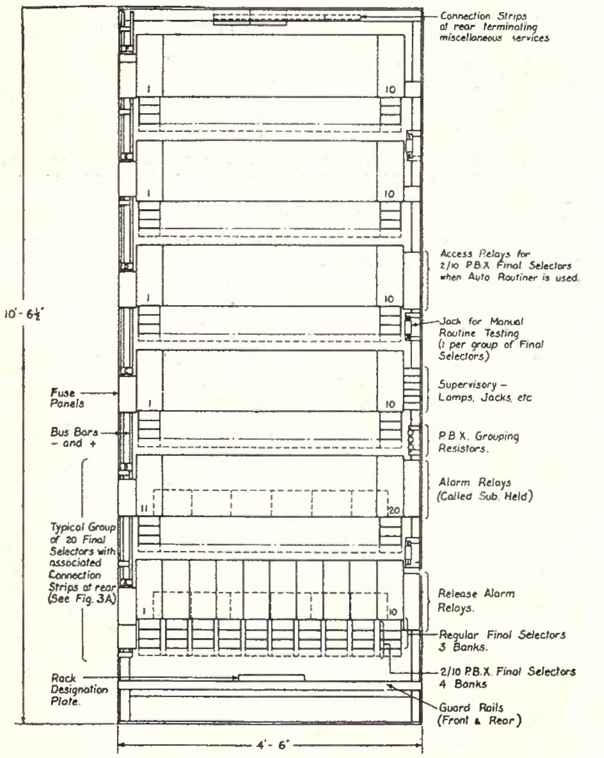

Fig. 4.—Final Selector Rack.

group of 200 subscribers' line circuits is permanently connected to the banks of an associated primary finder group and thence extended by switchboard cable to the aforementioned duplicate set of tags on the bank multiple connection strips of a 200 line final selector group.

Initially the duplicate tags are strapped to the bank multiple tags. When it is desired to transfer a subscriber's line to utilise another line equipment in a different finder group, the straps are removed and the final selector bank tags are jumpered to the duplicate tags associated with the line equipment chosen. An examination of the cabling explanatory diagram shown in Fig. 3 will readily show the simple nature of the wiring revisions necessary to effect such changes.

Having outlined the scheme of effecting a cross-connection, it is now appropriate to give a brief description of the L.I.D.F. construction.

Behind each row of connection strips at the rear of the final selector shelves are seven moulded iron brackets, each bracket being so constructed that, in addition to supporting the

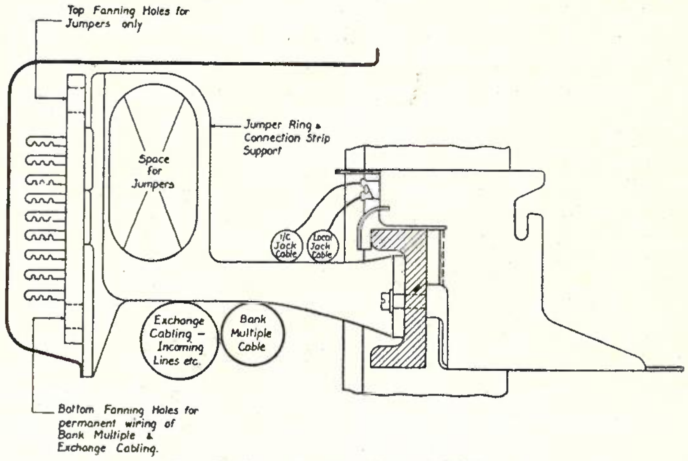

Fig. 5.—Cross Section View of Shelf.

strips and local shelf wiring and installer's cabling, it forms a jumper ring of very generous proportions. Fig. 5 is a cross-section view taken through a shelf and shows the disposition of the local cables, etc., on the brackets.

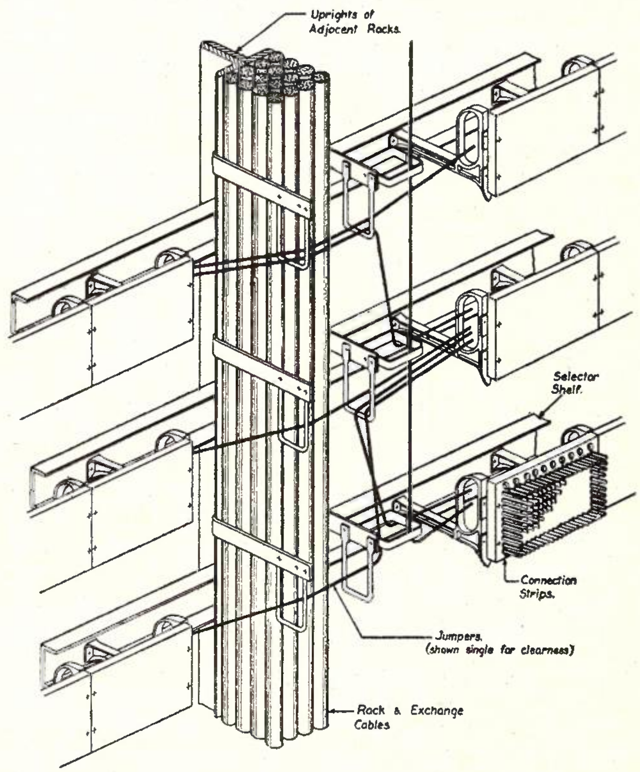

Fig. 6.—Isometric Sketch Showing Jumpering.

At the rear of the rack on the main vertical members, and placed at suitable intervals, are bent iron brackets for the purpose of supporting the vertical runs of both the rack and installer's cables. The brackets also act as supports for two other types of jumper rings. One of these rings is mounted in such a manner as to permit jumpers to pass, within its compass, from rack to rack when in the same suite; the other ring is to pass jumpers in the vertical plane between shelves on the same rack or out at the top of the rack to racks situated in another suite.

The isometric diagram (Fig. 6) shows pictorially how jumpers may be run in any chosen direction. It will be noted that the rings are so arranged that, although the jumpers lie in close proximity to the rack and its cables, they are confined to paths quite clear of any contact with them.

The jumpers may be directed, as desired, into racks in other suites in the exchange by means of large jumper rings disposed at suitable points on the superstructure above the racks.

TELEPHONE RECEIVERS NOS. 2P AND 10A

T. T. Lowe

This article describes the No. 2P Telephone Receiver. This receiver is an improvement on the No. 1L type which is in service on handset telephones. A similar receiver No. 10A for use on telephonists' headsets is referred to also.

General: In Bell's original telephone a device consisting of a permanent magnet, a coil to produce flux variation in accordance with current variation, and an iron diaphragm to change electrical energy into acoustical energy was used both as receiver and transmitter.

It is remarkable that this device has been used ever since as a telephone receiver, no fundamental changes in design having taken place until quite recently. The improvement in receiving efficiency which has been achieved particularly with the modern receiver type 1L used on handset telephones has resulted mainly from the greatly improved quality of the magnetic materials used.

The essential parts of a telephone receiver (see Fig. 1) are the magnet N.S., a coil C, and an iron diaphragm D. The diaphragm is clamped rigidly round its outer edge between the receiver case and the earpiece, but is free to vibrate in the air space S1 between the diaphragm and the case and the air space S2 between the diaphragm and the earpiece. The function of the receiver diaphragm is to transform electrical energy into mechanical energy and then to radiate acoustical energy. It has a natural period of vibration which is governed by its mechanical properties of mass and stiffness and by the load in the air spaces on each side.

For **good quality reception,** if the resonant frequencies of the diaphragm fall within the audio band, the damping effect of the air in the air spaces on each side of the diaphragm must be large.

On the other hand, for **maximum volume efficiency** the fundamental resonant frequency should fall in the middle of the audible band or the resonances should be spaced at intervals within the band. The older types of receiver have two pronounced diaphragm resonances. In receiver 1L used on handset telephones the fundamental resonance occurs at 1000 to 1100 cycles per second with another resonance at about 3500 to 3800 cycles. The latter is too high to be of value on telephone circuits with a cut-off frequency at about 3000 cycles.

The damping effect of the air in a confined air space on a telephone receiver can readily be observed. When a receiver is held closely to the ear, a larger acoustic load is impressed on the diaphragm and the damping effect is far greater than for a receiver in free air, with the result that the quality of reception is improved. When the receiver is lying on a table its output is considerably distorted when compared to a receiver held against the ear, due to the absence of the damping effect of the air in the space between the earpiece and the ear.

Magnetic Materials Used in Earlier Receivers, including Type 1L: The earliest type of watch-case receiver used in Commonwealth and Swedish Ericsson Magneto telephones was provided with a circular carbon steel permanent magnet, soft iron pole pieces and a tinned iron diaphragm. The permanent magnet consisted of a number of flat steel rings each magnetised across a diameter, the rings being placed one above the other with like poles together.

The well-known Bell receiver in use for so many years on magneto, C.B. and automatic wooden-cased wall sets and pedestal type table sets was provided with a tungsten steel U-shaped magnet, soft iron pole pieces and a "Stalloy" diaphragm, varnished black on both faces. Stalloy is an alloy of iron, silicon and aluminium containing 3.5 per cent.-4 per cent. silicon, and 0.1 per cent.-0.2 per cent. aluminium.

The 1L receiver in use on moulded handsets is provided with a cobalt steel bar magnet, cobalt iron pole piece and a stalloy diaphragm varnished black on both sides. The thickness of the diaphragm over the varnish is 10 to 11 mils.

Telephone Receiver No. 2P

General: The new type of telephone receiver (see Fig. 1) is designed to give a more uniform frequency response than the former types without loss in volume efficiency, thus providing better quality reception. Briefly, this is achieved by three resonances which are spaced at intervals and damped by acoustic networks. The

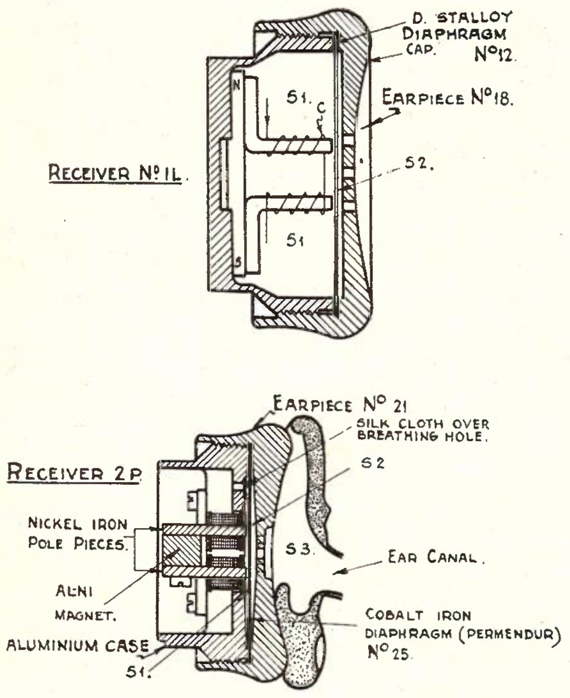

FIG. 1. RECEIVERS 1L & 2P.

acoustic pad behind the diaphragm consists of a shallow chamber (space S1) directly behind the diaphragm and connected with a larger chamber at the back by a small hole which is covered with a silk diaphragm of very fine mesh. The acoustic pad in front of the diaphragm consists of a shallow chamber between the diaphragm and the earpiece, connected by four small holes in the centre of the earpiece to the air space S3 between the earpiece and the ear. The loss in volume which results from damping the diaphragm is compensated for by the use of much better quality magnetic materials and improvements in the design of the magnetic circuit.

Construction: The 2P receiver is similar in construction to the 1L type. The receiver fits into the moulded handset to which it is secured by two fixing screws which also make the electrical connections. The die-cast aluminium case on which the pole pieces and magnet assembly are mounted incorporates the shallow chamber (S1) behind the diaphragm. The small silk diaphragm or cover is held in position by a small metal washer which is secured by staking the metal of the frame in three places. The magnet assembly is secured by fixing screws to the aluminium case, the pole pieces projecting through slots in a moulded plate insulator which is sealed to the aluminium frame and to the pole tips to make an air-tight joint.

Receiver 2P is provided also with a new moulded earpiece which will be known as Earpiece No. 21. The external dimensions are practically the same as those of the earpiece used on Receiver 1L, but slight changes in design have been made to assist in determining the earcap resonance. An important difference in the outside shape of the new receiver earpiece is that the four holes in its centre are arranged in the bottom of a small recess ½ inch in diameter and 1/10th inch deep in the front of the earcap, as it is essential that none of the holes is obscured by the cartilage of the ear when the receiver is in use.

The inside surface of the new earpiece is conical instead of flat to provide air flow to the centre holes and a more uniform cross-section of air in the air space when the receiver is in use.

Magnetic Materials: The 2P Receiver is provided with a short "Alni" bar magnet, the approximate composition of the alloy being nickel 25 per cent., aluminium 10 per cent., copper 5

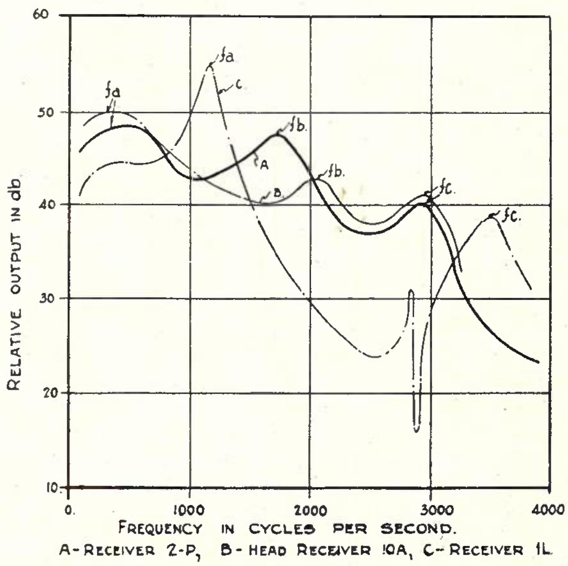

FIG. 2. FREQUENCY RESPONSE CHARACTERISTIC CURVES.

per cent., the remainder iron. This alloy gives a high flux density per unit of volume and the specific gravity of the alloy is lower than tungsten or cobalt steel, thus giving some further reduction in weight.

The soft iron pole pieces are of nickel iron containing approximately 36 per cent. nickel. This alloy has been chosen on account of its high permeability and high specific resistance, the latter reducing eddy current losses.

The new receiver diaphragm, which will be known as Diaphragm No. 25, is of "Permendur" and is varnished black on one face only, the side nearest to the ear when in use. Permendur is an iron, cobalt, vanadium alloy containing approximately 50 per cent. cobalt and 7 per cent. vanadium. Permendur has high permeability at high values of flux density, an essential requirement, as, in order to obtain as small a diaphragm mass as practicable it is necessary to use the thinnest possible diaphragm. The use of vanadium in the alloy is necessary to enable the material to be rolled into very thin sheets and considerably increases the specific resistance which otherwise is rather low, thus reducing eddy current loss. The thickness of the diaphragm over the varnish is about 10 mils.

It is claimed that the cross-sectional area of the pole pieces is the maximum practicable and

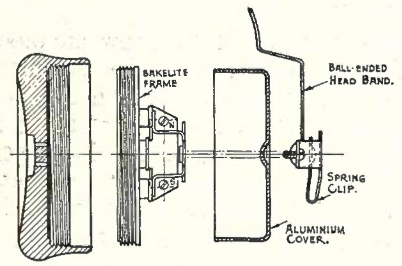

FIG. 3. RECEIVER 10A.

the separation between the pole pieces and diaphragm is the minimum consistent with security against pulling in the diaphragm against the pole pieces.

The D.C. resistance of receiver 2P is about 55 ohms and its impedance at 1000 cycles when fitted with a dummy ear is about $455\ \underline{/65^\circ}$ ohms. Receiver 10A has a D.C. resistance of about 60 ohms and an impedance at 1000 cycles with a dummy ear of $225\ \underline{/57^\circ}$ ohms. Its weight is 6¼ ozs. with the headband.

Improvement in Performance: The frequency response characteristic of receivers 2P, the handset type, and 10A, the headset type, when compared with receiver 1L, which is typical of the older type receiver, is shown in the curves (Fig. 2). Curves A and B are flatter than C and the output between the frequencies from 1500 to 3000 cycles per second has been raised about 10 db. above that of receiver 1L. This increased efficiency over the upper part of the voice frequency range is one factor which is responsible for the improved performance of the new receivers. Another advantage is that the absence of defined resonance peaks reduces the masking effect, which may be pronounced with the older receivers when the frequencies around the diaphragm resonance tend to mask other frequencies which are produced relatively weakly, resulting in loss of intelligibility.

Research Laboratory tests (Test Reports Nos. 943 and 944) indicates that the volume efficiency of the new receivers is about 2 db. above the 1L type (voice ear tests), and that the articulation efficiency is about 9 per cent. better than the 1L type. After an accelerated life test no marked loss in efficiency occurred.

A further advantage which is claimed for the new receivers is that the effect of surges or abrupt interfering noise on the ear is considerably reduced due to the fact that the new receiver has no very pronounced resonance. This should result in an overall gain in transmission efficiency, as the user will hold the receiver more closely to the ear, thus improving reception.

Applications: Apart from general use, the new receiver will be particularly suitable for use on telephones in noisy situations and by persons with defective hearing and also on telephones associated with amplifiers. It should also be of particular use to telephonists who usually work under rather noisy and trying conditions.

Method of Obtaining Improved Frequency Response (Figs. 1 and 2): As mentioned earlier, in the older receivers such as the 1L type the fundamental resonance occurs at about 1100 cycles per second (fa) due to the mass and stiffness of the diaphragm and the damping effect of the air in the space S1 between the diaphragm and the case. A second resonance called the "earcap resonance" occurs at about 3500 cycles (fc) due to the damping effect of the air in the space S2 between the diaphragm and the earcap, the air in the earcap holes and the air in the air space S3 between the earcap and the ear. This resonance is too high to be of value in telephone circuits having a cut-off frequency at, say, 3000 cycles per second.

In the new receivers, types 2P and 10A, the combined effects of the mass and stiffness of the diaphragm, and the damping due to the air in the shallow chamber S1 and the air in the leak hole, give rise to two resonant frequencies at about 300 (fa) and 1700 (fb) cycles per second for receiver 2P and 300 (fa) and 2000 (fb) cycles per second for receiver 10A. The fine silk covering over the leak hole serves to flatten out the peaks and the troughs, thus producing a flatter curve.

The effect of the acoustic chamber S2 between the diaphragm and the earcap, the air in the four earcap holes and the air in the air space S3 between the earcap and the ear is to produce a moderately sharp resonance in the region of 2900 cycles per second (fc), i.e., within the audio frequency band.

The change in earcap resonance (fc) for the new receivers, when compared with the earlier types such as 1L, is due to the altered shape of the inside of the earpiece, the reduction in the number and size of the holes in the earpiece, and the concentration of the holes at the centre.

Telephonist's Head Receiver No. 10A

The new telephonist's head receiver has the same magnet and pole pieces as the 2P type, but the weight is still further reduced by the substitution of a bakelite frame for the die-cast aluminium case. A pressed sheet aluminium cover is fixed to the back of the receiver by two screws, which also serve to attach the spring clip which holds the ball-ended headband (see Fig. 3).

Conclusion

The improvement in reception with the new receiver is primarily one of quality, and this has been achieved without loss in volume efficiency. The receivers were developed by Messrs. Standard Telephones and Cables, in conjunction with the B.P.O. Research Department.

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A CONSTANT POTENTIAL POWER UNIT

S. Mulhall

Introduction.—For small exchanges, P.A.B.X.'s and R.A.X.'s, where commercial A.C. supply is available, the power plant consists of simple static charging equipment employing a rectifier and a single battery.

With a suitable filter circuit, a rectifier could be used without a battery, but a battery is necessary to provide against failure of the A.C. supply. Advantage is taken of the battery to carry peak loads, as this makes possible the use of a rectifier of a lower output than if it were the sole source of power.

The power supply unit for a small exchange should have the following characteristics:—

(i) The output should be controlled without the use of moving parts or complicated switchgear.

(ii) The output voltage within the range of the unit should remain fairly constant and at the same time maintain the battery in a fully charged condition.

(iii) Should the exchange load exceed the output of the power unit, the battery should assist the power unit. When the load decreases the unit should maintain full output until the battery is re-charged to maximum voltage.

(iv) When the battery voltage has reached maximum, a trickle charge should be maintained, of sufficient extent to neutralize standing losses and obviate the need for overcharges.

(v) Provision for overcharging the battery, as this may be necessary after a series of failures of the commercial power supply.

The "Westat" Rectifier

The "Westat" constant potential rectifier unit manufactured by Messrs. McKenzie and Holland (Australia) Pty. Ltd., meets these conditions. Some of the features of the "Westat" rectifier are:—

(1) The output is full wave rectified 3-phase A.C. with a ripple content of 5 per cent. of the peak output volts at 300 cycles per second.

(2) The output voltage is controlled automatically by the load.

(3) The output curve can be adjusted so that it has a sharp cut off slightly above the maximum output, thus avoiding possibility of damage due to overload.

(4) It can be utilized as a "cyclic charger"; that is, the point at which the charge is cut in can be adjusted, so that the battery has alternate periods of charge and discharge.

Briefly, the "Westat" provides a means of converting single phase A.C. to 3-phase, which is passed through a copper oxide rectifier bank, to give a D.C. output. The D.C. output regulates the A.C. input in such a way that the D.C. potential is maintained at an approximately constant value from no load up to the full output of the unit.

The conversion of single phase A.C. to 3-phase in the "Westat" is accomplished by an adaptation of the "Scott" transformer connection.[1] The "Scott" connection shown in Fig. 1 was developed to derive two single phase outputs from a 3-phase supply, the output voltages being displaced by 90 degs. The "Westat" makes use of a reversal of the "Scott connection"; but as there is only a single phase to commence with, a phase splitting scheme is resorted to.

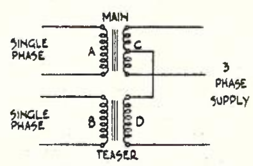

Fig. 1.—Scott Transformer Connection—D turns = 86.6% of C turns.

In Fig. 2, if the capacity, inductances and resistances are so proportioned that the voltage across A lags the supply current by 45 degs., and the voltage across B leads the same supply current by 45 degs., there is therefore a phase displacement of 90 degs. between the voltages across A and B. The induced voltages in C and

[1] "Electric Transformer Theory," S. G. Monk.

D will be displaced also by 90 degs. Retaining the Scott connection and turns ratio (100 turns in C to 86.6 turns in D) the resultant voltages can be set out as vectors as in Fig. 3. The voltage D (which according to the turns ratio, will be 86.6 per cent. that of C) is connected to the centre point of C. A neutral point N can be found one-third the way along D from its junction with C. Inserting NX and NY

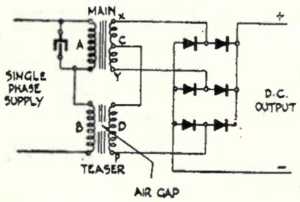

Fig. 2.—Elementary Circuit of "Westat" Rectifier.

completes the 3-phase vector diagram, the phase voltages being NX, NY and NP. Leads taken from points P, X and Y (which correspond with the free end of D and each end of C) carry a 3-phase current.

So far, discussion has been based on a 90° displacement between the voltages across A and B windings, and the capacity, inductances and resistances were proportioned to give that result. Variations in any of these factors will result in variation of the voltage displacement. In practice, the capacity and resistances are fixed. It is obvious that the inductances depend to a great extent on the degree of magnetic saturation of the cores; and that any variation in core flux density will be reflected in the inductance values. The "teaser" transformer, however, is built with an air gap in its core, and working well below saturation point, it is not critically influenced by

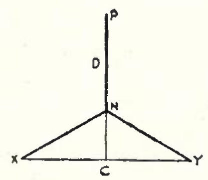

Fig. 3.—Vector Diagram showing Voltages Across C and D in Fig. 2.

flux changes. The "main" transformer is built to work within a definite section of the permeability curve of its core, so that any changes in its flux density are immediately reflected in the inductance of the A winding.

If the current in C winding (the output or load) can be made to vary the inductance of the A winding, then in conjunction with a correctly proportioned condenser, variation in the load can be made to vary the phase displacement between voltages across A and B, and hence the phase displacement between output voltages across C and D. The "Westat" is designed to give this effect, and at command of the load, there is available anything from a single phase to a three phase output. Single phase output is only achieved with "no load." In actual practice, at 100 mA trickle charge there is already a 3-phase output from the transformer, but the phase voltages and displacements do not reach the optimum value until the full output current is drawn.

The output of the transformers is fed to a bank of copper oxide rectifiers, arranged for 3-phase full wave rectification, and the DC output is used for charging the battery. The mean DC voltage value of rectified single phase is approximately 65% of the peak voltage, but the mean DC voltage when 3-phase is rectified is almost 95% of the peak value. This is graphically shown in Fig. 4; and herein lies the reason for changing from single phase to 3-phase output from the transformers. At low load (trickle charge approximately 100 milliamps) the output voltage is say 50V. As the load on the battery increases, the battery voltage will fall eventually below the output voltage of the rectifier; and the rectifier is then called on to supply current. The increased current flow from the rectifier causes a phase shift of transformer voltages, and the building up of three phase output with its higher mean voltage of DC output. This effect keeping pace with the increase in load, boosts the DC output voltage to compensate for the voltage drop caused by the increased current flow.

