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A DISCRIMINATING SWITCHING REPEATER

E. C. Marks

An interesting switching problem occurred in the Adelaide network in connection with the trunking of Port Adelaide Level M traffic. The M exchanges are Prospect (M1, M2 and M3) and Woodville (M6 and M7), both of which are branches of Tandem Exchange, while special services such as Test Desk, Complaints, Phonograms, Trunk Enquiry, Information, etc., situated in and adjacent to Tandem are trunked from the MO level. Port Adelaide is a main exchange using the prefix J. The relative geographical positions of the exchanges and the junction cables between them are shown in Fig. 1.

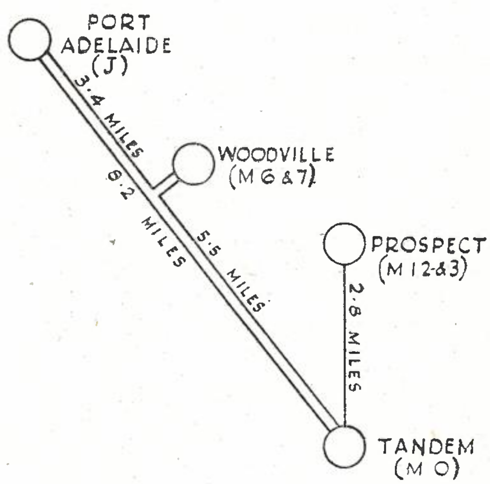

Fig. 1.

It is possible to route traffic from Port Adelaide to Woodville, but all Port to Prospect traffic must be routed via Tandem as no direct cable exists between these two exchanges. Under the original scheme all Port Adelaide level M traffic was routed through Woodville, the junctions terminating at Woodville on Switching Selector Repeaters arranged to switch on the first digit. Woodville traffic on levels 6 and 7 was trunked to local third selectors and levels 1, 2, 3 and O traffic was repeated via an incoming second selector repeater at Tandem to incoming third selectors at Prospect or local third selectors at Tandem.

Transmission difficulties were experienced with this arrangement, as the cables between Port and Woodville and between Woodville and Tandem are not loaded. Calls from Port to Prospect had a comparatively high junction loss, whereas the transmission in the reverse direction, i.e., from Prospect to Port, was good as the Tandem-Port Adelaide junctions were in loaded cable. The difference in level in the two directions was appreciable and caused comment by subscribers who frequently used this junction route.

As an alternative to loading the Port-Woodville and the Woodville-Tandem junction cables, the effect of trunking all Port Adelaide level M traffic via Tandem was studied. This would considerably improve the transmission on calls to Prospect, but degrade the transmission on Port to Woodville traffic to almost the same level as the Port to Prospect traffic under the existing trunking scheme. As the Woodville to Port traffic would be trunked direct it would also introduce a variation of transmission level between the Port-Woodville and the Woodville-Port directions.

It was apparent, therefore, that the solution of the problem lay in discriminating between Woodville and Prospect traffic at Port Adelaide and trunking each over the cable route with the lowest transmission loss. The scheme decided upon was a switching relay arrangement on similar lines to the Switching Repeater to Drawing C.E.61. As it was necessary to discriminate between three groups of junctions a uniselector which would step under the control of subscribers' dials was chosen as the simplest means of selecting the appropriate switching relay. Two separate groups of junctions are provided to Woodville and on calls to this exchange the second digit is absorbed in the discriminating switch. A selector repeater at Tandem is used as the second rank switch for Prospect and MO calls, therefore only one group of junctions is necessary to Tandem.

An outgoing secondary lineswitch for each junction group is tied to each discriminating repeater. Although the traffic carried would not warrant these in the case of straight trunking using ordinary repeaters, they are necessary in this case