The boosting effects reaches a limit at the full current output of the rectifier, i.e., when the production of three phase reaches maximum. Any further current demand on the rectifier only reduces its DC voltage output below that of the battery. From this point, although the rectifier

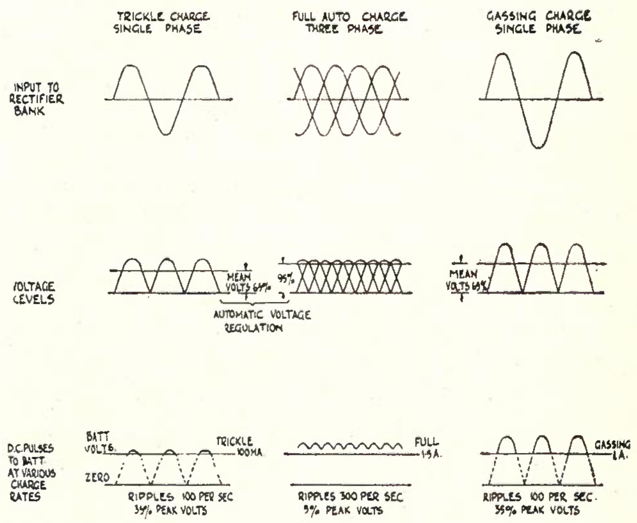

Fig. 4.

continues to contribute its rated output, the excess current demand is carried by the battery. This "cut off" point in the rectifier ensures that it cannot be overloaded and damaged.

When the load falls off, as the battery voltage is then most likely below the rectifier voltage, the rectifier continues to develop the three phase output to recharge the battery. As the battery voltage gradually rises due to the charge, the three phase boost is progressively reduced, and the charge rate tapers off until only the trickle charge remains.

A drop in battery voltage of 0.5V below the rectifier voltage is sufficient to swing in the three phase boost. The cut in and cut out points are readily adjusted by means of tappings on the transformer windings and the condenser. The adjustment is so wide, that, by suitable tappings, the cut in may be delayed until a given ampere hour output has been taken out of the battery; and the recharge prolonged until the battery is again fully charged. Under these conditions the rectifier would be operating as a "cyclic" charger.

The complete circuit is shown in Fig. 5, and the first point of interest is the switch marked "Auto-Gassing." The explanations given in preceding paragraphs cover the operation of the unit when the switch is in "Auto." position. But when the switch is moved to the "Gassing" position, the "Scott" connection is broken, and the single phase output of the main transformer only is used. There can be no injection of 3-phase to boost the DC voltage. Since the mean DC voltage of rectified single phase is only 65% of peak voltage, the switch is connected to a higher tapping on the output side of the transformer, to give a higher voltage to bring the battery up to the gassing stage. As the battery voltage rises, there is a tapering off of the charge rate.

The capacity unit is built up of three fixed condensers, and simple wiring connections give ready adjustment to the capacity. The capacity is not placed directly across the A winding of the main transformer as in the theoretical diagrams, but is connected in series with an additional "Condenser" winding, which acts as an auto transformer and applies an increased potential across the condenser. This gives the same effect as if a larger condenser were used.

The whole output level is controlled by the taps on the secondary of the main transformer, but in adjusting these, it must be remembered that to maintain the "Scott" connection equal steps, in or out, must be made on both sides of the centre point.

If the output voltage gradually falls below normal battery voltage before the full output current is reached more 3-phase injection is required. This additional boost may be obtained by tapping up on the condenser winding; or, if necessary by adding capacity to the condenser, and by using the C taps as a fine adjustment. This additional boost may lift the output voltage too much, but this is readily corrected by tapping down on T2 secondary.

The boost may also be increased by tapping up on T1 primary, but this may cause the output voltage to collapse altogether before full rated output current is reached. This is especially noticed if the commercial AC voltage tends to be on the low side.

Reducing secondary turns of T1 reduces the boost, and makes it more gradual, and variation of T2 primary may be used as a fine control on the output voltage.

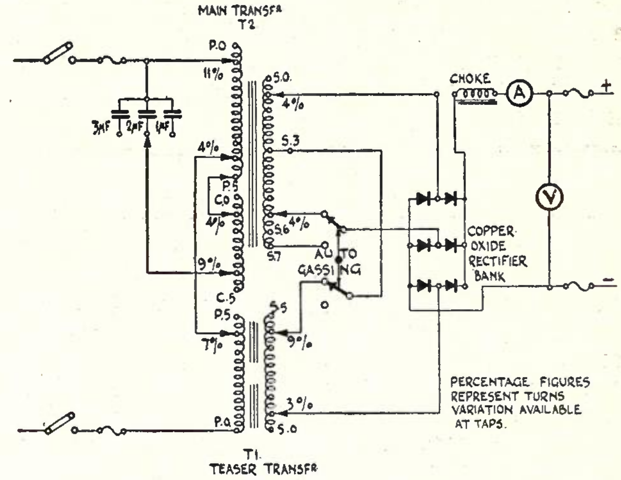

Fig. 5.—"Westat" Rectifier Circuit.

Working Adjustments.—The working adjustments described hereunder cover the 75 watt type (48-52V at 1.5 amp.), but the same principles of adjustment apply to all types.

It is necessary to fix on a working voltage, taking into account that a 48V battery cannot be charged by applying only 48V to it. The Westat unit is rated at 48-52 volts, and as most automatic telephone equipment operates within that range, 51-52V can be fixed as the working voltage.

Disconnect the rectifier from the battery, and across the output terminals connect a 200 ohm variable resistance, capable of carrying 2 amps for a short period. With maximum resistance in circuit, switch on the AC supply. Note the voltage and current as shown by the meters on the rectifier. Gradually decrease the resistance, noting the voltages at 0.1, 0.2, 0.5, 1 and 1.5 amps. The voltages noted should not exceed 52 nor fall below 48. Most likely the range will be low. Reduce current to zero and switch off. Add capacity or tap on condenser winding. Repeat tests. If the voltage range is still low, restore the condenser and winding tappings to original position, and tap outwards, equally on both sides, from centre point of T2 secondary and repeat tests. Consider the effect of tappings as described earlier and, if necessary, adjust accordingly. A stage will be reached where the voltage at low output rate is 51-52 volts and at full 1.5 amp. output, it is from 48-50V. A further test should then be made by increasing the output to 1.6 or 1.7 amps to ensure that the voltage falls below 48V proving the cut off point. The rectifier may now be considered satisfactory and reconnected to the battery. Observation of the battery over several weeks is the final test proving that the rectifier can maintain the battery at full charge.

The following table gives the correct taps to use in going from minimum to maximum turns and vice versa, as recommended by the manufacturers to maintain correct proportions between transformers:—

No. of turns	Transformer T1: Primary Taps	Transformer T1: Secondary Taps	Transformer T2: Primary Taps	Transformer T2: Condenser Taps	Transformer T2: Secondary Taps
Minimum ..	P0 P1	S2 S3 ..	P2 P3	C2 C3	S2 S4
(Increase ↓ / Decrease ↑)	..	S1 S3 ..	P1 P3	C1 C3	....
	P0 P2	S0 S3 ..	P0 P3	C0 C3	....
	..	S2 S4 ..	P2 P4	C2 C4	....
	P0 P3	S1 S4 ..	P1 P4	C1 C4	S1 S5
	..	S0 S4 ..	P0 P4	C0 C4	....
	P0 P4	S2 S5 ..	P2 P5	C2 C5	....
	..	S1 S5 ..	P1 P5	C1 C5	....
Maximum ..	P0 P5	S0 S5 ..	P0 P5	C0 C5	S0 S6

The writer desires to express appreciation of the assistance afforded by Messrs. Dickens & Wilson; McKenzie & Holland (Australia) Pty. Ltd., in the preparation of this article.

Staff Location System—Brisbane General Hospital

O. V. Hoskin

Introduction. The Brisbane General Hospital buildings are spread over a site of some 15 acres. In any hospital a reliable and rapid telephone service is a necessity, and for an institution so widespread a telephone system which will cope with fluctuating and probably unforeseen traffic demands, both day and night, is essential. This requirement has been met by the installation of a Private Automatic Branch Exchange with equipment for 200 extension and 16 exchange lines.

This fully meets general service requirements, but it is obvious that even with a P.A.B.X. valuable time would be lost in locating doctors who may be required urgently and who, at a particular time, may be located in any one of the many wards of the hospital.

Unless a special call equipment was provided it would be necessary for calls to be made to extensions in wards in which a particular doctor was likely to be engaged, and apart from delay in locating the doctor annoyance and inconvenience would be caused to the staff in the several wards.

A code call system was the obvious answer, but as the system in general use is limited to 12 codes, and any one of up to 50 doctors may be required, it was not suited to this service.

Therefore it was necessary to design a system to provide for up to 50 codes to be displayed at approximately 40 separate locations throughout the buildings. The code call equipment had to be controlled from a central point. Also the system had to be flexible in that a very large building programme was in progress, older buildings being demolished and new blocks erected at other locations.

Alternative Schemes. The several schemes investigated were:—

(a) **Lamp cabinets operated on a "lamp per wanted party" and a "wire per lamp" basis:** The particular lamp required could be operated by means of a jack fitted on the manual position. This scheme would require lengthy runs of relatively large underground cables from the control centre to the ground floor of each block of buildings, and thence by block cabling to a lamp cabinet in each ward of that block. The arrangement of a 10-point system on this basis is shown schematically in Fig. 1. Owing to the building programme which was proceeding, alterations to

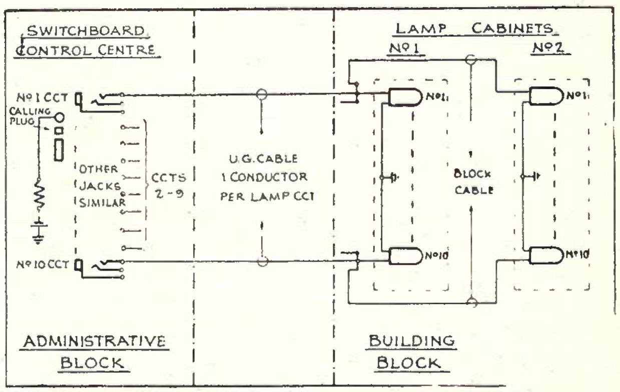

Fig. 1.—Lamp Cabinets operated on a "Lamp per Wanted Party" and "Wire per Lamp" basis.

the locations would be necessary from time to time, and considerable difficulty would be experienced in effecting the large U.G. cabling rearrangements involved in each move.

(b) **A small group of coloured lamps at each point operating on a colour combination basis for indicating the wanted party:** As the number of parties to be called was 50 ultimately this scheme was not favoured, although it has an advantage over scheme (a) in the matter of lower underground cable pair requirements. However, as a very highly developed colour sense, not possessed by the average person, would have been necessary to identify correctly up to 50 distinct colour combinations this method was passed over.

(c) **A scheme whereby each doctor was allotted an individual lamp, but the lamp operated from the bank contact of a uniselector provided in each building block:** This scheme embodied the desirable features of (a) in that an individual lamp was allotted to each doctor. The calling signal was definite and the ward staffs who would also become familiar with specific numbers could, if necessary, call the attention of the wanted party. The U.G. cable pair requirements from the control centre to the switch station in the building block were reduced to a minimum, as only one signalling wire and a power lead were required. As telephone services were already provided in the various buildings, spare pairs for this purpose were in some instances already available. The transfer of a ward from one block of buildings to another was, therefore, a simple matter as the few U.G. pairs required would probably be already available to the new building. In addition, the number of pairs to the vacated block which would be thrown idle, was negligible.

For the reasons outlined scheme (c) was adopted.

Grouping and Layout. Having decided on the general outline of the scheme, the development of the circuit arrangements and layout of the apparatus was a relatively simple matter. The fact that facilities had to be provided for calling up to 50 doctors, suggested the use of standard 50-point uniselectors. The simplest method appeared to be to "mark" a bank contact on a master control uniselector switch and cause the switch to rotate to the marked contact. In stepping, this master switch should repeat a corresponding number of driving impulses to all the "controlled" switch stations, one of which generally would be provided in each building block. The bank contacts of the "driven" switch were wired to the individual lamps in the various lamp cabinets associated with that switch station. The equipment was controlled from 50 jacks installed on the second position of the P.A.B.X. manual switchboard and wired to the banks of the master control uniselector located with the P.A.B.X. equipment. From this switch, cable was provided to 50-point uniselectors installed at nine control stations located at strategic points in the main buildings and the lamp cabinets were wired from the banks of these switches. A survey of the building grouping which was made to determine the minimum amount of block cable required, indicated that these stations could be controlled most satisfactorily by nine "controlled" switch stations.

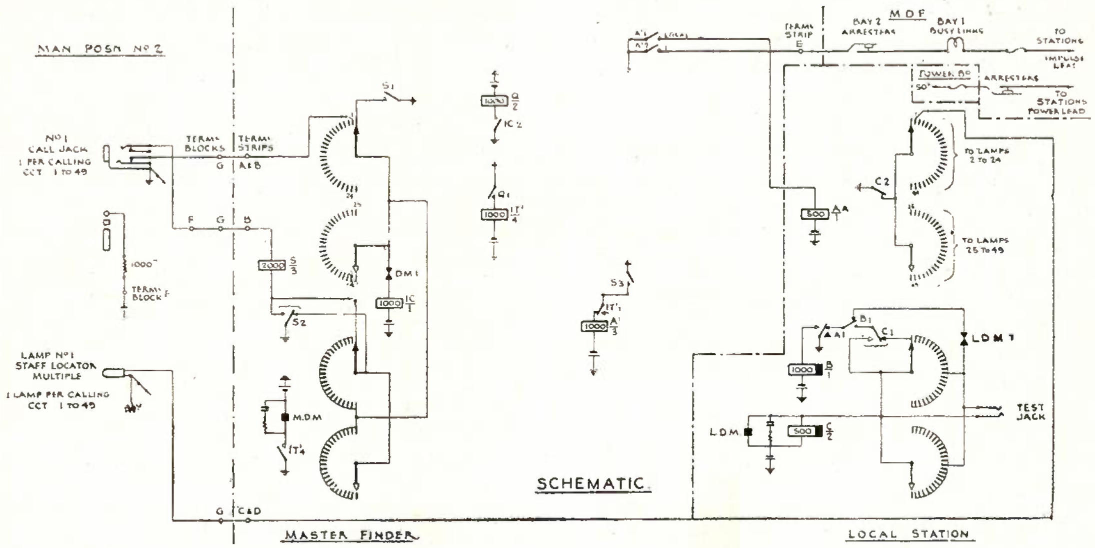

Fig. 2.—Staff Locator System—Schematic Circuit.

In the type of cabinet decided upon provision has been made for 50 signal lamps, standard switchboard lamp jacks in strips of 10 being utilised. In order to facilitate the identification of the lamps in each row, it was decided to arrange the lamp caps in a sequence of white, red and green. Assuming No. 1 lamp was coloured white, this grouping ensured that No. 11 lamp would be red, No. 21 green, and so on. Some difficulty was anticipated in the larger wards owing to the small size of the standard switchboard lamps, but it was found in practice that the combination of the coloured lamp cap and its relative location in the strip was readily identifiable both by the called person and other observers. As a further help, large number plates were provided which enabled the ward staffs, who were furnished with number lists, to easily identify the person sought. In public spaces, corridors, etc., a buzzer was provided in association with each lamp cabinet, but in wards where silence was essential the lamp signal only was relied upon.

Circuit Arrangements. The operation of the circuits will be evident from an examination of Fig. 2. On receipt of a call for a doctor the telephonist inserts the staff locator calling plug into the appropriate jack on the manual position. Relay S operates via the "home" contact of the master switch. Contact S1 prepares a driving circuit via "home" contact, DM1 and relay IC. Contact S2 provides a locking circuit for relay S. Contact IC2 operates relay Q, which in turn operates relay IT. Contact IT4 closes the drive magnet of the master switch which, then rotates until it encounters a contact which is "marked" by the absence of earth on calling jack. Synchronously with the stepping of the master switch, relay A of the master switch transmits an equivalent number of impulses to the station switches. With the original operation of contact S3, relay A operated via contact IT1. Contact A1 on the master switch station operates relay AA on the "controlled" switch station. Contact AA1 operates relay B, which prepares an impulsing circuit to the drive magnet (LDM). As the master switch rotates under the control of contact IT4, relay A releases in unison under the control of contact IT1. In order to prevent the operation of lamps as the wipers pass over the bank contacts, slow release relay C is maintained in the operated position during searching. When the marked contact is reached, C releases and contact C2 closes and the lamp associated with the marked bank contact lights. As all "controlled" switch stations have been stepped similarly the appropriate calling lamp glows at all lamp cabinets in the system. The complete "set-up" is released on the withdrawal of the plug on the manual position, when relay S is released. Contact S2 prepares a circuit for the intermittent operation of relay IC, which in turn controls relays Q and IT and the drive magnet of the master switch. In the case of the "controlled" switch stations the release of contact AA1 closes the drive magnet circuit via interrupter contact LDM1. This arrangement ensures that all "controlled" switch station uniselectors return to normal before the master switch and thus prevent any mutilation of the next "set-up" signal. This was considered essential as there was a possibility that if the master switch returned to normal before the "controlled" station switch and a second call had been set up in the meantime, portion of the drive impulses to the "controlled" switch station would be lost.

Conclusion. The scheme was brought into service in conjunction with the P.A.B.X. and has given every satisfaction to the hospital authorities. The value of the system is not difficult to assess as the saving in telephonists' time alone is readily apparent, e.g., a call for Doctor "X" is received by the operator, who, by plugging into a jack (the number of which has been allocated to this doctor, say, No. 24), causes lamp No. 24 to be displayed at some 40 different locations throughout the buildings. Both the doctor concerned and the staff know from the number of the displayed lamp who is required. On observing his call signal the wanted party then calls the telephonist from the nearest extension telephone, when the caller is connected with practically no delay.

THE USES OF A CABLE FINDER

E. J. Bulte, B.Sc.

Cable Finder is the name given to an apparatus designed for the purpose of giving an indication as to when its associated search coil is in the vicinity of a particular cable on which a suitable tone has been impressed.

The complete unit is shown in Fig. 1 and consists of a two-stage, low frequency amplifier with suitable supply batteries, headphones, and tuned search coil. The gain of the amplifier is approximately 35 db at 800 cycles. The use of the tuned search coil is a big advantage, particularly when split pairs are being located, as it minimizes the effect of extraneous fields due to electric trams, trains, power cables, etc.

The essential principle of operation of the unit is that an external magnetic field is produced by the alternating current flowing in the cable, and if an exploring or search coil is introduced into this field, an alternating e.m.f. is induced in it, the magnitude of which depends on the relative position of the cable and coil. The coupling between exploring coil and cable is a maximum when the coil axis is at right angles to the run of the cable.

A portable tone generator which was developed for use with the cable finder is shown in Fig. 2, a circuit diagram being shown in Fig. 3. It consists of a single tube 800 cycle oscillator, the output of which is interrupted by a self interrupting relay device, to give a pulsating tone which is fed out to the cable under test. The maximum output of the oscillator is approximately 1000 milliwatts, regulation being available by a five-stop fader device. The purpose of the interrupter is to provide a tone with a characteristic interruption, which is much easier to distinguish than a continuous tone, especially when there are interfering tones present in the locality of the test, and also when the field intensity is small. In passing, it might be mentioned that the oscillator can also be used as the source of tone in the test for locating open circuited pairs, or for capacity unbalance tests.

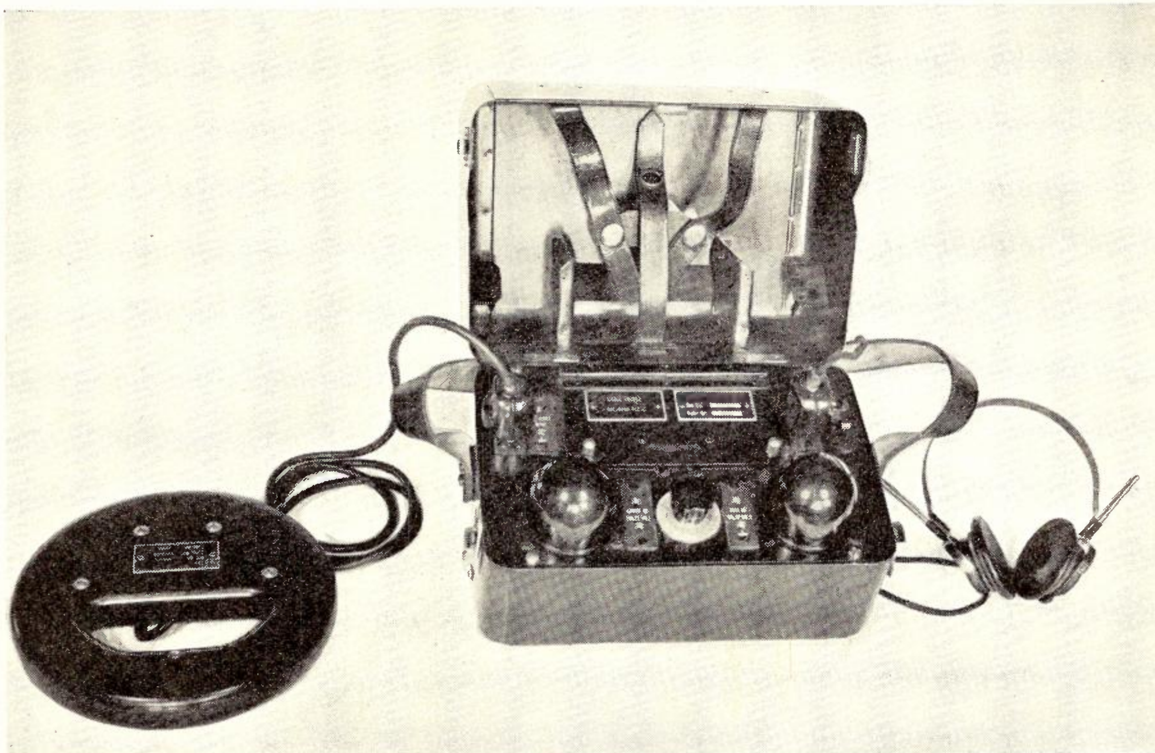

Fig. 1.—The Cable Finder.

Locating Position of Cables

Many cases occur in which it is desired to locate the exact run of a cable which has been laid for some time, and because of faulty or missing records, road deviations, etc., uncertainty as to the exact position exists. The procedure is to connect one side of the interrupted tone to a wire or group of wires in the cable and the other side to earth. The wire is then earthed at the far end. It is best not to use the lead sheath of the cable as an earth but to employ an independent earth in order to increase the effect of the field. When the instrument is switched on, the search coil is moved near the probable site of the cable. The interrupted tone sent over the cable will be heard in the headphones, and changes in intensity will be observed as the coil is moved, the maximum noise corresponding to a position of the coil held horizontally over the cable.

With the axis of the coil horizontal the position of the cable is indicated by maximum noise, but in practice it is better to determine the position from the minimum noise, as the human ear can detect this more readily. A minimum tone is obtained directly over the cable (due to cancellation of induced E.M.F.'s) if the axis of the coil points directly to the cable, i.e., with the axis vertical. With the coil held this way, maximum tone is obtained a little to either side of the minimum tone. Using this method, the position of buried cables can be located to within a couple of inches under average conditions of use, cables up to 8 ft. deep having been readily localized. By holding the coil at various angles, the depth of laying may also be estimated.

Locating "Split" Pairs

The problem of crosstalk caused by the existence of "Split" pairs has long been the despair of the Lines Engineer, as there has been no simple method by which a location may be given for the jointer to open the cable and remove the split, and the average cost of clearing cables of these troubles is consequently very considerable. The cable finder has also been applied to this problem with good results. The method depends for its result on the fact that the amount of separation between the wires of a pair is considerably increased where that pair is "split" with the wires of another pair. In addition to air space separation, the separation distance between the two wires of a normal cable pair is equal to twice the thickness of the paper wrapping on a wire. In the case of two adjacent pairs which are split with each other, the **maximum** separation between the wires which form the split pair, in addition to air space separation, is equal to six times the paper thickness plus twice the diameter of the cable wire. If an alternating current be passed along the pair, the external field created in the section which is split will be considerably greater than that created in the section where the pair is straight, the field strength being in direct proportion to the wire to wire separation of the conductors.

The practice followed is to short-circuit one of the split pairs at one end and connect the

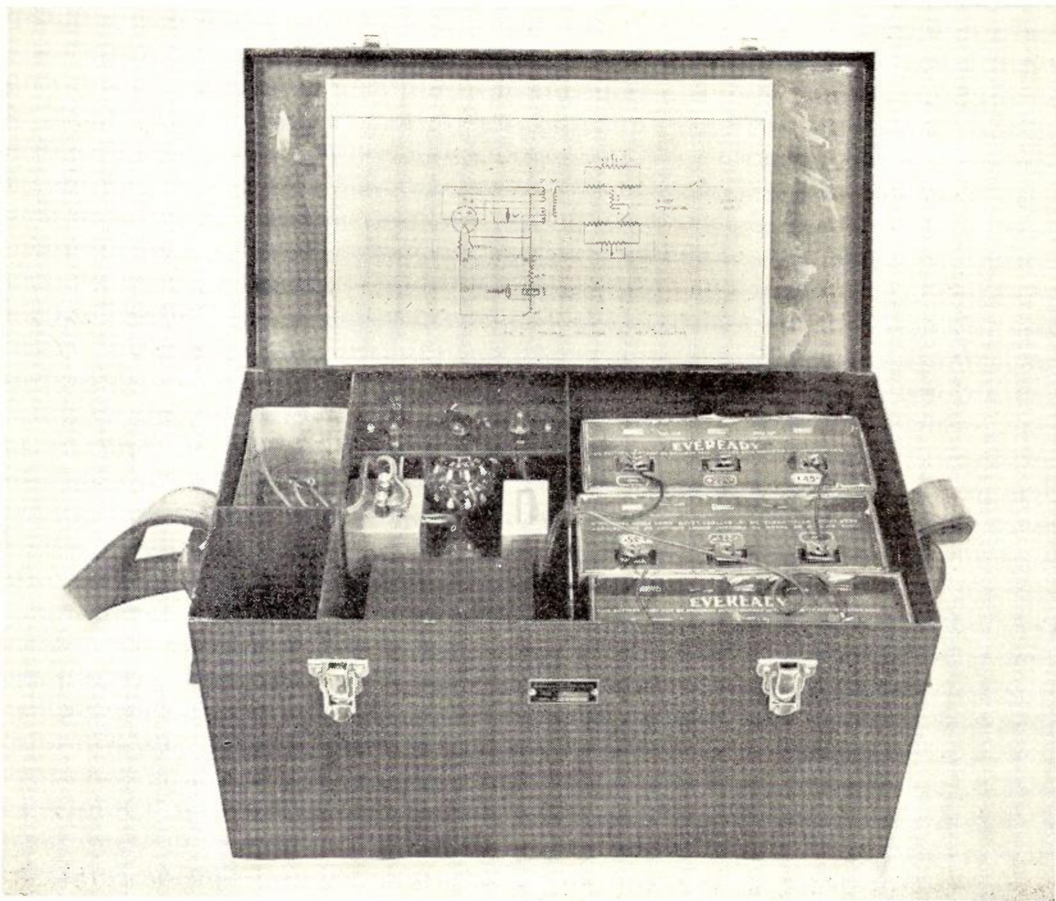

Fig. 2.—Portable Tone Generator.

interrupted tone to its other end. Under very favourable conditions, such as cables laid shallow, no interfering fields such as tramway induction, the tone may be picked up above the surface of the ground where the tested pair is split. In a case of this kind a marked decrease in the volume of the tone heard in the receivers will be apparent when the search coil is above those sections of the cable in which the pair is straight; in fact, the tone may disappear altogether. In practice, a big proportion of split pairs are found in cables of the type in which each pair is represented by wires, one wrapped with red and the other with white coloured paper. This class of cable, which is not used to the same extent, is mostly in ducts laid many years ago, and frequently is set deep in the ground, very often in roadways, in accordance with earlier practice.

Under these circumstances, the current necessary in the split pair test to create a field strong enough to be audible above ground is such as to cause very serious interference throughout the

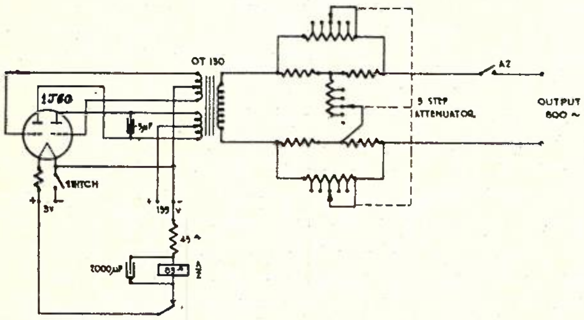

FIG. 3 PORTABLE OSCILLATOR WITH SELF INTERRUPTER.

cable. Thus in most cases it is necessary to take the cable finder into the manholes and pick the tone differences on either side of the joint in the cable under test. Even with this necessity the time saved in unnecessary joint openings and identifications is very considerable. In order to increase the field without disturbance to neighbouring circuits, a modulated carrier frequency current instead of the 800 cycle current may be used.* The location of incorrectly jointed star quad cables is, of course, not covered by this method unless in the rare case of splitting between quads. This is to be expected, as the space difference between the wires 1 and 2, and 1 and 3, in a quad is too small to be of any use in detecting external field differences.

Location of Wet Cable Troubles

The time element in the clearing of cable trouble of any kind is important. Thus any means whereby the testing and locating time may be reduced is well worthwhile. The experience in locating wet cable troubles is that a good proportion of the total clearing time is spent in identifying, testing, running loops, etc., for the performance of the usual Varley loop test. Some instances are occasionally met where the unit resistances of faulty pairs which are used in such locations are different from the standard values, or incorrect calculations are inadvertently made, and incorrect time-wasting cable openings are consequently made, with further loss of time in fault clearing. The increase in the use of pillars with identified links has greatly facilitated the problem of obtaining identified faulty pairs along subscribers' cable runs in metropolitan areas, but there still remain many areas where these facilities cannot be availed of. In the outer areas, the growing practice of ploughing in long lengths of cable to serve subscribers, as an alternative to provision of service with pole lines which are more costly to maintain, has accentuated the difficulty of obtaining a "good" wire for the Varley loop test when faults occur in such cases.

The Cable Finder has been applied to wet cable location with excellent results in cables laid under different conditions. The method followed is to apply the interrupted tone at one end of the cable to two pairs which are as far apart as possible in the faulty cable. The procedure is now much the same as for split pairs, as the output current is short-circuited at the fault and a big drop in the intensity of the tone occurs when the fault is passed. The external field created in this test is, for the same input current, greater than for the split pair test, as the separation distance between the current-carrying wires is greater in the former case; consequently, above ground results are possible in the majority of cases.

In the case of cables in iron pipes laid fairly deeply, sometimes the field created above the ground is not sufficient to give results using this method; in which case it is necessary to use the instrument in a similar way as is done in the cable location test as described for "Locating Position of Cables" (i.e., using an earth return circuit), except, of course, that the faulty pair or pairs are not earthed at the far end of the cable as the return circuit is completed at the fault. In this test it is sometimes necessary to use an independent earth such as an earth stake, water pipe, etc., as the field created is much greater. The point to guard against in using the instrument this way for fault location, is that the tone may carry on beyond the fault due to the existence of a positive earth, apart from the wet cable trouble, on a pair in the cable under test.

Excellent results have been obtained in cases tested so far, and although it is not expected at this stage that the instrument will entirely replace the Varley loop test, it is considered that it will be a most valuable adjunct in the location

*"Telecommunication Journal," Volume 2, No. 4, page 241 — "Identifying Working Cable Pairs with a Modulated Carrier Frequency"—C. M. Hall.

of wet cable troubles, and action is in hand to have more sets made available for use. A typical case illustrating its use in this direction was in the recent location of a fault in a 50 pair cable, which has been laid direct in the ground to a depth of about 15 inches some 13 years ago. The length in which the fault was located was approximately a mile long, and no facilities existed for obtaining a "good" wire via alternative routes to perform a Varley loop test. The first discovery that was made, after the tone was connected across two pairs in the cable, was that the cable was situated 18 feet from the fence, whereas the cable plan indicated that the original distance was 3 feet, it being subsequently ascertained that the road had been widened in the meantime. The hole in the sheathing, which was the cause of the fault, was located to within approximately 2 inches using the cable finder, the test being completed about 10 minutes after the connection of the tone to the cable.

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SOFT SOLDERS, SOLDERING AND WIPING

G. O. Newton

PART III.

WIPING (Continued)

Methods and Practices. It can be stated definitely that the technique of wiping cannot be acquired by studying textbooks. Such books may give much information that will be helpful, but demonstration and practice are essential before the necessary skill can be acquired. As for ordinary soldering, cleanliness is the first essential. All parts to be wiped should first be cleaned and immediately coated with flux (stearine or tallow) to prevent further oxidisation or soiling of the surface. As the lead sheathing of telephone cable is comparatively thin every effort is desirable to avoid any reduction in strength at joints. As the shave hook tends to remove too much of the lead, cleaning of lead surfaces should be done with a wire brush as far as possible, and the shave hook should only be used to clean any indentations in the surfaces or to clean the edges of the lead.

It is preferable, but not essential, that the cleaned surfaces be tinned (surface soldered) wherever possible before wiping. This applies more especially to large complicated joints. The adequate wetting of all surfaces to be wiped by such preliminary tinning ensures complete adhesion between wiping solder and surfaces—more particularly in regard to those parts which fit closely. Whilst experienced operators will, no doubt, find no difficulty in making sound wipes without this precaution, it is advisable that it be adopted by those who have not acquired sufficient skill to give them complete confidence in the soundness of their work.

For the purpose of making the actual wipe, suitable wiping cloths, preferably of good quality moleskin and well soaked with flux, are required. Wiping cloths made from soft hide or from fine felt have also been used with success. Tallow appears to be the best flux for use on wiping cloths since it does not tend to make the cloth as stiff as stearine does. With a view to retaining the solder in a plastic state as long as possible, the surfaces to be wiped and wiping cloths should be warmed beforehand with the torch or blow lamp. The warming of surfaces to be wiped requires care to ensure that the lead sheathing or sleeve is not melted by the application of too much heat at one point. This danger also arises if the wiping solder is too hot when applied or is overheated when using the blowlamp after application of the solder as referred to later.

There are two methods of applying the wiping solder, known as "pot" wiping and "stick" wiping—the difference being indicated by Figs. 12(a) and (b) respectively. In the former case the solder is melted in a pot over a furnace and applied by means of a ladle held in the right hand. A large cloth called a "catch" cloth is held in the left hand beneath the joint to catch any solder which falls or runs off. The molten solder is splashed on to the joint by a rotary movement of the ladle in such a way that the metal does not fall in a confined area (which would tend to melt the lead), but is spread over as large an area as possible and gradually builds up a mass of plastic metal of even temperature sufficient to form the wipe. At the same time, any solder which runs down on to the catch cloth is worked back on to the joint by an up and down movement on each side with a view to obtaining an even thickness of solder all around.

As soon as sufficient solder has been applied, a wiping cloth of suitable size is taken, usually in the left hand, and the solder worked into a neat shape as quickly as possible, taking care at the same time that all spaces are filled with solder, and that cavities or holes in the solder are avoided. The shaping of the wipe should be commenced from the back near the top, thence around underneath and up to the top again on the near side. Excess solder brought to the top is removed finally by a longitudinal movement. The thin edges which cool quickest should be formed first. During the process it is necessary to watch closely the underside to avoid any solder running off. The usual method of holding

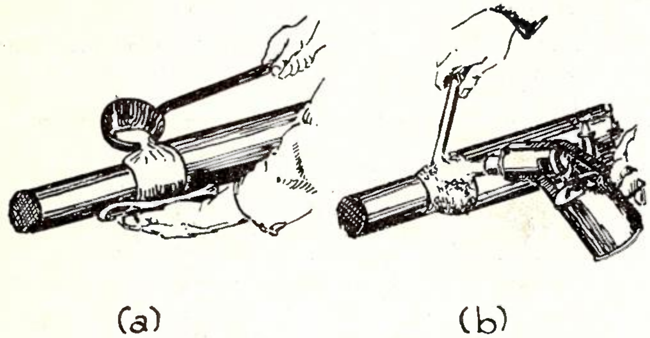

Fig. 12.—Showing method of applying Solder for (a) "Pot" Wipe. (b) "Stick" Wipe.

the cloth is to lay it on the four fingers shaped to the required curve of the wipe with the thumb along the edge of the cloth. In the case of large wipes, a larger cloth covering the hand as well as the fingers will be necessary.

Normally, for cable work, the use of the blowlamp or air-acetylene torch which is usually held in the right hand, is necessary to keep the solder in the plastic state for a sufficient period to enable the forming to be done. It is necessary to acquire sufficient skill to keep the use of the blowlamp or torch down to a minimum and to keep the temperature of the solder at all points as even as possible throughout the operation. The latter requires frequent short applications of the blowlamp rather than less frequent applications for comparatively long periods. Although, as a general rule, the wiping cloth is held in the left hand and the blowlamp or torch in the right hand for the purpose of forming the wipe, it may be necessary to reverse these arrangements under some conditions for all or portion of the operation.

The solder for making pot wipes should not be heated beyond a temperature a little over the melting point of lead (i.e., about 650 deg. F.). If a suitable thermometer or other temperature indicator is not available, the usual method of judging this temperature is to insert the end of a length of folded clean dry paper into the molten metal. If it chars without any burning the temperature is correct. If it burns or ignites, the metal is too hot. Immediately before using the metal, all dross should be removed and the clean metal carefully stirred.

Stick wipes are performed by applying the solder direct from the stick on to the sheathing with the blowlamp or torch, the stick being moved from point to point around the joint until sufficient has been applied. The solder is not completely melted during this process, but is only softened sufficiently to permit of the solder being "dabbed" on so as to obtain a suitable volume over the area to be wiped. It is then warmed in situ with the blowlamp until it becomes evenly plastic throughout and is then worked into shape with the wiping cloth, as in the case of a pot wipe. Care is necessary when warming the solder in situ, that too much heat is not applied at any one point, thus "burning" the lead sheathing.

Pot Versus Stick Wipes. Under most conditions the stick wipe is considered the more suitable for cable work. It is easier to learn to wipe by this method, and it is much faster. Pot wipes necessitate the use of mates in most cases and involve the use of the objectionable fire pot or a furnace, together with considerable time in getting the solder ready, and considerable danger in handling the pot of molten solder, especially where deep or congested manholes are concerned. Stick wipes on the other hand are readily applied without the need of assistance or of heating equipment additional to the blowlamp or torch, and are less wasteful in the use of solder. Where the required skill has not been developed the danger of burning the lead sheathing when splashing on the molten solder is also removed. Another objection to pot wipes is the tendency for the tin content of the solder to be gradually reduced by oxidization due to repeated heating in the pot.

Defects in Wiped Joints. Before dealing with defects in wipes it will be as well to draw attention to the fact that, if the lead sleeve is made

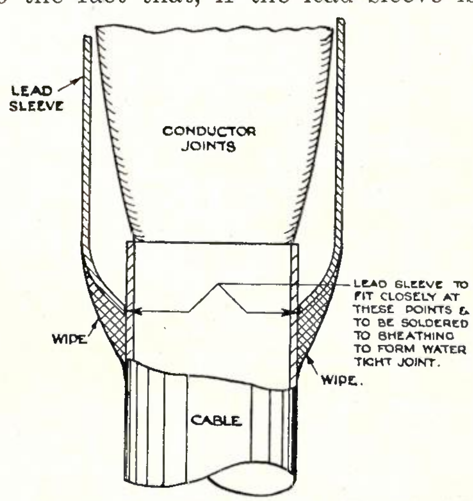

Fig. 13.—Showing method of Fitting and Wiping Lead Sleeve to Lead Covered Cable.

to fit the sheathing closely, and the space between the lead sleeve and cable sheathing filled with solder completely bonded to both surfaces, it will ensure that the joint is watertight even if the wipe itself is defective. (See Figs. 13 and 14.) A reasonably close fitting sleeve is also necessary to prevent solder running inside to any great extent. In a similar manner, where sheet lead sleeves are fitted, the inner surfaces of the overlap seam should be cleaned (and preferably tinned also) before fitting, and the solder allowed to run in and bond both surfaces throughout after the manner of the overlap joint shown in Fig. 9 (iv) (a). (See Fig. 14 also where solder has run on the surface inside the sleeve beyond the overlap.)

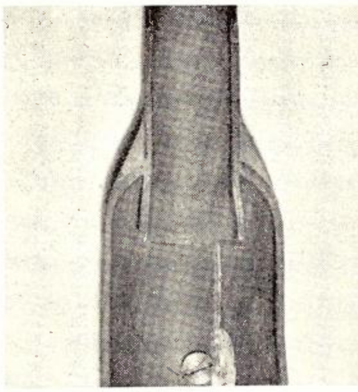

Fig. 14.—Example of method of Fitting and Wiping end of Lead Sleeve.

The chief causes of defects in wiped joints are:—

(i) Imperfect adhesion to the lead surface due to lack of cleanliness and/or imperfect fluxing. (See Fig. 15.)

(ii) Burning of lead sheath or sleeve due to concentrated application of heat.

(iii) Cracks caused by movement or jarring of the joint before the wipe has properly set.

(iv) Cavities due to the plastic metal not being

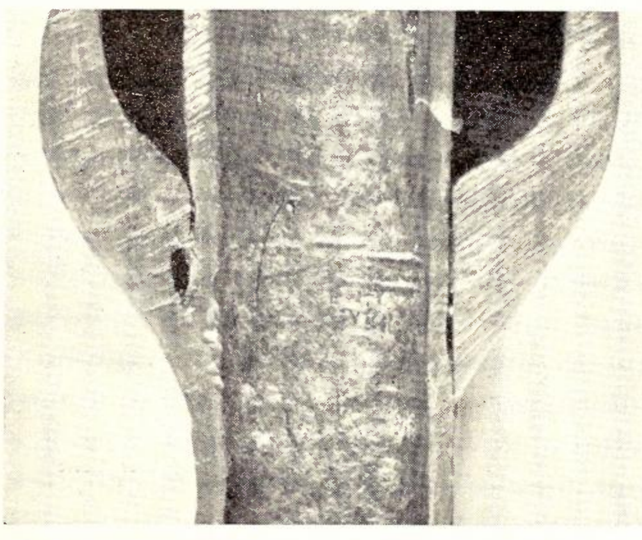

Fig. 15.—Example of imperfect adhesion between Solder and Lead, also of cavity in Wipe.

pressed against the lead sheath so as to fill completely all spaces adjacent thereto, and to close any cavities in the body of the solder. (See Figs. 15 and 16.)

(v) Porosity of the solder.

Causes (i) and (ii) have already been mentioned, whilst (iii) and (iv) are within the control of the operators. A wipe containing cavities is not necessarily faulty, but is a potential source of failure, especially in combination with any tendency to porosity in the solder. In addition to the above causes of defects, trouble will arise if any attempt is made to seal a cable containing air or gas under pressure.

Porosity. The factors conducive to the avoidance of porosity in wiped joints are:—

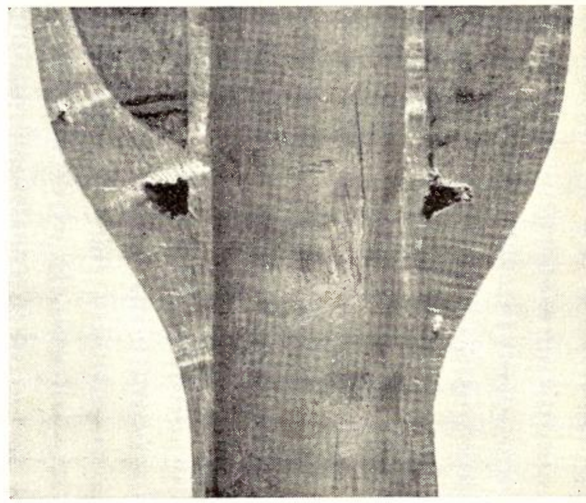

Fig. 16.—Example of cavities in Wipe.

(i) Adequate eutectic content of solder.

(ii) Small and even grain size in completed wipe.

(iii) Minimum use of blowlamp.

(iv) Adequate use of flux on wiping cloths.

The necessity for an adequate tin content to ensure complete wetting of the surfaces and constituent lead particles by eutectic has been mentioned previously. (Page 288, Part II.) A small and even grain size is a necessary adjunct for satisfactory cohesion within the solder. This requires minimum and uniform temperatures combined with quick and even cooling so that thin wipes similar to those shown in Figures 13 and 14 are the most suitable. Such wipes are sufficiently heavy for strength purposes. It is very undesirable to cool wipes by applying tallow, stearine or wax. Although this hastens cooling, it tends to make it uneven and therefore may affect cohesion. It is also readily blown out by the pressure test if the wipe is porous. Overuse of the blowlamp tends to drain the tin rich eutectic out of the wipe, and if too much of this takes place the operator will be left with a porous composition.

Adequate fluxing of wiping cloths is necessary to assist the wetting of the lead particles of the solder as it is wiped and so offset any tendency to lack of cohesion in any part of the solder, due either to the composition of the solder or to oxidization brought about during the wiping process. On completion of any wiping or soldering operation of a cable, the work should be closely and carefully inspected, using a mirror (a concave one for preference) to obtain a view of any portions not directly visible to the eye. If there is any doubt regarding the soundness of a wipe, it should be re-wiped.

LEAD SLEEVES FOR SEALING JOINTS IN TELEPHONE CABLES

General. To make this series of articles complete, when read in conjunction with the previous series on Cable Jointing, some discussion on the making and fitting of lead sleeves for sealing joints in lead-covered telephone cables is required. Here again to a considerable extent demonstration and practice are essential for the acquirement of complete skill under all conditions. The information to be imparted will therefore, to a large extent, be of a general nature and cover the simpler and more common conditions encountered by a Cable Jointer.

Lead sleeves for the purpose of sealing the completed splice of a telephone cable may be either:—

(a) A Slip Sleeve made from a suitable length of spare cable sheathing or from commercial lead soil pipe; or

(b) A Sheet-lead Sleeve made from commercial sheet lead.

Slip Versus Sheet-Lead Sleeves. The former type should be used wherever possible since they obviate the forming of the sleeves from the sheet, and there is no longitudinal seam to seal with solder. They have the further economic advantage that to a large extent requirements can be met by the use of sound sheathing removed from scrap cable or pieces of sheathing removed from cable ends when making joints. When slip sleeves are used, it is necessary to perpare them beforehand and place them on the cable on one side or other of the joint so that they can be slid over the joint after the conductors are jointed. On most occasions this necessitates sufficient space in the jointing chamber to obtain a straight length of cable to permit of this, since only in the case of very small cables is it usually possible to slide a slip sleeve around bends. On main cable routes this requires long manholes, in which case joints can be made in a staggered arrangement as shown in Fig. 17.

It is necessary that the portion of the sheathing over which slip sleeves are slid be clean and free from grease, jelly, etc., and there should be no possibility of water or moisture working along the surface of the cable sheathing to the inside of the sleeve. Care must be exercised in deciding the internal diameter so that it will be certain that the sleeve will slide over the joint after it is completed and wrapped.

Sheet lead sleeves are necessary where local conditions render the use of slip sleeves inadvisable (danger of water, grease, etc., entering sleeve, complicated conditions requiring sleeves of irregular shape, etc.) or where, owing to confined space, number of branches, etc., it is not possible to slide a slip sleeve along the sheathing until the conductors are jointed. Sheet lead sleeves have advantages that their dimensions can be decided accurately after the completion of conductor jointing, and that they can be adapted to the shape of the joint more readily. In the case of a slip sleeve, if the joint is made too bulky for the internal diameter of the sleeve placed on the cable, its use must be abandoned and a sheet lead sleeve fitted.

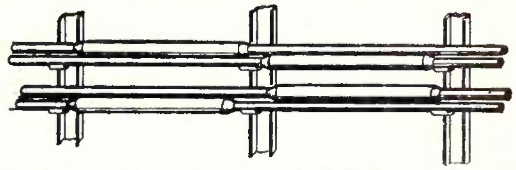

Fig. 17.—Showing staggered arrangement of Joints on wall of Manhole permitting the use of Slip Sleeves.

Dimensions of Lead Sleeves. The size of sleeve to be used will depend on:—

(a) Size, type and gauge of cables involved;

(b) Whether straight or branch joints are involved. In the latter case the joint may vary from a case where it is straight at one end with two cables at the other to one where there are three or even more cables entering the joint at either or both ends;

(c) The length of the opening between the ends of the sheathing. Where space permits this should be ample and should approximate to the dimensions shown in Table 4. In confined spaces, e.g., in jointing pits, cramped locations in buildings, etc., smaller openings may become necessary, requiring shorter sleeves of larger diameter.

Table 4 sets out what are considered to be suitable openings between sheathing ends, suitable lengths and internal diameters of slip sleeves, and approximate dimensions of sheet lead for formed sleeves for the various sizes of 10 lb. cables where joints are made under straightforward conditions. The details given are intended as a guide only and the dimensions finally adopted should be based on local conditions and experience. The amount allowed in Table 4 for the overlap of the sleeve beyond the opening between the sheathing ends should, however, meet requirements on most occasions. Generally the wipe should extend beyond the end of the sleeve for a distance about equal to the amount of overlap of the sleeve after it is dressed down.

Fitting Slip Sleeves. Using Table 4 as a guide and adopting dimensions to suit the conditions which exist, the required length of sheathing or soil pipe of suitable diameter should be cut, the ends cleaned and trimmed and inside edge bevelled (using rasp, shave hook and wire brush for these purposes), and then slipped over the cable. After conductor jointing is complete and the joint dried out and wrapped, the sheathing ends up to the limit of the wipe should be adequately cleaned with the wire brush and coated with flux if this has not already been done when setting up the cable. The sleeve should then be slipped into position and the ends dressed down to fit closely around the cable sheathing after the manner shown in Figs. 13, 14 and 18. The slope of the sleeve, where dressed down, generally should not exceed about 45 degs. If branch joints are involved, the end of the sleeve will probably require some flattening to clear the two (or more) cables, after which it can be dressed down to fit the cable sheathing and clipped down between the two cables by the use of pliers or dressed with some narrow rounded tool on the lines shown in Fig. 18. When doing this it is necessary to ensure that the branch cables are suitably spaced to permit wiping inside the forks. Generally the minimum separation between branch cables should be three-eigths of an inch for small cables, increasing to a maximum of three-quarters of an inch for large cables. When the sleeve is finally dressed into position, the area to be covered by the wipe should be carefully cleaned with the wire brush and coated with flux. Special care should be taken to clean and flux the portion adequately where the sleeve and sheathing meet. Wiping can then proceed, using a thin folded pad for working the portion of the wipe in the forks of the branches.

It is necessary during the wiping process that the cables be held in a rigid position to avoid any possibility of movement or jar before the wipe sets. In manholes it is usually possible to strap the cable to rests or to temporary supports so that the joint can be readily pushed into position on the rests on completion. In the case of joints in pits, under floors, etc., special frames to support the cable during jointing and plumbing, clear of the pit or of the cavity below the floor

TABLE 4

SHOWING DIMENSIONS OF LEAD SLEEVES FOR VARIOUS SIZES OF 10 LB. CABLE

(S.Q. TYPE EXCEPT UP TO 15 PAIRS IN SIZE)

All dimensions in inches

Size of Cable (pairs)	Length of opening between ends of cable sheaths	No. of rows of paper sleeves on outer layers	Amount of longitudinal overlap for sleeve each end, including allowance for dressing down of ends	Size of Slip sleeve. Length x Internal diameter	Approximate size of sheet lead	
					Gauge (lbs. per sq. ft.)	Length x Breadth (includes allowance for dressing down of ends and for seams)
Straight Joints						
10	6	2	¾	7½ x ¾	4	7½ x 3
10	8	3	¾	9½ x ½	4	9½ x 2½
15	8	3	¾	9½ x ¾	4	9½ x 3
28	8	3	¾	9½ x 1¼	4	9½ x 5
38	10	4	1	12 x 1¼	4	12 x 5
54	10	4	1	12 x 1½	4	12 x 6
54	12	5	1	14 x 1¼	4	14 x 5
74	12	5	1¼	14½ x 1½	4	14½ x 6
100	12	5	1¼	14½ x 1¾	5	14½ x 7
100	14	6	1¼	16½ x 1½	5	16½ x 6
150	12	5	1½	15 x 2	5	15 x 7½
150	14	6	1½	17 x 2	5	17 x 7½
200	14	6	1½	17 x 2½	5	17 x 9½
200	18	8	1½	21 x 2	5	21 x 7½
250	18	8	1½	21 x 2½	7	21 x 9½
300	18	8	1¾	21½ x 3	7	21½ x 11
400	20	9	1¾	23½ x 3	7	23½ x 11
500	22	10	1¾	25½ x 3½	7	25½ x 13
600	24	11	1¾	27½ x 3½	7	27½ x 13
800	26	12	2	30 x 4	7	30 x 14½
1000 & 1100	30	14	2	34 x 4	7	34 x 14½
Branch Joints						
7 + 10 into 15	8	3	¾	9½ x 1	4	9½ x 4
10 + 15 into 28	8	3	1	10 x 1¼	4	10 x 5
10 + 15 into 28	10	4	1	12 x 1¼	4	12 x 5
3 — 15 into 54	12	5	1¼	14½ x 1½	4	14½ x 6
2 — 28 into 54	12	5	1¼	14½ x 1½	4	14½ x 6
4 — 28 into 2-54	12	5	1½	15 x 2½	5	15 x 9
4 — 28 into 2-54	14	6	1½	17 x 2¼	5	17 x 8
28 + 54 into 74	12	5	1½	15 x 1½	5	15 x 6
28 + 74 into 100	12	5	1½	15 x 2	5	15 x 7½
28 + 74 into 100	14	6	1½	17 x 1¾	5	17 x 7

Where local conditions do not permit adherence to these dimensions they will serve as a guide.
The exact size of sheet lead to be used for a sheet lead sleeve should always be determined by measurement.
Where two sizes are indicated the longer one should be adopted wherever circumstances permit.
Wherever possible the opening between the ends of the cable sheaths should be on the full side for branch joints and for straight joints to which branch cables are likely to be connected at later dates.
Overlap of seam of sheet lead sleeves should vary from about ⅜" for cables up to 15 pairs in size to about 1" for large joints.

level, are necessary. These should be so arranged that the joints can be readily set down on to rests in the pit or under the floor after plumbing is complete.

Fitting Sheet-Lead Sleeves. Sheet-lead sleeves can be made with either butt or overlap seams—the difference being shown in Fig. 19. The former type of seam is the more difficult to make since it necessitates very correct cutting and forming to ensure that the two edges abut throughout the length of the seam. When the

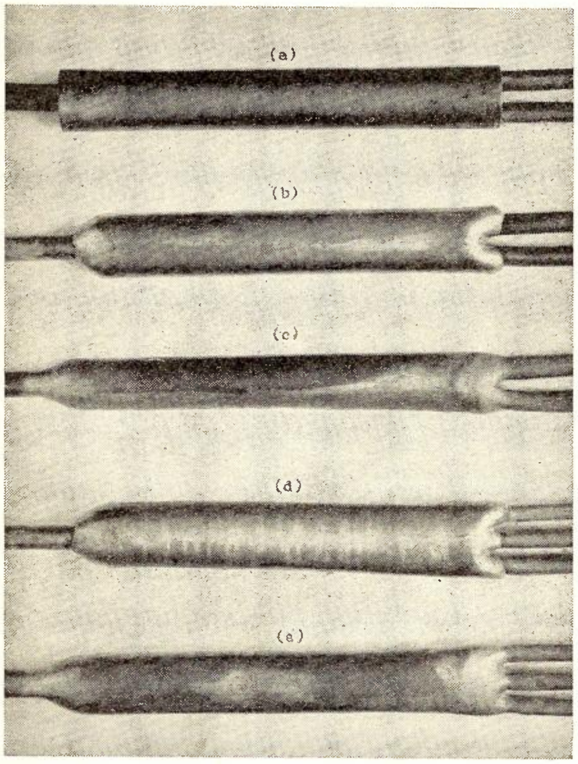

Fig. 18.—Showing examples of Plumbing work on Lead Covered Cables.
(a) Lead sleeve in position ready for dressing down ends.
(b) and (d) Ends of sleeves dressed down ready for wiping.
(c) and (e) Completed work.

two edges have been made to abut, the final setting and bevelling of the upper edges of the seam is done with the shave hook, and the cleaned surface is then covered with flux, preparatory to soldering. As the seam is usually on the horizontal, it can be sealed by melting solder direct from the stick into the groove with the blow lamp, care being taken to build up a good continuous body of solder. Usually in this case the seam is not completely soldered until the wipes are complete, since it readily permits any traces of moisture which may not have been dried out previously, to escape during the wiping process. Butt seams have an advantage that they simplify action when localizing cable faults where localization tests are not possible since the direction of the fault can be obtained readily by merely opening the seam and cutting the handiest pair at the top, after which it is a simple matter to re-joint the pair, knock the seam together and re-solder it.

On the whole, however, owing to its simplicity and lower cost, the advantages are considered to be on the side of the overlap seam, and normally this type will meet all requirements. Where irregular shapes are involved or in certain locations where it is desired to present a specially neat appearance, sheet lead sleeves must be carefully measured, shaped and fitted, and the making of such sleeves requires a considerable amount of skill and experience. For ordinary purposes, however, a piece of sheet lead of suitable dimensions folded around the joint and dressed down at the ends to fit the cable, meets all essential requirements and is by far the more economical.

The length of the piece of lead of suitable gauge required to form a sleeve of this type will depend on the opening of the joint plus the required amount of overlap as set out in Table 4. The required width of the piece of lead is best obtained by passing a strip of lead of the same gauge as the sleeve around the wrapped joint and cutting it to the required dimension of the circumference. The measurement should be made at the bulkiest portion of the joint, and in the case of branch joints a check should be made to ensure that the dimension is suitable for the ends. In each case when taking the measurement a little latitude should be made to cover possible variations in the circumference, and it will be necessary to make allowance for the amount of overlap of the seam. This should vary from about $\frac{3}{8}$ of an inch for very small cables up to 15 pairs in size, to about one inch for the large joints involving sizes such as 800 or 1000 pairs.

After cutting the sheet lead to the required dimensions, the area of the seam overlap plus a margin for safety both inside and out, together with an equivalent area beyond on the outside (i.e., the areas to be wiped together with the two faces which adjoin), should be cleaned with the wire brush and coated with flux (tallow or stearine). At the same time the inner and outer edges should be bevelled with the rasp and/or shave hook, as shown in Fig. 19, and coated with flux. The piece of lead is then folded in position around the cable to form a tube, and the seam is overwiped thinly with solder in a longitudinal direction (See Fig. 19.) so that, when the wiping is finished, the sleeve is similar in outward appearance to a slip sleeve. The remainder of the operation then consists of dressing down the ends to meet and fit closely to the cable sheathings as for a slip sleeve, after which wiping can proceed as for a slip sleeve. Typical samples of plumbing work are shown in Fig. 18.

Re-plumbing Cables. It is often necessary to re-open joints on account of faults and alterations, and where care is taken with the removal of the existing sleeves they can be re-used on most occasions. Where, however, it has been necessary to re-open a joint more than once,

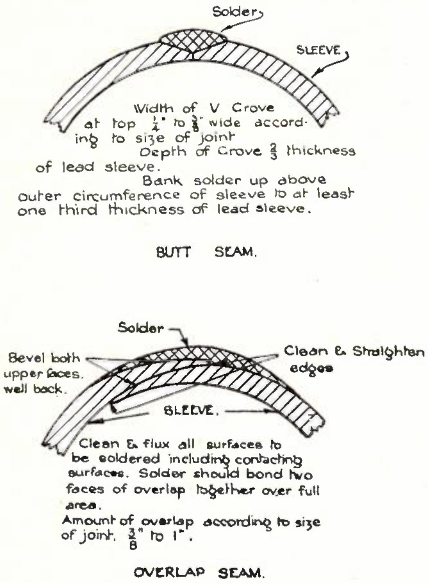

Fig. 19.—Showing methods of making Butt and Overlap Joints.

there is a tendency towards an increase in crystal size in the lead at the ends of the sleeve and sheathing, due to the repeated heating and cooling. This in turn gives rise to a tendency for the lead to fracture, which may only appear as light surface cracking when the lead is bent. The cables and sleeves, where the latter are to be re-used, should therefore be carefully examined to ensure there is no sign of cracking of the lead before re-plumbing proceeds, and if there is any doubt regarding the condition of the lead it is advisable to fit a new and longer sleeve so that wiping is performed on entirely new surfaces.

Conclusion.

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Note.—In connection with Fig. 10—Brittania Joint (October, 1939, issue)—a correspondent has brought under notice the advisability of increasing rather than lessening the amount of single wire turns with a view to damping out vibration and minimizing the possibility of resultant fatigue failure of the wire. The single turns would still be left unsoldered as suggested. On one work the length of the single wire turns on each side was increased by him to 1½ inches. The suggestion is one which might well be incorporated in the altered design.

THE SYDNEY-NEWCASTLE-MAITLAND CABLE—PART 2

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

Introduction. This paper is the second of a series of three dealing with the Sydney-Newcastle-Maitland cable, and deals with its installation. Part 1 dealt with general features of the design and reference is made in this part to the survey of the route, assembly of plant and personnel, preparation of estimates, methods used and procedure generally associated with the work.

Survey of Route and Preliminary Work.

Purpose of Survey and Description of Route. Although the route had previously been surveyed throughout, it was not definitely decided when these first surveys were made that armoured cable would be used for a considerable portion of the route, and in carrying out these earlier surveys consideration had to be given to the possibility of ducts being laid. Road alterations had been made or were contemplated, which rendered desirable many alterations to portions of the route as originally surveyed. A series of plans was prepared for each section, showing a mile of route on each sheet of double foolscap size and in such a form as to be readily handled by workmen on the job and readily adaptable to serve as plans of the finished work. Fig. 1 shows a typical plan.

A considerable length of new ducts had to be laid in different places along the route through various towns as well as in portions of Sydney, Newcastle and Maitland, and particulars of these were determined and shown on the plans, and consideration given to requirements for ducts for other cables being laid concurrently or at some future date.

The class of country traversed by the cable can generally be described as difficult. Although for a considerable distance the cable is laid alongside the Pacific Highway, the ground alongside the road pavement within the road reservation is in a more or less virgin state with numerous trees, stumps, rocks, ditches, and generally uneven surfaces. For some distance on the Woy Woy side of the Hawkesbury River and also between

Cowan and Brooklyn on the southern side of the river, very difficult conditions were encountered in the nature of precipitous, rocky country, much of which was inaccessible to ordinary means of transport. Elsewhere along the route there were numerous outcrops of rock, shale, and heavy clay formation as well as numerous trees and stumps.

Concurrently with the survey, notes were taken of the class of excavation for estimate purposes and field notes were prepared for the instruction of the cable-laying squads as to methods generally to be followed in excavation, protection of cable at roadways, creek crossings, etc.

Position of Cable Trench and Collaboration with Other Bodies. Wherever practicable, the route was surveyed so as to place the cable at a distance of 4 or 6 ft. from the boundary alignment of roadways. Only in a few cases where there was no other alternative was the cable placed on road shoulders and then at a distance of at least 3 ft. from the edge of the road pavement. Close co-operation was maintained with the Department of Main Roads in such matters as road widening, deviations, etc., and with the Railway Department where cables were to be laid within railway enclosures or under railway crossings. Where obvious advantages existed and there was no other practicable alternative, the cable was laid through private property for short distances, but such cases were kept at a minimum. In all such cases the permission of property owners was obtained. Between the Hawkesbury River and Woy Woy the cable extends through Crown land for some considerable distance. The assistance of the State Government authorities was sought in taking soundings of the proposed submarine cable crossings in the vicinity of Dangar Island in the Hawkesbury River. These soundings were taken at 50 ft. intervals along four parallel lines spaced 50 ft. and 100 ft. on each side of the route and samplings were taken of the river bottom throughout to ensure a satisfactory bedding for the cable.

Road crossings were avoided as far as possible and were only made where obvious advantages were apparent for some distance by changing to the other side of the road and avoiding felling of trees, rock excavation, rough country, ditches, low-lying ground, etc.

Types of Cables, Statement of Requirements for Contractor, Methods of Protecting Buried Cable. A description of the four types of cable used on this work is contained in the previous paper, together with details of the total lengths ordered.

Ducts of various classes were used, depending upon requirements along the route. Most of these were existing, but where new routes were required a self-aligning 4-inch diameter reinforced concrete pipe was laid to carry the two cables. In the majority of cases on the armoured cable sections three 2½-inch G.I. pipes were laid (one for each cable and one spare duct) at metalled or concrete road crossings. At minor road crossings or through ditches and culverts, as well as on road shoulders, in private property or at any place where disturbance of the surface appeared likely in the future, the armoured cables were covered with reinforced concrete slabs, 4 ft. x 8 ins. x 2 ins., which were made on the work.

As the survey of each repeater section was completed, the contractors were furnished with detailed plans of the route and a statement setting out the drum lengths of various classes of cable was prepared. This statement indicated the positions in which the various lengths and types of cable would be placed.

Subsidiary Cables. Concurrently with the laying of the main trunk cables it was deemed desirable to lay in the same trench cables of various sizes and lengths to carry minor trunks and/or subscribers' circuits, thus enabling aerial pole routes to be taken down. Unless certain of these cables were provided it would still be necessary to retain many miles of the main pole line which the through trunk cables would relieve, seeing that the main route carried intermediate and minor trunk lines and subscribers' lines, in addition to through trunk lines. While the design of the cable is such as to permit of the use of sections of the conductors therein for V.F. purposes, it was obviously impossible to carry all the various intermediate circuits therein. Furthermore, it was undesirable to take circuits out at intermediate points other than at repeater stations. A typical subsidiary cable is that between Woy Woy and Gosford. At Woy Woy, which is a seaside resort some six miles south of the Gosford repeater station, there are several channels south to Sydney and north to Gosford, with subscribers' circuits along the route between Gosford and Woy Woy. A loaded 20-lb. conductor cable was provided from Woy Woy to Gosford in this section to carry Woy Woy-Sydney circuits via carrier channels from Gosford, voice frequency circuits Gosford to Woy Woy and wayside subscribers' lines at each end connecting to the Gosford and Woy Woy exchanges respectively. This cable was laid at the same time as the through trunk cables. Altogether 27,836 yds. of 10-lb. cable (28, 38, 54 and 74 prs.) and 22,336 yds. of 20-lb. cable (28, 54 and 74 prs.) were laid at the same time as the main trunk cables. The savings in capital costs by utilizing the common trench and laying these subsidiary cables in conjunction with the main cables are obvious. Maintenance costs will also be considerably reduced, as many miles of aerial wires and poles will be taken down and costly renewals of aerial construction, otherwise necessary in the near future, will be avoided.

Both at the Sydney and Hamilton terminals provision was made for cables to extend the V.F. channels on a four-wire basis from the trunk cable terminals to the G.P.O., Sydney, and Newcastle P.O., where the existing trunk switchboards will be retained for some time.

Buildings and Sites. Concurrently with the survey of the route, consideration was given to the position that new buildings for various repeater stations would occupy, also to the design of such buildings, and preliminary action was taken with a view to their early construction by the Department of the Interior. New brick buildings for repeater stations were necessary at Brooklyn, Gosford, Wyong and Swansea. At the three first-named places it was possible to erect the buildings on existing postal property immediately adjacent to existing premises. At Gosford and Wyong consideration had to be given

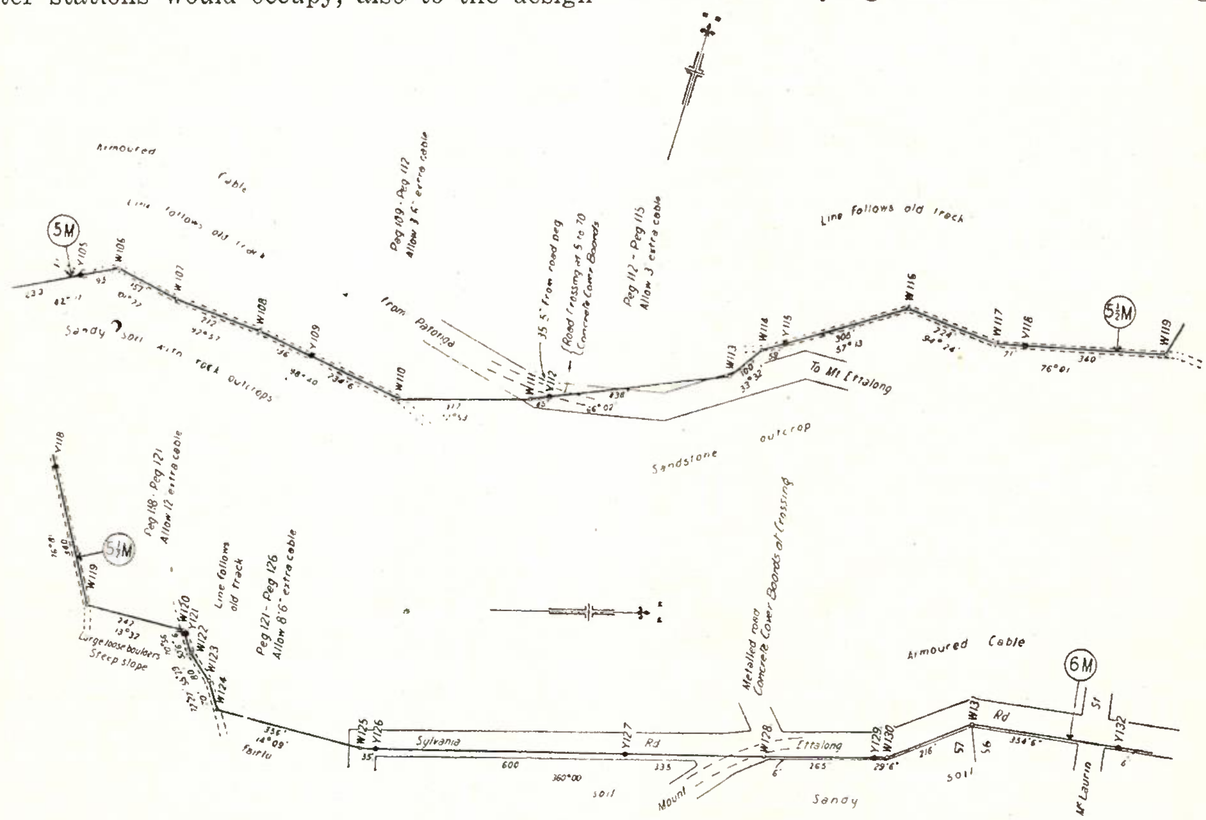


Fig. 1.—Typical Survey Plan of Route.

NOTE.—(i) "W" indicates white peg at angles on route.
(ii) "Y" indicates yellow peg at joints in cable.
(iii) Reference marks same colour as pegs.
All bearings are magnetic.

Peg	Bearing	Distance	Identification Mark
Y.105	N.W.	1 ft. 4 ins.	On rock.
W.106	E.	3 ft. 8 ins.	,,
W.107	S.E.	2 ft. 8 ins.	,,
W.108	N.W.	5 ft. 2 ins.	,,
Y.109	N.E.	1 ft. 3 ins.	On flat rock.
W.110	N.	3 ft. 5 ins.	On rock.
W.111	N.W.	9 ft. 5 ins.	On Stump.
Y.112	,,	33 ft. 4 ins.	On tel. post.
W.113	,,	8 ft. 0 ins.	On rock.
W.114	,,	8 ft. 3 ins.	,,
Y.115	,,	20 ft. 8 ins.	,,
W.116	,,	12 ft. 8 ins.	,,
W.117	N.E.	2 ft. 4 ins.	,,
Y.118	,,	1 ft. 7 ins.	,,
W.119	,,	12 ft. 2 ins.	,,
W.120	N.	2 ft. 1 in.	,,
Y.121	N.W.	3 ft. 1 in.	,,
W.122	,,	7 ft. 5 ins.	,,
W.123	S.W.	2 ft. 0 ins.	,,
W.124	N.E.	8 ft. 3 ins.	,,
W.125	S.E.	16 ft. 0 ins.	On Stump.
Y.126	,,	39 ft. 2 ins.	On E.L. pole.
Y.127	W.	16 ft. 3 ins.	On fallen tree.
W.128	N.E.	9 ft. 8 ins.	On E.L. pole.
Y.129	N.E.	29 ft. 7 ins.	,,
W.130	S.W.	5 ft. 5 ins.	On honeysuckle.
W.131	W.	6 ft. 5 ins.	On cor. post.

to the possibility of automatic exchanges being provided at some date in the future and to designing and placing the repeater buildings to permit of extensions for such a purpose. At Swansea, in order to limit the length of the repeater section Wyong-Swansea to under 21 miles, a suitable site was selected on the route of the cable approximately 3½ miles south of the Swansea township and power supply lines extended thereto.

At Belmont the cables were extended to a special rack in a small building so that several V.F. trunk circuits to Newcastle could be provided. A suitable piece of land was selected on the route of the cable and of size and position adaptable for the erection of a P.O. building thereon at a later date.

At Maitland a two-storied brick building to accommodate open wire and cable carrier apparatus had already been commenced to take the place of the existing building, the size of which had become inadequate for normal requirements.

At Hamilton a building was planned for erection on the site acquired some time ago for the Hamilton Automatic Exchange, which is on the route of the trunk cables. The building will ultimately accommodate the main trunk switching centre for Newcastle as well as an automatic exchange, and was designed accordingly.

In Sydney an existing building was acquired in Dalley Street, between George and Pitt Streets, approximately half a mile from the trunk centre at the G.P.O. towards Circular Quay.

Details of the design and layout of equipment in the various buildings will be discussed in a later paper dealing with the equipment installation.

On Dangar Island on the Brooklyn side and on the mainland on Patonga side of the Hawkesbury River suitable blocks of land were acquired. On each of these two blocks manholes for joints between submarine and land cables and gas alarm apparatus, also approaches for submarine cable, had to be provided and trenches had to be cut through steep, rocky country for the land cables. As the value of the land in these localities is comparatively low, it was thought desirable to acquire outright ownership of the blocks.

Staff Requirements and Organization

Survey Work. This was carried out one repeater section at a time, and commenced in July, 1938, with the Brooklyn-Gosford section so that the possibilities and costs of this alternative could be considered in comparison with the Kangaroo Pt.-Gosford route along the Pacific Highway. The field staff consisted of a draftsman, who is also a competent surveyor, a line foreman, and two temporary employees, one of whom was a chainman and the other a truck driver and general assistant. The writer also spent a considerable time in the field examining various alternatives, interviewing officials of the Department of Main Roads, Councils, and others and generally detailing the exact route to be followed. Plans and measurements taken in the field were forwarded to the Chief Draftsman, and plans were prepared as the survey progressed. The line foreman prepared field notes which were used later on as a basis for estimating and for issue to the men on the work. The survey of the whole route took a little over six months to complete and necessitated the preparation of over 100 separate drawings.

Office Staff. An office was established in the Dalley Street building in Sydney shortly before the first deliveries of cable were made. This staff at first consisted of a clerk and typist. It was augmented later by the draftsman engaged upon survey work who assisted in the issue of plans to the field staff, work progress charts, and later was responsible for measuring and marking the route and converting the survey plans into plans of completed work.

A line foreman was employed in the office assisting generally in the assembly and supply of plant, tools and material, inspection of cable on arrival from overseas and transport of same to the work, development of special items of plant, preparatory work associated with submarine cables and supervision of the laying of such cables and various special duties.

When jointing was commenced, four senior mechanics and four assistants carried out various field tests, recording results, preparation of jointing schedules, testing and balancing sheets. Generally, half this staff was continuously employed in the field on actual testing work, while the remainder was in the office on selections and preparations of jointing schedules for subsequent operations.

A second clerk commenced when the work started, for the purpose of preparing wages and allowance sheets and arranging payment to the staff.

Field Staff. At the outset of the work an organization chart was drawn up and duty sheets were prepared for various supervisory officers. This chart showed the average strength of each party and designations of various employees, also the class of work each party was expected to perform and the main items of plant such as tractors, air compressor and "Barco" hammers, cable trailers, motor trucks, etc., which would be available for each unit. During the progress of the work various factors such as the nature of the country and methods to be followed, also the availability of cable supplies, necessitated changes in numerical strength and disposition of staffs. The difficult sections, such as Wahroonga-Brooklyn, also Brooklyn-Gosford, where much rock and rough country were encountered, necessitating miles of open trench in difficult country and considerable manhandling of cable required many more men than easier sections where ploughing and cable laying by the special mole plough method were possible. The total number engaged upon the work, both in the field and in the office, varied between 40 and 140.

Preparation of Working Estimates

Close detailed working estimates of cost of the work as a whole could not be completed until the whole of the route was surveyed and measured and information as to the probable cost of apparatus for the gas pressure alarm system was available.

A preliminary estimate of costs of the whole work was prepared, but later separate working estimates were prepared for each of the seven repeater sections, enabling the costs of each section to be separately recorded, thus facilitating analysis of material, labour and incidental costs during progress and upon completion of the work.

Assembly of Plant and Material

Supplies of Material, Working Tools and Camping Equipment. On a work of this nature it was essential to ensure continuity of supplies of all items of material, especially such items as jointing sleeves, which might take some time to procure. A list of all tools likely to be required, such as picks, shovels, axes, etc., as well as camping equipment, was prepared. The variety of tools and equipment required was considerable and over 200 different items of plant had to be available. The number of individual items, such as picks, shovels, handles of various kinds, lamps, axes, hammers, cable rollers, tool boxes, jointers' tents and tools, was necessarily large, and the number in active use at any one time varied considerably.

On certain sections of the work well away from places of accommodation camps were established, but the maximum number of men in camp at any one time did not exceed 30.

Many items of material not normally stocked, such as timber, explosives, metal, sand, cement, etc., were obtained locally as required.

Supplies of Special Plant for Excavation, Cable Laying and Transport. Before the work commenced, consideration was given to the methods to be used, having in mind the class of country to be traversed, and requirements of special plant were listed so that steps could be taken to invite tenders and purchase such plant. The details of special plant obtained for the work are listed below with reasons influencing the choice of such plant.

Excavation. As many miles of ploughing had to be done and much of it in comparatively rough country, and as a considerable number of trees, stumps and roots had to be cleared from the track of the cable, two 60-h.p. "Cletrac" type DD Diesel engined tractors of the crawler type were purchased. One of these was equipped with a power winch at the rear. Each tractor had a ground clearance of 15¾ inches and an overall width of 5 ft. 7¼ ins. Maximum ground clearance and minimum overall width were desirable factors. Each was capable of exerting a pull of over 10,000 pounds at the draw bar and the winch equipped tractor, which carried a length of 200 yds. of flexible steel wire, was capable of exerting a pull of over 30,000 pounds. When ploughing through heavy clay, uprooting stumps and pulling large trees and logs from the bed of some stream, the power available was a very necessary and desirable feature. The Diesel engines started from cold by means of a 12-volt battery self-starter, and were very economical in operation. The crawlers were fitted with angle iron grousers and when it was necessary to travel over macadamized roads it was necessary to lay hardwood planks. On rare occasions where much travelling on concrete roads was necessary, the grousers were removed and no planks were necessary. When long distances had to be travelled, the tractor was driven under its own power from a suitable embankment on to a heavy motor truck.

The ground contact area of each tractor was 2390 sq. inches and each tractor weighed over 6 tons.

After the work commenced the winch equipped tractor was fitted with a jib crane at the rear over the winch, for lifting and carrying cable drums. This facilitated loading and unloading cable reel trailers when cable laying by the mole plough method.

For rock excavation on the roadside and in places where access with a mobile unit was possible a "Broomwade" type Diesel engined air compressor plant, model S.V.D.1, was obtained complete with two each heavy and light duty pneumatic breakers for use as concrete, rock and pavement breakers and for rock drilling. Two spaders were also obtained. This machine could operate two of the large hammers or three of the smaller simultaneously, and was mounted on an old "Leyland" motor truck chassis adapted for the purpose.

A great deal of rock excavation had to be done in places where access by a motor truck was not possible because of the rough nature of the country and steep inclines. Small isolated patches of rock or road crossings some distance apart were also encountered where it was not economical to shift the "Broomwade" compressor. To satisfactorily deal with these, six "Barco" hammers, type H6, each weighing approximately 96 lbs., and one "Barco" hammer, type J2, weighing approximately 78 lbs., were purchased. These machines are two-stroke gasolene engines and the piston movement is transmitted to the pick, drill or spader, thus giving much the same effect as a pneumatic hammer. Fig. 2 shows a "Barco" hammer in operation.

A plough of the road ripper type (No. 67) was obtained, also a heavy single-side mouldboard type (No. 69). A mole-draining type of plough was also used and special trenching and deep rooter ploughs were developed and made specially for the work. These are referred to later.

Cable Laying and Drawing. Many miles of cable had to be drawn into ducts and the two cables were drawn concurrently. The drums of unarmoured cable were small enough to enable two to be accommodated side by side on the spindle of the larger type of cable reel trailer fitted with pneumatic tyres.

In the case of the buried armoured cable, many portions of the route were such as to necessitate the excavation of an open trench into which the cables would be laid direct by manhandling from trailers carrying the drums and travelling alongside the trench or by pulling the cable from a stationary drum over suitable wooden rollers placed over or alongside the trench. As the drums of tape armoured cable weighed 18 cwt. each, a lighter type of cable trailer carrying up to 2 tons was evolved and six of these were purchased for the work.

For carrying several drums of cable at the one time from adjacent cable dumps and for drawing the cable either into ducts or over rollers two 3-ton trucks, each fitted with power winches operated by the engine and controlled from the driver's seat, were obtained.

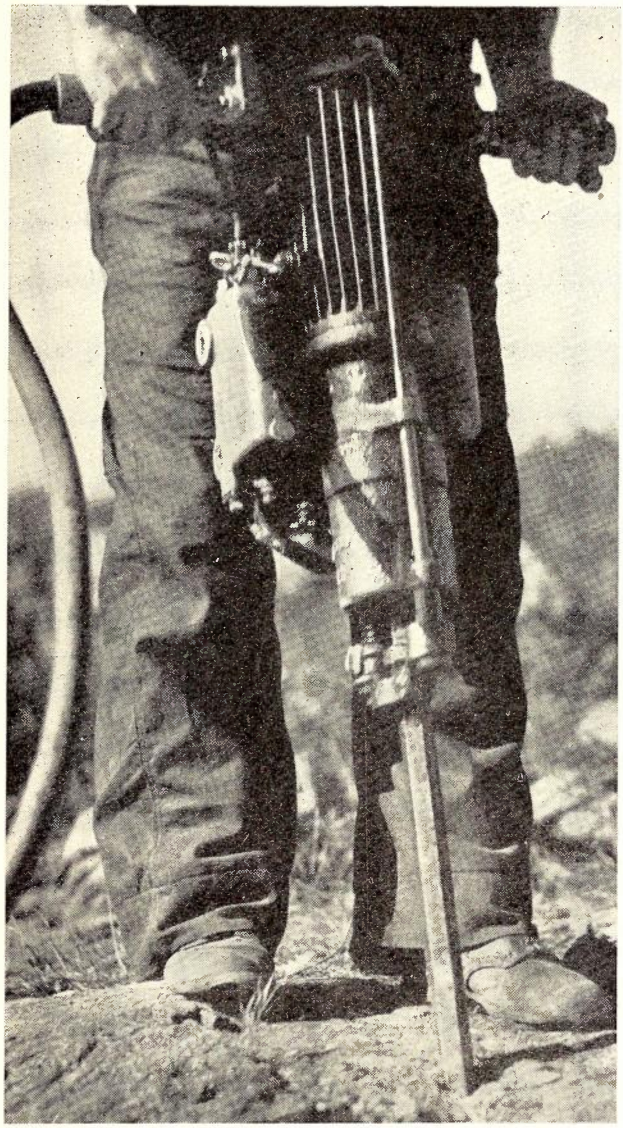


Fig. 2.—"Barco" Hammer in operation. The hose at left carries leads to coil and battery.

A number of wooden cable rollers large enough to take two cables side by side was obtained and these were mounted on the work, using sections of old wooden cross-arms as bearers mounted on pieces of lagging from the cable drums bolted together.

For supporting the heavy drums of submarine cable for the Hawkesbury River and Sydney Harbour crossings, two special stands were made of oregon pine baulks and two chrome nickel steel spindles 4 ins. in diameter and 8 ft. long were obtained. Two of these drums weighed 15 tons each and four weighed approximately 10 tons each. These stands were fitted with special braking gear bearing on the underside of the cheeks of the drums.

General Transport. For general transport of men, tools and material on the work, three 30-cwt. "Bedford" trucks were used. It was necessary, at times, to supplement these with hired trucks. Generally, the cartage of cable from wharves or railheads to depots on the route was arranged by contract and rates as low as 3d. per ton mile were obtained on certain sections. For the use of supervisory officers, one "Ford" V8 sedan and three "Bedford" utility trucks were provided.

Jointing and Testing Equipment

Complete kits were assembled for from 15 to 20 cable jointers. While the number of men actually jointing at any one time would not exceed, say, 12, other jointers were required to assist the testing officers and to carry out pressure tests, including preliminary tests on a portion of drums in each delivery and pressure tests on completed sections of cable after jointing. Miscellaneous items, such as pressure testing outfits, sealing caps and gauges, had to be obtained.

A considerable amount of testing equipment for the various tests made during jointing and upon completion of each repeater section had to be assembled. The cable contractors supplied, on loan, a quantity of this equipment. This was fitted in three 20-cwt. "Chevrolet" type panel vans of generous dimensions and head room. Van No. 1 was used for tests at 1K.C./sec. on primary groups generally 800 yds. in length. Van No. 2 was used on secondary (3200 yds. lengths) and subsequent groups, such as 1/4 or 1/2 repeater sections, and the equipment therein, enabled tests to be made both at voice and carrier frequencies. Van No. 3 was equipped for overall tests on completed repeater sections, including attenuation, cross-talk and impedance. Van No. 2 could be used for testing on primary groups when jointing work on two such groups was being carried out simultaneously or it could replace No. 1 Van if the latter were temporarily out of commission. Certain items of testing equipment were held as spare and No. 3 Van could at any time temporarily replace or assist Vans Nos. 1 and 2. Each van was specially fitted up with shelves, cupboards, seats and accommodation for writing and recording results, and the main items of special testing equipment in each van were as hereunder:—

Van No. 1

Trunk Cable test set.*
Oscillator, 1000 cycles/sec.

*Described in Engineering supplement, Siemens' Magazine, February, 1939.

Condenser, Sullivan, variable, 3 dial (range 0.001-1 mF.).
Condenser, variable, air, Sullivan (range 0-1200 mmF.).
Megger, 500 V., motor driven (12 V.), 1000 megs.
Universal Avo minor meter.
Portable telephones and buzzers, head receivers, test leads, etc.

Van No. 2

Same as Van No. 1 except Oscillator is variable over range 0.2-150 K.C.'s/sec. and additional equipment as follows:—

Non-reactive Resistance Box, 1000 ohms in steps 0.1 ohms.
Megger, 500 V., motor driven (12 V.), 1000 megs.
Wheatstone Bridge.
Condenser 0.001-1 mF.
Condensers 0-1200 mmF., air, variable.
Test leads, etc.

Fig. 3 is a view of a test van on the work.

Advance Work

Electrolytic Survey and Soil Resistivity Tests. This subject is referred to in the first paper on this project which appeared in the October issue of the Journal. Soon after the survey of the route was completed a testing officer with a motor truck and driver working under the direction of the Electrolysis Engineer, made soil resistivity tests along the route of the buried cable at intervals of 200 yds. These results were plotted in graphical form on sheets of foolscap size, each sheet covering 6000 yds. of route. Chemical analyses of water and soils were taken where thought necessary. A detailed study was made of conditions in areas subject to tractive influences, that is, in Sydney and Newcastle. Before jointing together two mile sections of cable in each repeater section, steps were taken to measure the magnitude and direction of current flow.

From the test data obtained it can be seen where trouble from electrolysis (stray tractive and "long line" currents) may be expected and what remedial measures can be taken initially in the way of providing zinc earth plates, drainage bonds, etc.

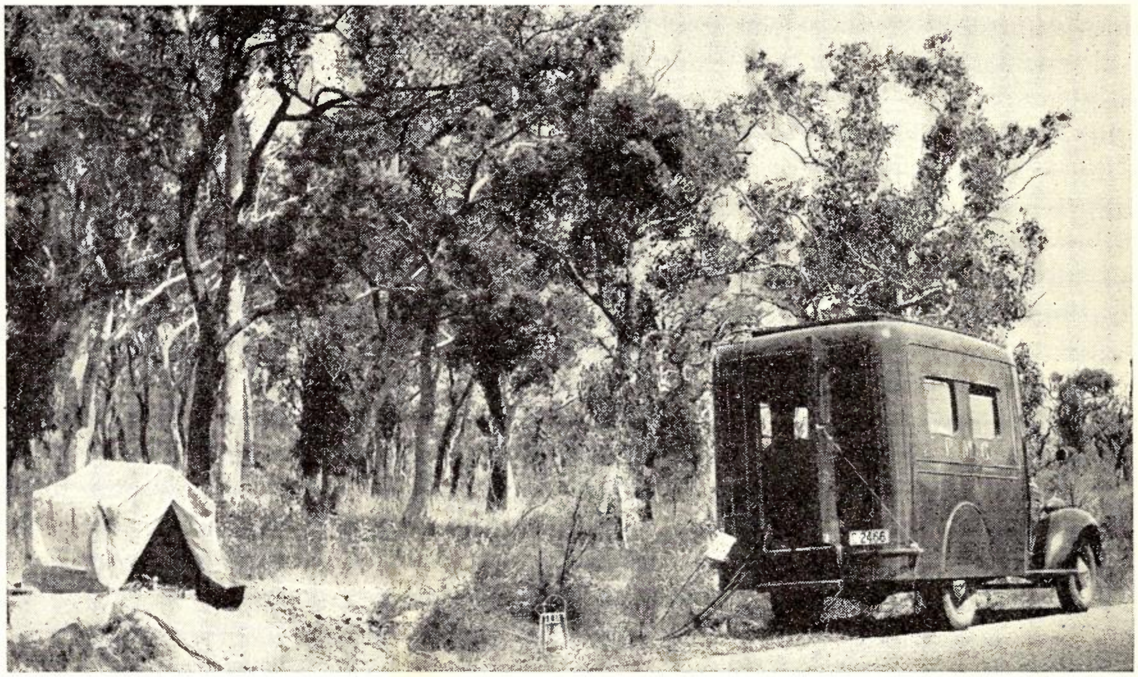


Fig. 3.—Test Van on the Work.

Detector Amplifier, Siemens (range 0.2-150 K.C.'s/sec.).
Admittance Test set, Siemens (range 0 to ± 50 micromhos in 0.1 steps and 0 to ± 240 mmF. in 1 mmF. steps).
Resistance Unbalance Test set, Siemens.
Terminations simulating characteristic impedance of cable, test leads, etc.

Van No. 3

Unbalance Test set (Sullivan).
Oscillator 0.2-150 K.C.'s/sec. (Siemens).
Amplifier Detector 0.2-150 K.C.'s/sec. (Siemens).
Admittance Test set (Siemens).
Resistance Unbalance Test set (Siemens).
Attenuator (0-110 dbs. in 0.5 db. steps), Muirhead.
Attenuator (40 db., fixed) (Siemens).
Galvanometer, portable, reflecting, Tinsley (160 m.m. per microamp).
Carrier Frequency Bridge (Siemens).

Careful attention was given to the permanent drainage of all pits and manholes along the route where this was practicable.

Examination of Cable on Arrival from Overseas, Transport to Work, Preliminary Tests, and Marking of Drums and Plans. As each shipment of cable was received from overseas the drums were examined with a representative of the contractors for signs of damage. Each drum of heavy type submarine cable was specially tested on arrival for insulation and ability to withstand an internal pressure of 50 pounds per sq. inch.

As shipments were received they had to be transported to suitable storage depots along the route from which individual drums could later be taken for use as and where required.

As soon as the cable was received at storage depots along the route steps were taken to carry out preliminary pressure tests on a percentage

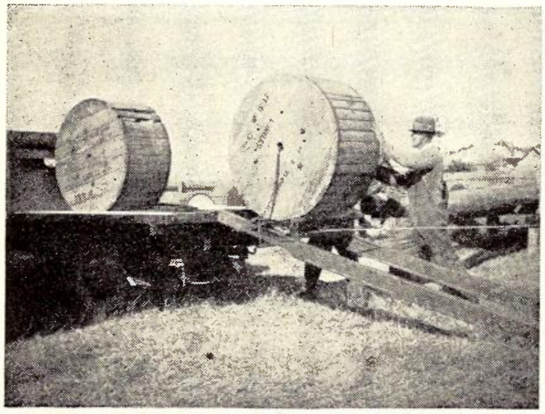


Fig. 4.—Appliance for Loading or Unloading Cable Drums. This picture shows a drum being loaded.

of drums. Each drum tested was required to withstand an internal pressure of 50 pounds per sq. inch for a period of three hours. At the same time as these tests were in progress the "A" and "B" cables (go and return) were specially marked at each end to ensure their separate identity being maintained when they were later drawn off the drums and laid in the ground or drawn into ducts.

To assist in the loading and unloading of cable drums at these depots, a special device was designed and used in the form of a travelling cradle on hardwood skids. This enabled two men to either load or unload a drum with safety in the space of a minute or two per drum. By holding the free end of flexible steel wire with several turns on a winch barrel on the underside of the cradle one controlled the unloading, whereas for loading both ends were fixed and the barrel turned by a ratchet and lever movement on the side of the cradle. Fig. 4 shows the device in use loading a drum of cable.

The contractors supplied cable drum address schedules referenced to the survey plans, which also showed the particular drums in each successive primary group, which generally consisted of four drum lengths. The survey plans were marked to show the successive section numbers along the route between jointing points, and the numbers of the cable drums assigned to each "A" and "B" cable to be laid or drawn in each primary group in correct sequence. At this stage the location of joints between primary groups and the make up of secondary groups (generally three or four primary groups), quarter and half repeater sections, were determined and shown on the plans so that the supervisory officers to whom these plans were issued would know where such joints were necessary and could leave sufficient overlap for subsequent jointing and testing at such points when laying the cable. It was also necessary to build manholes for gas alarm purposes at the junction of secondary groups, that is, at approximately 3200 yd. intervals.

Establishment of Temporary Field Depots. Temporary headquarters for the supervisory staff were established in close proximity to the work on each section and space was obtained for the storage of material, tools, plant, fuel supplies and accommodation for the blacksmith and men making concrete slabs and cable markers. Several portable collapsible galvanized iron sheds were constructed which could be taken down and erected where required.

Preparation of Route for Cable Laying

Clearing and Ploughing. Before any armoured cable was placed in the ground advance parties proceeded over the section. Most of the route was rather heavily timbered and a considerable amount of tree felling and removal of stumps and roots was required. For this work one of the tractors was used. The route to be followed was explored with a ripper plough, type 67, and as stumps and roots were encountered these were quickly pulled up by the tractor and heavy flexible steel wire sling. At times explosives were used in breaking up or dislodging large stumps. The 3-ton winch equipped trucks were very useful in clearing small trees and stumps.

Before cutting trees on the roadside or excavating on railway property, it was the practice to confer on the spot with representatives of the authorities concerned. A supply of standard road warning signs as used by the Department of Main Roads was obtained and used as required when operating on the roadway or roadside. The services of a railway flagman were generally obtained when operating on railway property, especially while blasting.

Where cables were to be laid by the mole plough method the ground was explored to a depth of 20 inches and the ground loosened for a width of 6 or 7 inches to facilitate the subsequent passage of the mole plough with the cables. In carrying out this work it was not desired to throw up much spoil which might later foul the drop axles of the cable trailers and retard progress. No suitable plough for this purpose was available and it was necessary to design one, have a pattern built, cast the beam and have the necessary ploughshare, plates and handles fitted. The beam, of conventional shape, was generously proportioned and cast of manganese steel. A detachable pointed share of tool steel was fitted at the toe and a detachable and adjustable heel piece was fitted on which the weight of the plough was balanced. Bent detachable steel plates were fitted on each side of the yoke portion of the plough and long handles, of which the height was capable of slight adjustment, were also fitted. The overall length of the plough from front of beam to handle tips was

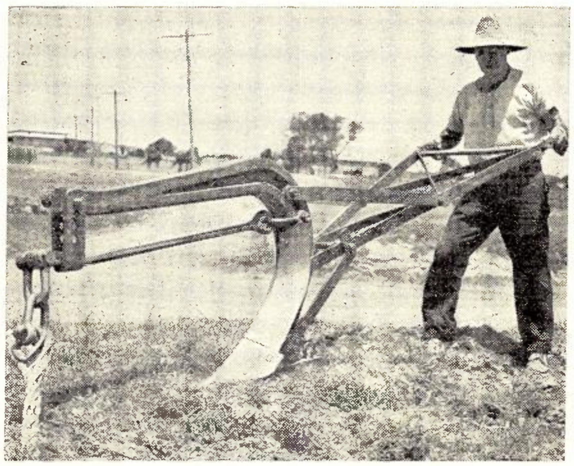


Fig. 5.—Deep Rooter Plough.

117 inches, depth from underside of beam to bottom of ploughshare 25 inches, and effective width of share and plates was 7 inches. Two such ploughs were obtained, as at times similar work was in progress on two sections simultaneously. By substituting specially shaped plates having a wing extension on each side at the top over the ground the plough could be converted from a "deep rooter" to a "trenching plough," which would leave a reasonably clear trench to a depth of 20 inches or more. Fig. 5 shows details of the plough and Fig. 6 shows it in use.

The type of country to be ploughed varied considerably from soft, mushy ground to very heavy clay or light shale formation. In ploughing sandy or loamy ground where the soil was reasonably friable good results were obtained by handling the plough in a normal fashion. In soft ground a special shoe or floater was fitted under the front end of the beam. In ploughing heavy clay or light shale the plough was pulled from the yoke end of the beam above the plates. In such country saplings were lashed to each handle of the plough to extend the length and give greater leverage. By this means ploughing to the required depth was possible in the heaviest class of clay. Excluding the time taken for clearing trees, stumps, roots, etc., which varied widely depending upon quantity, the average time for ploughing one mile of route preparatory to cable laying by the mole plough method varied from 30 to 50 manhours depending upon the nature of the ground.

A mechanical type of excavator such as the "Barber-Greene" arranged to back-fill the trench with the spoil it excavates, such as used on the Melbourne-Geelong work, is very suitable for the preliminary excavation in certain classes of country, but on the Sydney-Newcastle-Maitland route, which generally was heavily timbered throughout, a deep rooter plough drawn by a tractor was considered more suitable. It is very necessary to completely remove all dead timber below the ground in the vicinity of the cable, as such timber is liable to burn in a severe bush fire. In clay country, especially on sloping ground, a minimum width of trench is also desirable, as otherwise excessive costs will be involved in consolidation and packing with spalls to prevent subsequent scouring.

The plough was drawn by a hawser from the winch equipped tractor in many places where the width available would not permit of the passage of a tractor. Where there was excessive cross fall a plough was useful at times in levelling the route to permit of the subsequent passage of the cable trailers and mole plough cable laying equipment.

A heavy type single toothed ripper mounted between two heavy steel wheels of small diameter and wide tread and which is raised or lowered by an hydraulic jack or cable unit from a tractor should give very satisfactory results. Such a unit, if drawn by a high-powered tractor, should readily deal with roots and stumps and excavate heavy clay and shale. This may be tried on some future job.

Rock Excavation. A squad of men equipped with a "Broomwade" type Diesel engined air compressor plant and several "Barco" gasolene hammers, dealt with the various outcrops of rock encountered on the route. The quantity of rock to be shifted was considerable, and on the whole was estimated to be 7000 cubic yards. A great deal of this was encountered in the Hawkesbury River district. From Berowra, some 12 miles south of the Hawkesbury River to Ocean Beach, about four miles north of the river, 12 miles of trench were cut through solid rock in steep, rough country, in many places some considerable distance away from any road, thus adding to difficulties. Wherever possible the "Broomwade" air compressor unit mounted on an old "Leyland" truck chassis, was used, but in many sections it could not be transported and the "Barco" hammers proved very useful. For rock pick work these hammers were equally as effective as pneumatic hammers, but for drilling holes for explosives the latter were more effective.

Considerable use was made of explosives in opening up trenches in rock. Generally, 6 to 8 holes were drilled in staggered formation 12 to 15 inches apart to a depth of 15 inches sloping slightly, and in each a half plug of gelignite was placed. These were exploded electrically and simultaneously. In the proximity of railway lines and overhead wires special care was necessary and coir explosive mats were used. To illustrate the extent and nature of rock encountered in one section alone south of the Hawkesbury River over 3000 detonators were used.

A blacksmith was in constant attendance for the sharpening and repair of excavating tools, especially picks. For a while it was necessary to employ two blacksmiths. They made, from suitable rod steel, most of the picks required for the hammers and various small fittings required at times for various purposes. A special type of self-tempering steel known as "Progen" was used with satisfactory results. Picks of this material wore to a needle point in hard rock and generally outlasted three of ordinary tool steel.

Pipe Laying. At various road crossings, especially those with paved surfaces, under which tape armoured cable was to be placed, three 2½-inch G.I. pipes, including one spare, were laid. The ends of the pipes were securely held in a concrete block and lead insets were fitted over the edges of the pipe. Under concrete road pavements and under certain rail crossings the pipes were pushed through with a heavy type pusher worked on the lever and ratchet principle.

Creek Crossings. Before laying cable on any creek or river bed it was necessary to remove any trees, logs or debris away from the track of the cable on the river bed, and arrange suitable approaches. A drag line was used to connect with such obstacles and the tractor with winch was most useful in dragging them up the bank and out of the way. Many of these were of considerable weight.

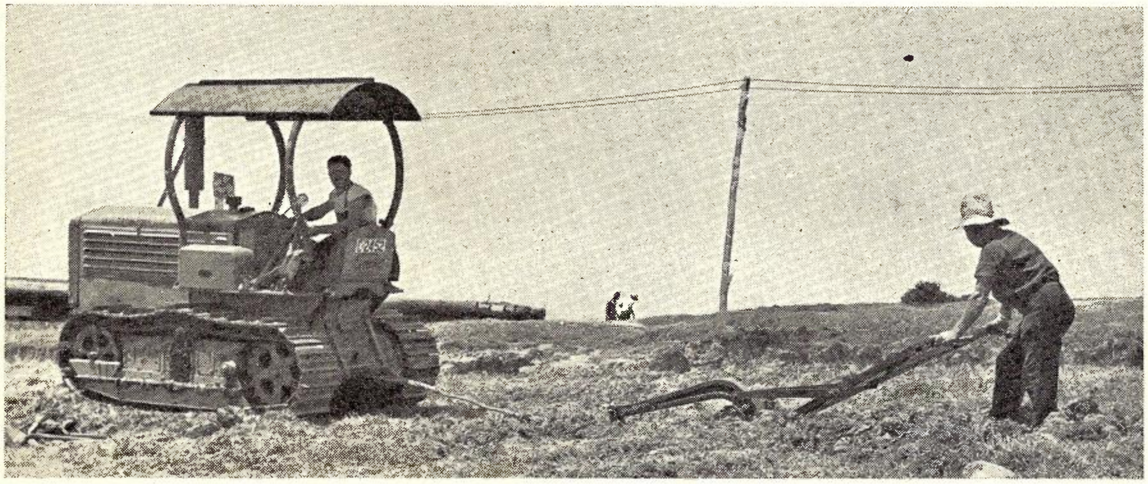


Fig. 6.—Preliminary Ploughing prior to Cable Laying by Mole Plough.

Concrete Slabs and Spalls. When the armoured cable was buried in places where there was a likelihood of damage through surface operations at some future date, such as on road shoulders, foot of embankments, under or close to fences or poles, across gateways or minor roads, through property which might be cultivated, in camping areas, under ditches or culverts, on footways in outer residential areas where no ducts were provided, etc., protection was provided by laying reinforced concrete slabs over the cables. These slabs were also laid over the ends of buried cables before joints were made and subsequently were placed over the completed joints. It was found more economical to manufacture these at some convenient centre on each repeater section. Generally, 5/16ths-inch slag screenings were used with sand and cement. River gravel was used if available and suitable. The slabs were four feet long, eight inches wide, and two inches thick, and were reinforced with one layer of welded steel wire, gauge 11, having a 4 in. x 2 in. mesh and 6 ins. in width, placed one-half inch from the bottom. Two men could make 100 of these per day at a total cost of about 6d. per ft. length. Over 10,000 such slabs were used on the work. Concrete marker posts, as described later, were made in conjunction with the slabs.

Many tons of stone spalls were used for packing trenches in clay country, in sloping ground, and through ditches or culverts, to prevent erosion, and most of these were obtained from convenient quarries at little cost by using the compressor plant and explosives. On one section of the work over 50 tons of spalls were obtained at a cost of less than 1/6 per ton.

Excavation of Trench for Buried Cable

Ploughing. Previous reference is made to the preliminary ploughing necessary before laying cables by the mole plough method. On many miles of the route, however, this method was not practicable for various reasons, such as proximity and excessive number of obstructions (trees, poles, fences), uneven nature of ground and excessive cross fall, parallel ditches or drains, rocky country, etc. On the Gosford-Wyong section, which was the first to be completed, the roadway generally is narrow and the space available between road shoulders and the road boundary alignment was either rather heavily timbered or was excavated for road drainage purposes. While it was possible to plough most of this section by hauling a plough with the winch on one of the tractors, it would not have been possible, except for a comparatively short length, to draw the mole plough and cable trailers over the proposed route of the cable. On the Wahroonga-Brooklyn section and on portion of the Brooklyn-Gosford section even ordinary ploughing was impracticable for most of the distance, due to the rough, rocky nature of the country. On the remaining buried cable sections cable laying by the mole plough method was practicable for from 50 per cent. to 75 per cent. of the lengths, and in view of the obvious savings this method effected it was used wherever possible.

Fig. 7.—Trenching Plough in use near Gosford.

When an open trench was to be ploughed the route was first explored with the road ripper or mole drain type of plough so that roots, stumps and rocks could be located and removed. Two further ploughings with a heavy single sided mouldboard (type 69) plough were generally necessary to ensure the desired depth being obtained. This depth generally was 20 inches, but was increased in certain places where a greater measure of protection seemed necessary. The first ploughing would bring the soil to the surface for a depth of 9 inches or more, but a certain amount of shovelling was required before commencing the second ploughing. After the second ploughing a team of shovellers was required to clear the trench ready for cable laying. The time taken to prepare a trench in this manner varied considerably, depending upon the nature of the soil to be ploughed and the presence of obstructions. Under average conditions a team of 12 men, consisting of one tractor driver, two ploughmen and nine shovellers, could prepare from 600 to 800 yds. of trench per day.

As most of the labour was expended in shovelling spoil out of the trench, some thought was given to the design of a plough, which in one operation would excavate and clean out a trench to the required depth, throwing most of the spoil on one side. A scoop which presented three detachable cutting edges to the ground with the bottom sloping upwards to the rear was supported between two angle iron runners built up in the familiar mole plough form with small platform and joy stick at rear. A mould board was built up from the rear of the scoop at the top to carry the spoil well away to the side of the trench. The scoop was shaped so as to cut a trench 10 inches wide at the top and 4 inches wide at the bottom for a depth of 20 inches. The shape of the trench was maintained and the sides consolidated by extending this formation to the rear of the angle iron runners. The bottom cutting edge of the scoop was extended for a few inches and set downwards at a slight angle to enable it to bite into the ground. To prevent excessive surface vegetation, such as thick growths of paspalum, clogging the front and lifting the nose of the plough a box-shaped overhead beam was extended to the front and a double side mould board or "duckfoot" was fitted to the front immediately behind the draw-bar attachment. This "duckfoot" attachment was set so that the bottom cutting edge was three inches below the level of the angle iron runners, which were flat on the ground, and it lifted all surface vegetation and rolled it away on each side well clear of the angle iron runners. This trench plough was not used very extensively on this work as it was obviously more economical to use the mole plough method, which practically eliminated entirely the huge amount of labour involved in taking spoil out of a trench and putting it back again. The trench plough and a tractor were loaned to carry out an urgent cable laying job at Canberra during June, 1939, where some 10 miles of trench had to be excavated in various types of soil, including clay and light shale. Substantial savings were effected by its use and where a considerable amount of trench work is necessary, such as for laying G.I. pipes, it should prove useful. One essential is to have a high-powered tractor available. Fig. 7 shows the plough at work.

The Roto-Tiller. In excavating a trench for multi-duct laying at the Sydney end in connection with this work, the engineer in charge of that section of the work effected savings with a petrol-driven machine worked on the rotary hoe principle known as the "Rototiller." This machine cut through shale as well as soil, and definitely eliminated all hand pick work. One operator with the machine could keep a team of eight shovellers fully employed. If the trench, when excavated, could be cleaned out by drawing a light scoop fitted with single mould board from a power winch on a motor truck, the machine could be made even more effective for pipe-laying operations.

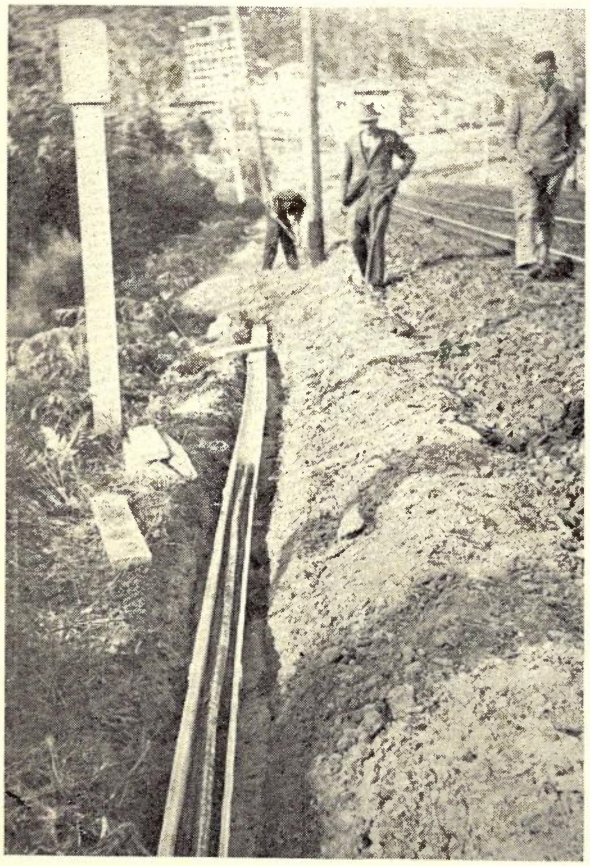


Fig. 8.—Railway Embankment, Gosford, showing asbestos-cement, sand filled troughing with concrete slab covering.

Excavation in Rock and in Places where Ploughing was Impracticable. Pneumatic and "Barco" gasolene hammers, also explosives, were used for rock excavation. Frequently when the "Barco" hammers were used for pick work two men took it in turns to work the hammer and remove the rock, as it was desirable to rest the hammers occasionally to prevent overheating, quite apart from the desirability to rest the operators. The heavier type of hammer weighed 90 lbs. and in rough country especially the work was strenuous. The operators wore leather aprons as the hammers became rather hot at times. Excessive carbonization and heating were prevalent at first until a lubricating oil, having a low carbon content, was used. Water white motor spirit mixed with oil in the ratio of eight parts to one was used as fuel and the daily consumption was approximately six quarts. Six dry cells were used for ignition purposes initially, but as the current drain was over one amp it was found desirable to change over to 6 V. accumulators of the motor-car type, which generally sufficed for two weeks' running per charge.

Immediately south of Gosford, for a distance of 1200 yds., two trunk cables, as well as a subsidiary cable, were laid on the edge of a causeway used for the main northern railway. This causeway was built of stone spalls with a light covering of ash and soil. Just sufficient width was available to permit of the cables being laid parallel to the rails and far enough away to clear any standards which might be erected later for electrification. As the spalls could not be disturbed there was little covering available, and as some form of protection was very desirable for the buried cables, steps were taken to obtain a supply of asbestos cement troughing, "U" shaped, in 8-ft. lengths with spigot and socket ends. Fig. 8 shows a view of the troughing in position. This troughing was 4 inches square in cross section and 3/16ths inch thick, but each side was extended outwards for half an inch and upwards for one inch so that reinforced concrete slabs, 5 inches wide and 3 ft. lengths, fitted snugly in the top. The troughing was set in sand or spoil, and sand was placed in the troughing around the cables to minimize vibration and exclude ash. Pre-cast pits (No. 5 type) were used for joints. Two of these were laid one behind the other in the line of the troughing and the trunk cable joints were made in one pit and the subsidiary cable joint in the other. In the pit adjacent to the joint the cables were given a downward set so that slack would be available if required. The reinforced slabs were made near the work and the total cost of troughing and slab lids was approximately 1/- per ft. length.

Editor's Note: This part will be concluded in the next issue and reference will be made to cable laying methods, submarine cable crossings, testing, jointing and balancing procedure, etc.

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.

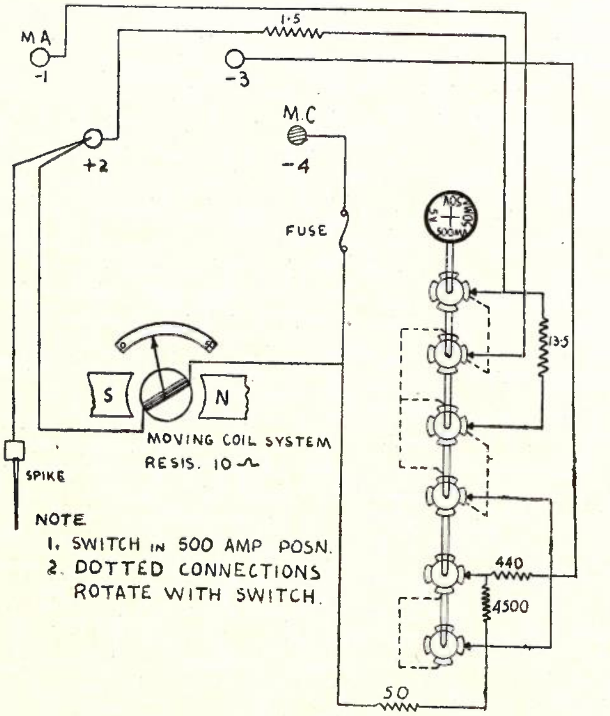
EXAMINATION NO. 2254—MECHANIC GRADE 2—TELEPHONE INSTALLATION AND MAINTENANCE.

D. F. BURNARD, B.E.

Q. 1.—(a) With the aid of a diagram, explain the principles of a Detector No. 4.

(b) How would you use the Detector to measure the resistance of a relay coil?

A.—(a) The Detector No. 4 is a portable instrument for measuring currents and voltages. It consists essentially of a moving coil pivoted between two permanent magnet pole faces and associated with a system of resistances that may be connected in four different ways



Q. 1, Fig. 1.

by means of a rotary switch. It can be used either as a voltmeter or an ammeter. The connections are shown in Figure 1. The switch contacts are made by rubbing surfaces, the "clicks" being between contacts.

The range of the instrument may be increased by the use of external shunts and multipliers which can be fitted to the terminals.

There are fifty divisions on the scale. The ranges of the instrument and the terminals used for the various measurements are shown in figure 2.

(b) In addition to the detector and relay coil, a battery is required. The resistance of the relay may be determined by the application of the following formula:—

Resistance of relay = resistance of detector (D/d — 1).

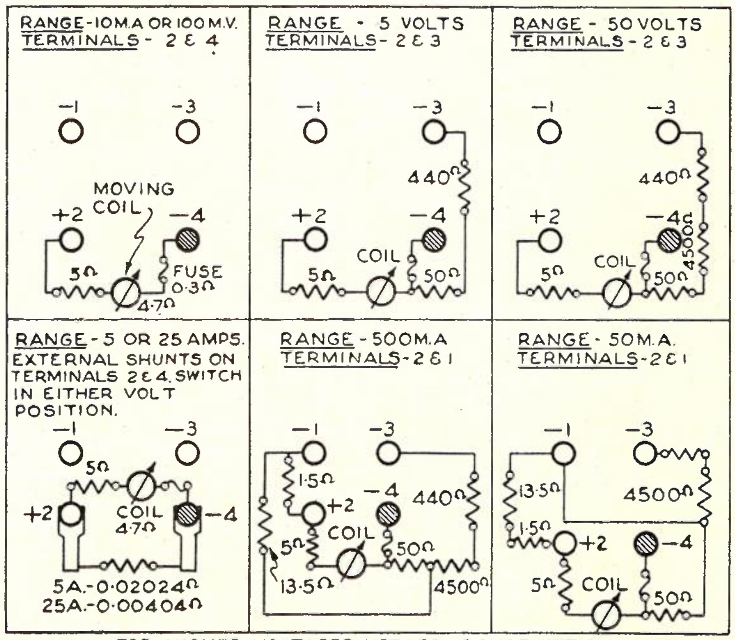
When D = deflection on detector when connected in series with the battery.

d = deflection of detector when connected in series with the battery and relay coil.

Either volt scale may be used—say the 5V scale, in which case the battery is connected across terminals 2 and 3 and the deflection in scale divisions noted—say 30 = D. Connecting the relay coil in series note the deflection—say d = 10.

Resistance of detector for 5V scale = 500 ohms.

Resistance of relay coil = 500 (30/10 - 1)
= 500 (3 - 1)
= 1000 ohms.



FOR HIGHER VOLTAGES USE 50V. RANGE WITH EXTERNAL MULTIPLIER.

Q. 1, Fig. 2.

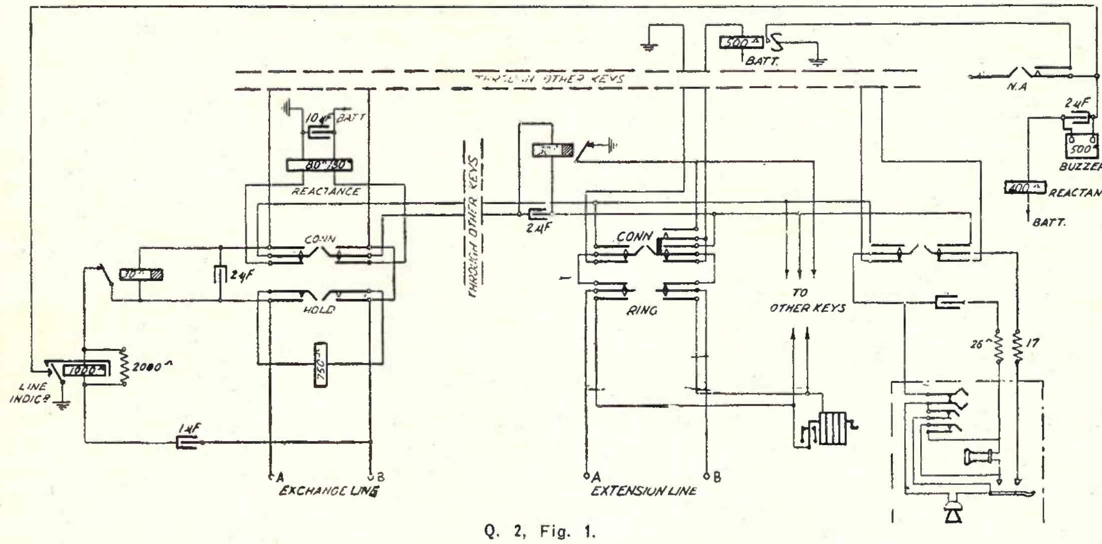
Q. 2.—Draw a schematic diagram of the exchange and extension line circuits of a C.B. cordless P.B.X.

(b) Briefly describe the operation of the switchboard for an exchange to extension call.

A.—(a) See Fig. 1.

(b) The incoming exchange ringing current passes through the 1000 ohms line indicator shunted by 2000 ohms resistance and through the 1μF condenser. The indicator is operated and earth is connected to the buzzer.

To answer the call, the telephonist throws the key associated with the particular exchange line, to the "connect" position, and throws the speak key. The exchange line is now connected across the telephonist's telephone in series with two 30 ohm relays, both of which operate. The relay controlling the exchange line indicator disconnects this indicator to prevent false operation. The telephonist ascertains the extension required by the incoming call. The battery on the exchange line is used in that the P.B.X. battery is cut off by the operation of the exchange line "connect" key. A key is associated with each extension and the position of the key indicates to the operator whether the extension is free or not. If free, the extension line key is thrown to ring position when the hand generator is connected across the line. After ringing, the telephonist throws the key from the ring position to the connect position and in so doing connects the extension to the exchange and restores the speak key. Until the extension answers the extension indicator is operated from ground on the connecting circuit supervisory indicator contacts. When the extension answers, the supervisory relay operates to restore the eyeball in-



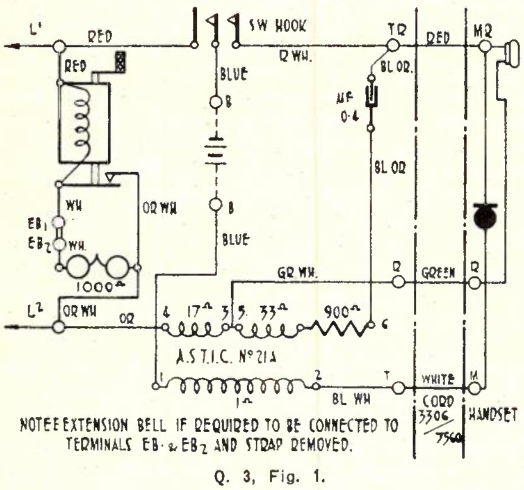
Q. 2, Fig. 1.

dicator and conversation proceeds. Alternatively, the telephonist could throw the exchange line key from the connect to the hold position and when the extension answered, advise that an exchange call was waiting. The P.B.X. battery would be used for this conversation, which could not be heard by the exchange caller. The exchange line key would then be thrown to the connect position, speak key restored and the conversation proceeds. When the extension replaces the handset the connecting circuit supervisory relay operates the extension indicator and telephonist restores keys to normal.

Q. 3.—(a) Draw a schematic circuit of a magneto telephone with an anti-side tone induction coil.

(b) Briefly describe the operation of the telephone.

A.—(a)



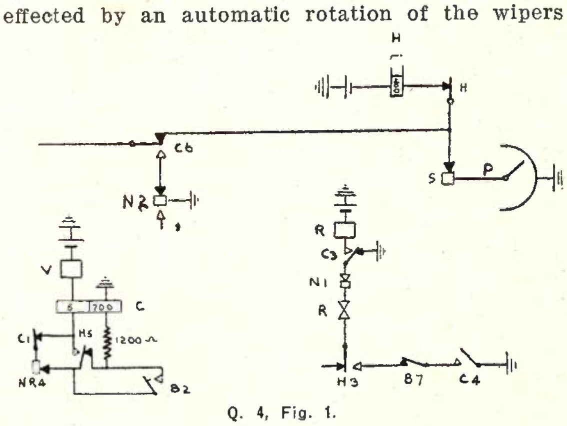
Q. 3, Fig. 1.

(b) An incoming ring passes through the generator from L1 to EB1, EB2, 1000 ohm magneto bell to L2. The generator is short-circuited. When ringing the exchange, the bell is short-circuited and the short circuit over the generator is removed. This is effected by the driving spindle of the generator moving outwards as the handle is turned. Removal of the handset from the switchhook completes the transmitter local circuit as follows: From dry cells, through 1 ohm winding of ASTIC to T, M, and transmitter, to MR and TR, switchhook contacts to cells. Speaking into the transmitter produces a varying DC through winding 1-2 of the ASTIC. The ASTIC has a transformer action and an alternating current is produced in the secondary windings 4-3 and 5-C. The path of this AC is from terminal 4 to L2, through line impedance to L1, through local balance network consisting of 0.4 μF condenser and 900 ohm resistance to coil. The receiver is connected between the mid-point of the coil and the junction of line impedance with the local network, i.e., at points of zero potential, so that no current (or a slight amount in practice) flows through the receiver. This is the effect of the anti-sidetone coil.

The incoming AC passes over line 1, through the switchhook contacts, receiver, 17 ohm winding 4-3, back to line 2. No current flows in the local network in balanced condition, because of the opposing voltage from the 33 ohm winding induced from the 17 ohm winding.

Q. 4.—Describe the release features of a group selector of the B.P.O. 2000 type.

A.—The release action of the B.P.O. 2000 type switch is effected by an automatic rotation of the wipers off



Q. 4, Fig. 1.

the bank contacts to the 12th step where a notch in the rotary disc comes in alignment with the comb plate, thereby leaving the wiper carriage free to fall.

During the fall of the wiper carriage, the 12th tooth of the hub, slides along the rotary detent until normal level is reached when it is freed to rotate back to normal position under restoring spring tension.

The circuit operation during release of a 2000 type switch used as a 100 outlet group selector is as follows. This is typical of the various circuits in which it is used. The circuit shows the holding condition when switched through; i.e., with relays H. and C. operated on release, earth is removed from the private wire at the selector ahead. Relay H releases which in turn releases relay C at contact H5. With contacts C3, C4 and H3 back to normal, a driving self-interrupted circuit is closed for the rotary magnet. The wipers are rotated to the 12th contact where they fall to normal level and return to normal position. N1 contacts open the rotary driving circuit.

During release, the switch is guarded by the earth at N2 via C6 to the P wire.

There is a short unguarded period while relays H and C release, but seizure at this stage does not interrupt the release action.

Q. 5.—(a) An automatic exchange subscriber frequently receives rings, but on answering there is no reply. The trouble is in a final selector; what are the likely causes?

(b) What adjustments would you make to a final selector to ensure that the wipers will cut in correctly on all bank contacts?

A.—(a) The likely causes for a 2000 type switch are:—

(i) Dirty contacts on ring cut off relay.
(ii) Open circuit battery feed relay or open circuit ballast resistance.
(iii) Open circuit transmission condenser.
(iv) Dirty contacts on battery feed relay.

(b) The adjustments being described are for a 2000 type switch.

(i) Ensure that the wiper assembly is securely fixed to the carriage.
(ii) Check that tension of both springs is outward or in other words that the fibre collar is holding them together. A simple test is to press either spring against the insulator at some point behind the collar. The other spring should show an outward tension.
(iii) When off the banks, the springs should be straight from the spring fixing to the collar, and each spring should be clear of the insulator.
(iv) When off the bank the gap between the wiper tips must be between 12 and 20 mils. This is adjusted on the spring behind the collar.
(v) Adjust position on carriage by loosening fixing screws and rotating wipers to the 6th contact of 1st or 0 level and positioning them between ⅓ and ½ way on the contact. Tighten fixing screws at this position and check on the other extreme level. If there is any appreciable difference in their positions, a mean adjustment should be made. When resting on a bank contact, each spring must be clear of the insulator.
(vi) Wiper tips must be clear of the bank insulation when raised or lowered from the normal or 12th rotary position.

Q. 6.—List the functions of one of the unit types of Private Automatic Branch Exchange equipment, such as Type "C" or "CA" or the Siemens and Halske type.

A.—The following facilities are provided on type "C" or "CA" P.A.B.X.'s.

(i) Extension to extension calls dialled direct.
(ii) Calls outgoing to the public exchange dialled direct by prefixing "Y" to the directory number.
(iii) Any extension may be barred direct access to the public exchange, in which case calls may be routed through the associated manual switchboard.
(iv) Calls incoming from the public exchange are received on a cordless type manual switchboard and routed to extensions by the use of key sender equipment. If the extension is busy, the call is completed automatically as soon as it becomes disengaged.
(v) Through clearing and automatic release on exchange calls. The exchange equipment is held busy until both calling and called terminations are free.
(vi) All exchange lines are night switched to predetermined extensions, but when the lines are free, any extension not barred may call the exchange.
(vii) Extensions call the manual switchboard by dialling 9.
(viii) A busy extension may be offered an exchange call; a warning tone is provided to advise the extension that the telephonist is across the line.
(ix) On exchange calls, the telephonist may speak to either the exchange or extension without the other party hearing.
(x) Outgoing exchange calls may be set up by the telephonist and reverted to any extension.
(xi) Automatic call back and transfer of exchange calls. If an extension telephone is fitted with a non-locking press button (which when depressed grounds one side of the line) an exchange call may be held and information obtained from any other extension by dialling the relative number. Alternatively, the exchange call may be transferred to the extension number dialled without calling the manual switchboard.

Q. 7.—(a) What are the main differences between a non-homing and a homing type uniselector?

(b) What are the advantages of the homing type?

(c) How would you adjust the armature assembly of any type of uniselector with which you are familiar, to ensure correct operation?

A.—(a) The main differences between a non-homing and a homing uniselector are as follows:—

(1) At the end of an operation, the homing switch automatically returns to its home position, whereas the non-homing switch in nearly all cases remains on the last outlet used.

(2) The bank associated with the homing switch has one continuous arc, broken only for the home position.

(3) When used as a primary line switch, with similar metering circuits—

(i) the homing uniselector has an extra pair of wipers and an extra level on the bank.
(ii) The L. and K. relays associated with the non-homing switch have a face plate designed to prevent relay K from operating fully unless relay L is first operated.

(b) Uniselectors are used in many circuits, but their most common use is for primary line switches. For this purpose the homing uniselector has the following advantages:—

(i) The outlets from the several groups of uniselectors can be graded giving a more flexible and more economical trunking to the first selectors. The number of first selectors is reduced by approximately 10%.

(ii) The face plate mechanism associated with the L and K relays is eliminated.
(iii) Bank contacts are kept clean by frequent wipings.
(iv) Special chain relays are not necessary to prevent continuous rotating if all outlets are engaged.
(v) It will step on over an open trunk.

(c) This answer applies to the A.E.C., Chicago, type of uniselector. The steps to be taken are:—
(i) Adjust armature stop to relieve the pressure of the pawl against the pawl stop, assuming that the pawl stop has already been correctly positioned with the armature against the armature stop, and the pawl engaged in a tooth there should be just perceptible play in the wiper assembly.
(ii) See that the armature does not bind on its bearings or on the locking spring.
(iii) See that the pawl does not bear against the frame or bind on its bearings.
(iv) Adjust the pawl spring tension to ensure that the pawl bears firmly against the ratchet wheel when the armature is operated.
(v) The stroke adjusting screw should be adjusted to allow the pawl to just drop in on the next tooth without binding on the tip of the tooth with a 2 mil gauge between the screw and the coil core and not to drop in without binding with a 5 mil gauge in same position.
(vi) The stroke adjusting screw should project through the armature from ½ to 1 complete turn and should be square with the magnet core when the armature is operated.

Q. 8.—Three methods of metering calls on automatic exchanges are in use:—
(a) Reverse battery.
(b) Booster battery.
(c) Positive battery.
Describe how each type of metering is accomplished.

A.—(a) A double wound relay is connected in the trunk from the primary line switch. A high resistance winding which becomes the polarising winding is connected to the P wire, while the other winding is in the positive wire. When the current is reversed in the positive wire from the final selector or repeater, the relay operates, short circuits the winding in the positive wire and holds operated by the other winding. A contact of this relay connects earth to the meter which operates and holds for the duration of the call.

(b) The meter is connected to the private wire and is so designed that it will not operate on the normal exchange voltage (50V), but will operate with double this voltage (100V). The cut-off relay in the subscriber's line circuit is in parallel. The additional 50V boost is given from the final selector circuit. The called subscriber answers, the battery feed relay operates and the booster pulse relay, whch is slow to release, releases. During its releasing period booster battery is fed back to the meter which operates and holds from 50V to earth on the private where earth has been reconnected by make before break contacts of the booster pulse relay.

(c) When a subscriber originates a call, the meter circuit is connected to the P trunk of the first major switch (group selector or line finder). A metal rectifier prevents current from flowing through the meter until the called subscriber answers, when a positive battery pulse is fed along the P wire from the final selector or repeater. This pulse is in the conducting direction of the rectifier and operates the meter.

Q. 9.—(a) Describe the construction of a type 600 relay.

(b) Why is this type used for line and cut off relays in an automatic exchange instead of the type 3000?

A.—(a) The 600 type relay is similar to the 3000 type, only smaller. The construction might be described under several headings.

Coil Assembly.—The coil assembly, comprising an annealed soft iron core with an enlarged pole face at the armature end, its winding with bakelite cheeks, is an independent unit which can be removed by unsoldering the wiring to the tags, removing the armature, and unscrewing the coil nut. The spool is wound for voltages not exceeding 75 and should not be expected to dissipate more than 4 watts.

Yoke.—The yoke is of an annealed iron in an elongated L shape. The coil is fixed to it by a slotted circular nut screwed on to an extension of the core.

Armature.—The armature is bent at an angle of approximately 110 deg. and is grooved to form a bearing on the end of the yoke which is sheared at an angle of 87 deg. and has no projected knife edge. At a distance of 0.065 inches from the bearing, the armature has a further bend to bring the total angle to 94 deg. An armature fixing screw holds the armature on its bearing. A phosphor bronze residual stud having a projection of 4, 8, or 12 mils in length is fitted to the armature.

Spring Sets.—The maximum capacity of the relay is 12 springs, arranged in two sets, one either side of the buffer block. The contact springs are made of nickel silver, 14 mils thick. Twin dome contacts are used and the tips of the springs are split. The buffer block differs slightly from the 3000 type relay. It is less robust and the steps are formed by circular projections. They are 1, 2 or 2/3 step and secured to the yoke by 2 screws and a clamping plate. Movement from the armature is transmitted to the springs by pins riveted in the moving springs and insulated from the resting springs.

(b) The 600 type relay is used in the subscriber's line circuit in recent automatic exchanges because it is less costly than the type 3000 and a saving is effected in rack and floor space. The functions of the L and K relays are simple and within the range of the 600 type.

Also the 600 type relay embodies the essential good features of the 3000 type relay.

Q. 10.—(a) What facilities are provided by Unit, Transfer No. 1A, used with an A5 Intercommunication Telephone System?

(b) Describe the operation of the system for a call from the exchange to an external extension.

A.—(a) Unit, Transfer, Intercommunication No. 1A, is used in installations having one exchange line, one external extension, and up to four internal extensions. It is associated with the main station and is equipped with an exchange line indicator and an external extension indicator. It offers the following facilities:—
(i) Direct connection from an internal extension to the exchange line.
(ii) The answering of incoming exchange line calls by any one of the internal extensions.
(iii) Connection of the external extensions to the internal extensions. Internal extensions may call the external extensions direct, but to get an internal extension the external extension must call the main station to request the required internal extension to call the external extension back.

(iv) Access to the exchange line by an internal extension "barred direct access."
(v) Exchange line can be switched through to the external extension for night service.
(vi) Connection of external extension to exchange line.
(vii) Provision for the connection of a second main station.

(b) The incoming exchange call ringing current operates the eyeball indicator. The answering extension (main station) lifts the handset and depresses the exchange key on the telephone. It is found that the external extension is wanted. The main station calls the external extension by depressing the appropriate local key. The operation mechanically restores the exchange line key, but the line is held by a 600 ohm coil across the line. While the extension key is fully depressed the ringing relay in the transfer unit makes and breaks its own contacts at a frequency of approximately 16-20 per second and the resultant reversals of potential ring the magneto bell at the external extension. When the external extension answers, he is told that there is an exchange call for him, whereupon the main station throws the extension to exchange key on the Transfer Unit, and replaces his handset. Battery is supplied from the exchange to the external extension. This restores all keys on the main station telephone to normal. At the end of the call the extension indicator on the transfer unit is operated. The main station will restore the extension to exchange key.

EXAMINATION NO. 2156. — SUPERVISOR — OTHER THAN SUPERVISOR (SWITCHING) — TELEGRAPH SERVICE

R. G. MILLS

Q. 1.—There are terminated at a Telegraph Office two type B telegraph carrier channels, designated H and K, respectively. A duplex multiplex system is operated over channel H while a manually operated duplex set is connected to channel K. It is desired to transpose these systems at the switchboard so that the multiplex might be operated over K and the manual duplex over H. Show by means of a diagram the switchings that would be necessary, and include in the drawing the electrical connections between the Telegraph Office and the carrier panel via the switchboard. Designate each piece of equipment shown in the diagram.

A.—See Fig. 1.

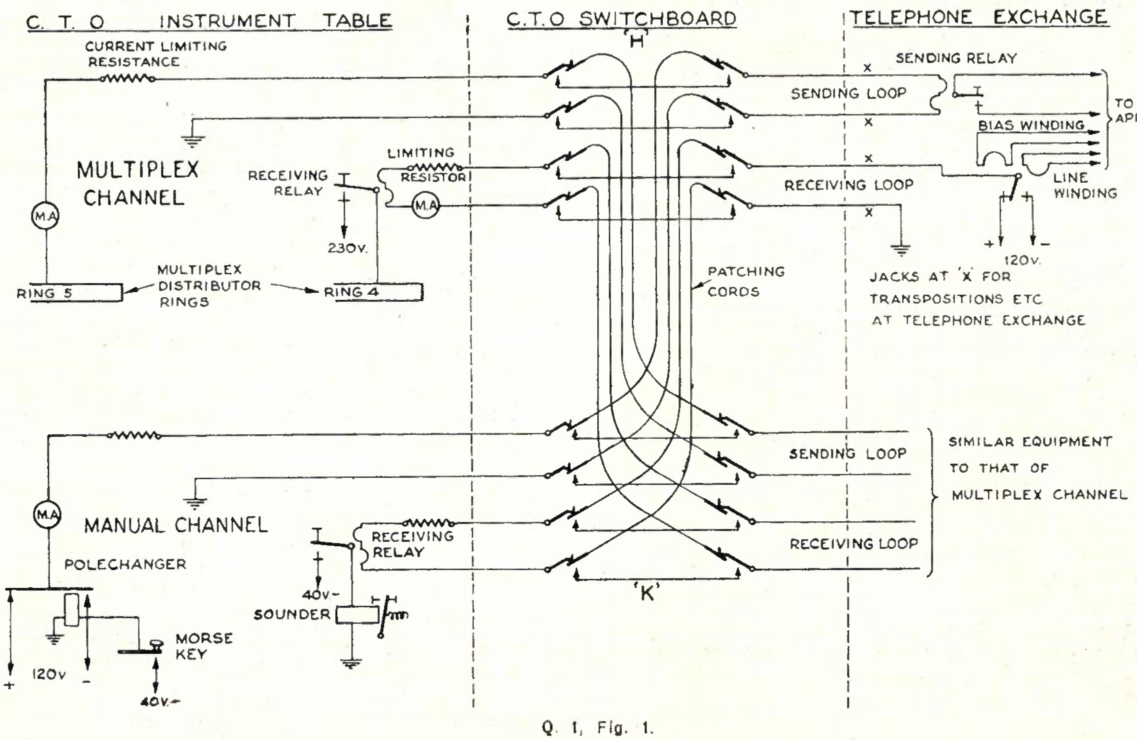
Q. 2.—Draw a diagram to illustrate the transmitting side of a teletype installation operated on the differential duplex principle. Explain fully the function of the biassing resistances associated with the transmitting relay.

A.—See Fig. 1.

In order to utilise double current transmission in teletype operation, a polarised relay is used in conjunction with the transmitting unit. This relay is known as the transmitting relay and its purpose is to convert the uni-directional current impulses made by the opening and closing of the transmitter contacts of the unit, into double current signals.

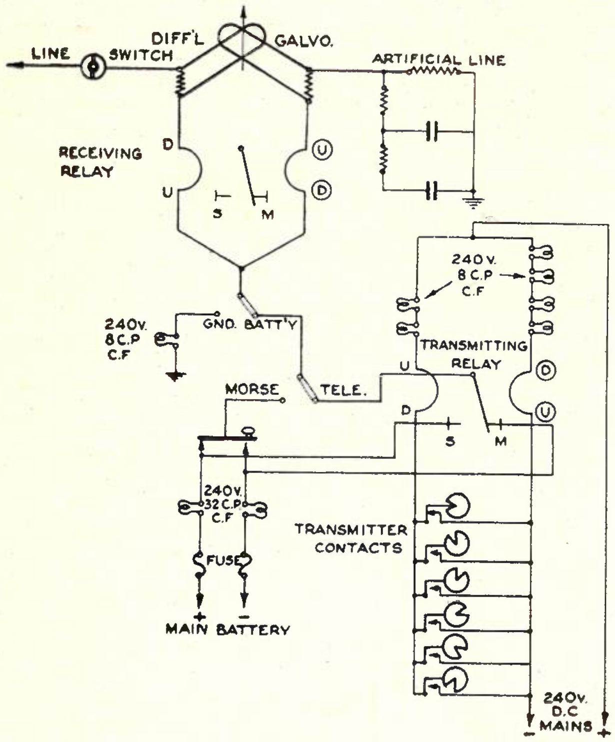
The function of the biassing resistances is similar to that performed by the retractile spring of a neutral relay. The tongue of the transmitting relay is held to the marking contact, thus applying negative (or marking) battery to line when the transmitter is in the unoperated position; this is secured by the passage through the U-D coils of a current equivalent to twice that flowing through the D(circle)-U(circle) coils, there being only two resistance lamps included in the former circuit and four in the latter.

There are connected in series with the D(circle)-U(circle) coils four 8-candle power carbon filament lamps, or a non-inductive resistance of similar value, and current is continuously supplied to this circuit from a permanently connected source of E.M.F., thereby influencing the tongue of the relay to spacing. The U-D coils of the relay are connected in series with the sources of E.M.F., the transmitter unit contacts and two 8-candle power lamps or a fixed resistance equal to one-half of that included in the D(circle)-



Q. 1, Fig. 1.

U(circle) circuit. During such time, therefore, as any of the transmitter contacts are closed, there is a preponderance of current in the U-D coils equivalent to twice that in the D(circle)-U(circle) and the tongue of the relay is, therefore, held to the marking position. When any key on the transmitter is depressed and



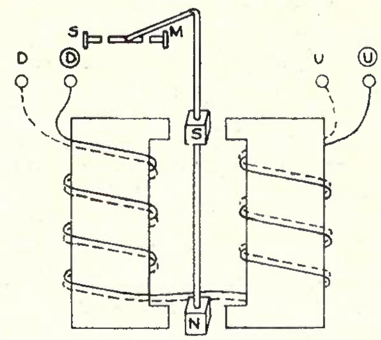
Q. 2, Fig. 1.

the start contact or any other contact is opened by a cam, the flow of current in the D(circle)-U(circle) coils takes control of the relay causing the tongue to move to the spacing contact, thus applying positive or spacing battery to line.

Q. 3.—Describe fully the construction and principle of operation of the polarised relay normally employed in duplex working in Commonwealth telegraph practice; and

(b) A fault develops in the non-polarised relay connected to a morse simplex channel and the only spare relay on hand is of the polarised type. Show schematically how the polarised may be substituted for the non-polarised relay in the morse circuit and describe fully any special relay adjustments that might be necessary to enable continuity of simplex working to be maintained.

A.—(a) The B.P.O. polarised relay consists of two separate electromagnets mounted vertically as illustrated in Figure 1 between both the upper and lower poles of which is a moveable soft iron armature. Each of these armatures is inductively magnetised by a comparatively large permanent magnet of the horseshoe type placed in proximity to them, the upper armature being of South and the lower of North polarity. To conserve space, the permanent magnet is curved round the coils. The contact arm or tongue which is tipped with platinum is carried on an extension of the pivoted spindle to which the armatures are affixed. The instrument is differentially wound, D and U being the terminals of one coil and D(circle)-U(circle) being those of the other.



Q. 3, Fig. 1.

There are three other terminals designated S, T, and M, which are connected respectively to the spacing contact, the tongue and the marking contact. The two contact screws between which the tongue plays are adjustable and are fitted on a carriage which can be moved by a biassing screw so that the proximity of the armatures to the pole-pieces of either electromagnet may be varied, the distance being increased on the one hand and decreased on the other, thereby creating a spacing or a marking bias if and as desired.

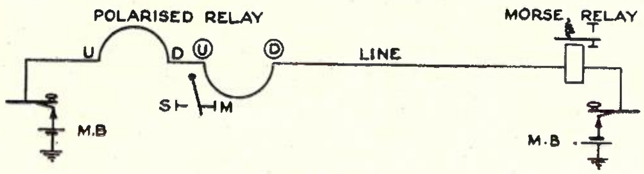
The unit is mounted on a wooden base and is enclosed in a tubular brass case fitted with a hinged lid provided with a glass top. The biassing screw projects through the glass case for convenience of adjustment.

A current through either coil in the direction D to U or D-circle to U-circle would produce a North pole at the top and a South pole at the bottom of the left-hand electromagnet illustrated in the diagram and a South pole at the top and a North pole at the bottom of the right-hand electromagnet. Since the extremity of the top armature is of South polarity, it would be repelled by the top right-hand South pole with a force equal to that of the attracting North pole created at the top of the left-hand electromagnet. Again the North pole created at the bottom right-hand electromagnet repels the bottom armature of North polarity with a force equal to the traction of the South pole created at the bottom of the left-hand electromagnet. The armatures are, therefore, influenced by four equal forces acting in unison, and in the same direction. A current from D to U or D-circle to U-circle moves the tongue to the spacing contact. If the current flow were reversed in direction, that is, from U to D or from U-circle to D-circle, the movement of the armature would also be in the opposite direction, that is, to the marking contact.

The relay is normally operated by alternately reversing the direction of the current flow or, when connected differentially, by a preponderance of current in one coil over that of the other. Each coil U to D and U-circle to D-circle is of 100 ohms resistance and the figure of merit of the instrument is 0.5 mA.

(b) Figure 2 illustrates one method of connecting a polarised relay for use in a morse simplex circuit. In this method the polarised relay must be given a spacing bias by adjusting the biassing screw so that when current is not flowing through the coils, the tongue will be drawn over smartly to the spacing contact. Care must also be taken to connect the relay in the circuit in such a manner that the passage of current through the coils will cause the armatures to be drawn over to the marking position.

The sketch shows the correct method of connecting the relay with the batteries joined as shown and the



Q. 3, Fig. 2.

two coils in agreeing series; if the direction of the flow of current were reversed it would be necessary to reverse the connections of the relay.

Q. 4.—Two banks of accumulators each of 240 volts are available at a terminal telegraph office for power supply. Describe, with the aid of diagrams, how power distribution might be arranged to provide—

(i) 240 volts positive and 240 volts negative to one differential duplex set;

(ii) 160 volts positive and 160 volts negative to one differential duplex set;

(iii) 160 volts negative to one morse simplex set; and

(iv) 80 volts positive to each of two morse simplex sets.

Show the fuses and designate their respective values.

A.—The figure illustrates the arrangements for the distribution of power from a secondary cell installation.

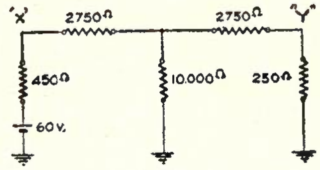
The leads from the battery are taken to a power panel upon which are mounted suitable meters for the measurement of E.M.F. and current, switches for the charging and discharging arrangements, the rotary switch used to equalise the load upon the groups of cells forming the battery and the main fuses.

In the case quoted there would be 120 cells in each battery providing for positive and negative supplies, the opposite end of each battery being earthed. Leads would be taken from the 40th, 80th, and 120th cell of each battery to provide the potentials required. A local battery of say 40 volts would be similarly provided.

From the power panel, the distribution leads are taken to the Battery Distributing Frame, where they are connected to bus-bars. From this point the power supply is fed to each individual line through an alarm type of fuse and a battery resistance, the latter being of such a value as to limit the current to approximately half an ampere in the event of accidental short circuit.

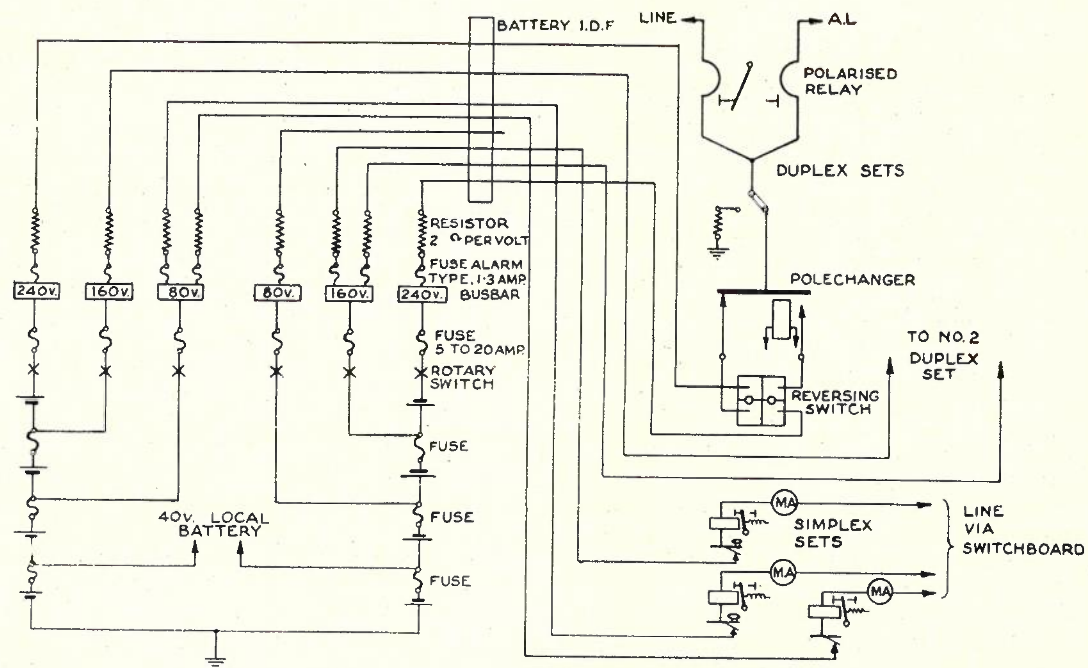
The provision of suitable fuses requires a knowledge of the current that would be normally taken from the battery. However, the main fuses on the power panel and the fuses between the groups of cells should be capable of carrying a large current, say, 5, 10, 15, or 20 ampere fuses as may be necessary. The fuse selected should be capable of carrying the normal current without any appreciable heating. The alarm type fuses are rated at 1.3 amperes.

Q. 5.—The resistance of a telegraph conductor connecting two terminal offices and operated on the earth-



Q. 5, Fig. 1.

return principle, is 5,500 ohms. The conductor resistance is uniform throughout and the wire is supported on 1,250 poles, the insulation resistance at each pole being 12.5 megohms. At office X the resistance of the equipment, including a battery of 60 volts, is 450 ohms, while at office Y, which has no battery connected to the circuit, the equipment has a total resistance



Q. 4, Fig. 1.

of 250 ohms. Calculate the current flowing at office Y.

A.—For all practical purposes, the insulation resistance, if evenly distributed over the line, may be regarded as being equal to a similar resistance placed between the line and earth at the electrical centre of the conductor. Therefore the problem is as shown in the figure.

$$\text{Insulation resistance} = \frac{12{,}500{,}000 \text{ ohms}}{1{,}250 \text{ poles}} = 10{,}000 \text{ ohms}$$

$$\text{Current taken from the battery} = \frac{60}{3{,}200 + \dfrac{10{,}000 \times 3{,}000}{10{,}000 + 3{,}000}}$$

$$= 60/(3{,}200 + 2{,}308)$$

$$= 60/5{,}508 \text{ or } 11 \text{ milliamperes approx.}$$

The current divides in the ratio of 3,000 : 10,000, i.e., 3 : 10 or 13 parts, i.e.,

3/13 of 11 milliamperes or approximately 2.5 milliamperes through the leakage path; and

10/13 of 11 milliamperes or 8.5 milliamperes through the relay at office Y.

Q. 6.—Discuss fully the effects on the magnetic traction of an electromagnet of each of the following:

(a) the material comprising the core;

(b) the length of the core of given magnetic material;

(c) the cross-sectional area of the core;

(d) the number of turns of wire comprising the coil;

(e) the value of the current flowing in the coil; and

(f) the shape of the electromagnet.

A.—(a) The use of an iron core or an iron alloy core in an electromagnet increases its tractive force tremendously as compared with a core of non-magnetic metal or other material because the magnetic flux in the former is much more intense as compared with the latter, the reluctance of iron being much less than air or non-magnetic materials. The tractive force of an electromagnet depends upon the production of lines of force or flux by the passage of a current through the coil.

(b) An increase in the length of the core of given material increases the reluctance and therefore decreases the tractive force. Hence it is desirable that the length of the core should not be any longer than is necessary to accommodate the required number of turns. Reluctance might be described as the measurement of the opposition of the magnetic circuit to the process of magnetisation.

(c) The reluctance of the core of an electromagnet may be reduced by increasing the cross-sectional area of the core and, by thus reducing the reluctance, the tractive force of the magnet is increased. By decreasing the cross-sectional area of the core, the reluctance is increased and the attracting power is decreased.

(d) The tractive power varies in direct proportion to the number of turns, therefore increasing the number of turns increases the tractive force and a reduction in the number of turns will reduce the tractive force, the current value remaining constant.

(e) The tractive force is also directly proportional to the value of the current flowing in the coil; an increment in the value of the current therefore increases the tractive force and a reduction in the value of the current will reduce the tractive force.

(f) The maximum tractive force practicable is secured by constructing the core in a U shape so that both poles of the electromagnet are brought to bear on the armature. In such an arrangement the air-gaps in the magnetic circuit are minimised, thereby producing minimum magnetic reluctance and securing maximum flux density. With a straight bar electromagnet only one pole can be used effectively to attract the armature and the reluctance is much greater, consequently the tractive force is much less than in the case of the U shape magnet.

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

V. St. G. MAGNUSSON

SECTION B.

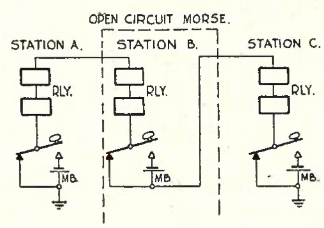
Q. 2.—A long morse simplex channel with five intermediate stations runs parralel with the coast throughout its length and is subject to leakage which varies in different sections. Discuss the advantages and disadvantages of:—

(a) Open circuit working, and

(b) Closed circuit working

for this channel. State what you consider would be the best arrangement for the most efficient working of the channel and indicate briefly your reasons.

A.—Open circuit morse working is seldom used in the Commonwealth. It has advantages, however, when

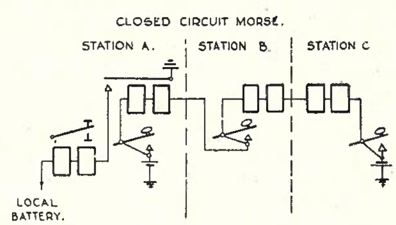


Q. 2, Fig. 1a.

working relatively short lines and there are not many stations per circuit. Fig. 1a shows the circuit arrangement of an open circuit morse system.

The outstanding advantage of the open circuit system is the economy in supply of working current as the voltage is not applied to the line except when any one station is transmitting. On the other hand it involves the installation of a battery at each station and maintenance costs are therefore high, particularly if stations are difficult of access.

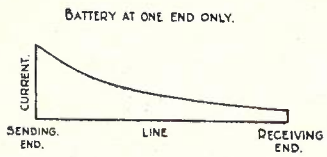
The battery at each station may vary in voltage, and due to this factor, together with varying line insulation, the current received at any particular office is not constant, depending on which station is signalling.



Q. 2, Fig. 1b.

Closed circuit working is shown in Fig. 1b. The current is derived from one battery which is usually placed at the terminal station. The current of any station is constant apart from leakage, and consequently the adjustment of a number of morse instruments in series is simple. As many as fourteen stations have been connected to one morse circuit.

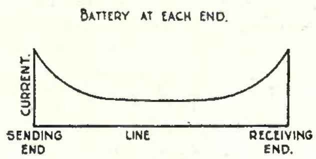
The value of the current received at the end of a long line is by reason of leakage often very much less than the current at the sending end. The received current in such cases may not provide a good working margin, and to increase the voltage at the sending end



Q. 2, Fig. 1c.

may be uneconomical and dangerous to apparatus. The alternative is to distribute the battery at stations along the line, so that the voltage is nowhere excessive and good working margins are available. See Figs. 1c and 1d.

For the morse simplex line it is considered that closed circuit working is preferable, especially as the line is long and subject to varying leakage. As pre-



Q. 2, Fig. 1d.

viously mentioned, the line current at such station would be more or less constant, and this is important on lines subjected to varying leakage. It is probable that the use of open circuit working on this line would be unsatisfactory and in any case a battery would need to be maintained at each station.

If necessary, the battery could be distributed over the line, but it is probable that if a battery is located at each terminal station, all requirements would be met, i.e., a good working margin at reasonable voltage.

Q. 3.—Discuss the circumstances under which you would consider installing each of the following items:—

(a) Box Sounder;
(b) Common Battery Duplex;
(c) Half Toye Repeater;
(d) Side Line Repeater;
(e) Polarized Relay.

A.—(a) Box Sounder: Box sounders could be used at intermediate and terminal stations or relatively short lines and for portable morse sets for use at Racecourses, Showgrounds, etc. When box sounders are used, relays and local batteries may be dispensed with, but the line current must be such that satisfactory signals are received.

(b) Common Battery Duplex: There is very little scope in this country for Common Battery Duplex Circuits, and this form of circuit is, therefore, not resorted to. The circuit is suitable for short lines between centres where a heavy traffic load is such that two morse lines would normally be required. The main advantage is the saving in equipment, particularly at the distant end where a line battery is not necessary.

Half Toye Repeater: When a Half Toye Repeater is installed and switched into the line circuit, the capacity of the circuit is reduced to that of a one way channel. Therefore, this type of repeater is only installed to meet special circumstances. A typical example would be the case of two stations "A" and "B" where the traffic load would normally require a Duplex circuit for its satisfactory disposal. Beyond "B", however, is a 3rd station "C" with a traffic load which only requires a Simplex circuit. If "A" at times has traffic for both "B" and "C", press for instance, the use of a Half Toye repeater at "B" would avoid hand repeating. It is under this and similar circumstances that Half Toye Repeaters are used.

(d) Side Line Repeater: At an intermediate station where a Simplex repeater is installed a second line to a station may terminate. To overcome the need for hand repeating to and from the terminating station, the Toye repeater could be modified to work also the side line circuit.

(e) Polarized Relay: A polarized relay may be defined as a relay in which the direction of the tongue movement is dependent upon the direction of the current. Polarized relays are mainly used on Duplex, Diplex and repeater circuits, and also to perform various functions in machine system circuits. Polarized relays are generally speaking more sensitive than non-polarized relays, due mainly to the fact that the armature has an induced polarity. They operate satisfactorily on line currents of a few milliamps. Polarized relays should be used where a positive response to weak currents is required, and positive and negative batteries would be used. Over a long fast speed circuit, particularly if the "KR" is high, polarized relays furnished with auxiliary windings to operate the relay on the Gulstad principle must be used.

(To be continued.)

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

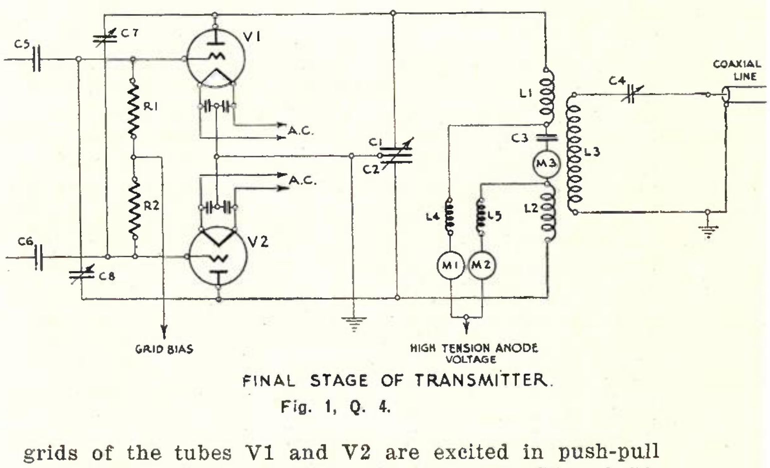
J. W. READ, B.Sc., A.M.I.E.E., A.M.I.E. (Aust.)

SECTION 2—RADIO TRANSMISSION AND ACOUSTICS

Q. 4 (a) Give a circuit diagram of the output stage of a radio broadcast transmitter designed for medium frequency operation, having two valves in a push-pull arrangement and coupled to a coaxial tube transmission line of 80 ohms impedance.

(b) If the output of the transmitter is 10 kW carrier power, what is the maximum peak voltage between the inner and outer conductors of the coaxial line when the carrier is modulated 100%?

A.—(a) Fig. 1 is a simple diagram showing the essential components in the output stage of a broadcast transmitter using one pair of tubes in push-pull. The



FINAL STAGE OF TRANSMITTER.

Fig. 1, Q. 4.

grids of the tubes V1 and V2 are excited in push-pull from the previous stage through condensers C5 and C6, the excitation voltage appears across R1 and R2, which are known as the grid swamping resistances. The purpose of these grid swamping resistances is to ensure that the load on the previous stage remains reasonably constant. The value of these normally is approximately 1200 ohms each, that is a very low value compared with the input impedance to the tubes themselves, so that the voltage across them due to grid current being drawn from the final stage tubes, is maintained at a relatively low value.

The filaments of the two tubes in the final stage would be lighted with AC from a Scott-connected transformer, that is a transformer which has two outputs 90 deg. out of phase. Noise due to AC on the filaments is thus reduced by approximately 5db. below the value which would occur if the tubes were lighted in phase.

The anode circuit of the final stage is tuned to resonance at the operating frequency of the transmitter by means of the condensers C1, C2 and the coils L1, L2, and the impedance of this tuned circuit when coupled to the line through L3 is made equal to the series plate impedance of the two vacuum tubes.

In order to prevent the stage from oscillating due to the energy which is fed back from the anode to the grid of each tube, energy is fed from the plate of each tube to the grid of the other through the condensers C7 and C8. The value of C7 and C8 is fixed so that the amount of energy fed back to the grid of any one tube from its own plate is neutralised by feeding back to the same grid the same amount of energy from the plate of the other tube in opposite phase. The condensers C7 and C8 are known as the neutralising condensers.

The high tension voltage on the anodes of the two tubes is fed from a common source through meters M1 and M2, radio frequency chokes L4 and L5, tuning coils L1 and L2 to tubes. This arrangement permits the plate currents of the two tubes to be read separately, the R.F. chokes L4 and L5 being for the purpose of preventing any radio frequency voltage from appearing across the meters or getting back into the DC anode supply. Condenser C3 is usually of a relatively high value (of the order of .1 or .01 microfarad) and it is for the purpose only of keeping separate the DC anode supplies to the two tubes.

The meter M3 reads the radio frequency current circulating in the tuned circuit (the circuit consisting of the condenser C1 C2 and the coil L1 L2 is the tuned circuit and is frequently referred to as the tank circuit).

The inductance L3 is coupled inductively to the tuned circuit and the degree of coupling affects the value of the load imposed on the anodes of the tubes. The condenser C4 between this inductance and the line is for the purpose of tuning out the positive reactance which would otherwise appear when looking back from the line into the transmitter.

The final stage shown in the figure would be an amplifier of modulated waves and as such would be operated normally as a class B amplifier, that is an amplifier which would normally be biased to a point approaching cut-off. The grid bias is fed as shown at the junction between the grid swamping resistances R1 and R2. The overall efficiency of the amplifier, that is the ratio of radio frequency output to DC input to the anodes, would be approximately $33\frac{1}{3}\%$.

(b) When a carrier wave is modulated to 100% it means that the peak value of the voltage of the carrier varies, at the modulating frequency, between zero and twice the normal unmodulated value. The R.M.S. unmodulated carrier voltage appearing across the inner and outer conductors of a coaxial line is given by the expression—

$$E = \sqrt{WR}$$

Where W is the unmodulated carrier power and R the impedance of the line.

If W is 10,000 watts and R is 80 ohms:

E (R.M.S.) is therefore 894 volts.

The peak value of the unmodulated carrier voltage is therefore:

$$\sqrt{2} \times 894$$

and when modulated to 100%, the peak voltage will be twice this value, that is—

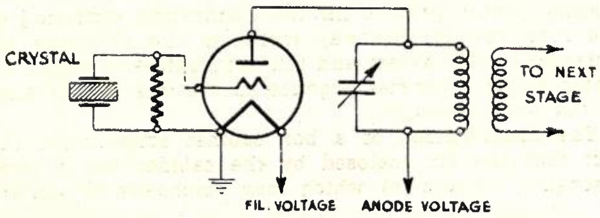
$$2 \times \sqrt{2} \times 894 = 2526 \text{ volts.}$$

Q. 5.—Explain the action of a quartz crystal when used as a Piezo-electric oscillator. Show how such an oscillator can be used to maintain the frequency stability of a transmitter and give a circuit diagram showing the manner in which it is coupled to the first valve.

A.—Quartz is oxide of silicon and occurs often in a crystalline form. The peculiar property of such a crystal, which is employed for controlling the frequency of an oscillator, is that if it is subjected to mechanical pressure a voltage is developed across it. The application of a mechanical tension instead of a pressure produces a voltage of the opposite polarity. Conversely, if a voltage is applied across the crystal it causes mechanical deformation, i.e., it contracts or expands according to the direction of the voltage. Therefore, if an A.C. voltage is applied across the crystal it will vibrate.

When this occurs the vibration may be considered to consist of two components, a forced vibration at the frequency of the applied AC voltage, and a free vibration at the natural frequency of the crystal. The frequency of the free vibration depends only on the mechanical properties and the dimensions of the crystal, and not on the frequency of the applied AC voltage. When the quartz crystal is used in conjunction with a vacuum tube oscillator, the forced vibration is generally of small amplitude, but if the frequency of the applied AC voltage is near the natural frequency of vibration of the crystal, conditions approaching mechanical resonance ensue and the magnitude of the free vibration reaches a large value. This free vibration sets up an AC voltage of correspondingly large value across the crystal faces. It is the latter AC voltage which may be applied between the grid and filament of a vacuum tube to maintain electrical oscillations in the tube and its associated circuit. The frequency of such oscillations is found to be almost the natural mechanical frequency of vibration of the quartz crystal, and it is almost independent of the electrical properties of the vacuum tube circuit. Frequency variation due to changes in these properties, which might be caused by a temperature variation, etc., is largely eliminated and the transmitted frequency is constant.

Fig. 1 shows a method of connecting a quartz crystal to a vacuum tube oscillator circuit. The anode circuit of the tube contains a tuned circuit. The input impedance to a vacuum tube, that is the impedance across the grid and filament, is a negative resistance when the load in the anode circuit is inductive, i.e., under this condition energy is fed back to the grid circuit from the anode circuit through the grid-anode capacity. Therefore, when the anode circuit of the tube shown in the figure is inductive, but approaching resonance, there will be a small amount of energy fed back to the crystal through the grid anode capacity and this will be sufficient to start oscillations. These oscillations will increase in value as the tuned circuit approaches resonance, and an oscillatory voltage will



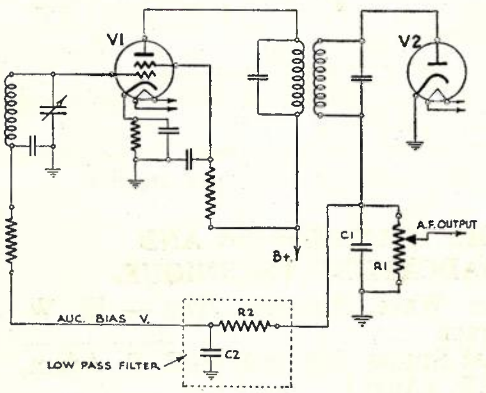
CRYSTAL OSCILLATOR
Fig. 1, Q. 5.

appear across the anode tuned circuit. The frequency of this AC voltage will be dependent upon the mechanical frequency of vibration of the crystal and will therefore be determined mainly by the mechanical properties and dimensions of the crystal. Variations of this frequency, therefore, will not occur unless the mechanical properties of the crystal vary. These do vary according to the temperature of the crystal, but in practice the crystal is contained in an oven, which is maintained at some constant temperature above ambient, so that changes in ambient temperature have no effect.

Research into mechanical and electrical properties of quartz crystals has also disclosed that the temperature coefficient of a crystal, that is, the change in natural frequency of vibration with temperature, can be reduced to a very low value, providing the crystal plate used is cut from the natural crystal in a certain manner, and modern crystal oscillators employ plates which have a temperature coefficient of not greater than 1 cycle variation in a million per degree centigrade.

Q. 6.—Describe a method used in a radio receiver to compensate for fading. Give a diagram to illustrate your reply.

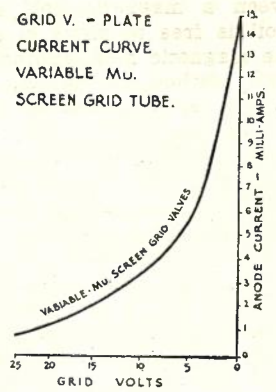
A.—The most common method used in a radio receiver to compensate for fading is by means of a device known as an automatic gain control. This causes the gain of the receiver to vary over wide



Q. 6, Fig. 1.

limits in accordance with the strength of the signal input to the receiver such that large variations in radio frequency signal input cause small variations in audio frequency output. It is possible with this method, using large multi-valve receivers, to reduce an R.F. signal variation of 80 db to an audio output variation of 6 db. It should be remembered, however, that with this method it is only possible to partially compensate for signal strength variations and no attempt is made to compensate for frequency or selective fading.

Briefly, the method of operation is as follows:—The receiver must be of a type using at least one radio frequency amplifying tube of the variable Mu type,



Q. 6, Fig. 2.

the grid volts plate current curve of such a type being shown in Fig. 2. An examination of this curve shows that as the grid volts are increased the amplification of the tube will decrease. A linear detector is used such that the magnitude of the DC component is proportional to the peak value of the carrier input. This component is then used to produce a grid bias, which is applied to the grid of the variable Mu tube, or tubes, thus varying the gain inversely as the power input. Fig. 1 shows a simple form of A.G.C. It represents a radio amplifying tube of the variable Mu type, followed by a simple diode detector. Following the circuit from the diode plate to earth, it will be seen that a DC potential difference capable of supplying a negative bias equal approximately to the peak value of the R.F. signal input volts is developed across R1, C1 being a by-pass for radio frequency only. This negative bias is fed back through a low pass filter R2 C2 to the grid of the variable Mu tube. The low pass filter is necessary to pass back only the DC bias due to the relatively slow changes in the amplitude of the R.F. carrier and to prevent frequencies above about 10 c.p.s., that is any variations due to the audio frequency modulation, being fed back to the grid of the amplifying tube. Thus, it will be seen that an increase in the strength of the carrier frequency reaching the diode detector results in an increase in potential difference across R1. This increases the grid bias to the amplifier valve, thus reducing the amplification of that valve, which partially compensates for the increase in signal input which gave rise to the above changes.

Q. 7.—(a) Describe the operation of a dynamic type loud speaker employing a paper cone.

(b) Discuss the desirability of using a box or the usual form of radio receiver cabinet as a baffle. What are the disadvantages and how may they be overcome?

A.—(a) A dynamic type loud speaker consists of three essential parts:—

(i) An electromagnet or permanent magnet.

(ii) A speech coil.
(iii) A paper cone.

The speech coil consists of a few turns wound on a former and rigidly connected to the paper cone. The coil is located in a strong field from the magnet, being suspended in a gap so that its movement cuts the field at right angles.

When speech currents are fed to this coil, a force is applied which is proportional to the value of the current, this force being a consequence of the normal interaction between a magnetic field and an electric current. The coil is free to move in a direction perpendicular to the magnetic field, subject to a restoring force due to the method of holding the coil. Its movement, therefore, is in accordance with the speech currents in the coil.

As stated above, the coil is connected to a paper cone, which moves with the coil and acts as a coupling device between the coil and the air or sound medium, so that the movement of the coil is translated into sound waves.

It is to be noted that movement of the cone is resisted by the air and it is the work done against this resistance which is the measure of the effective radiation of sound from the loud speaker. The cone, the driving system, and the magnetic fields are therefore designed to make the work done in this way approximately uniform throughout the frequency range desired.

(b) The desirability of using a box or cabinet arises from the need to improve the coupling between the air and the speech coil at low frequencies. The use of such a box prevents the flow of air pushed from the front of the cone, say, in a forward movement, from taking a short path to fill the rarification occurring at the rear and in this way increases the radiation resistances of the system and renders audible, frequencies, which would otherwise produce only a local disturbance at the loud speaker.

The disadvantage of a box cabinet arises from the fact that the air enclosed by the cabinet has natural resonance frequencies which may emphasise to an unnatural degree these frequencies when they occur. This disadvantage may be partially overcome by one of the following general methods:—

(i) Introducing within the cabinet means for absorbing sound energy at the resonant frequencies (i.e., resonators which do not radiate).
(ii) Using a sound absorbent lining within the cabinet, such as rock wool.
(iii) Dividing the interior into a large number of similar enclosed areas graded in size so that their resonant periods cover a wide range without any of them predominating. These cavities may be arranged so that they operate in effect as a folded horn within the cabinet.

(To be continued.)

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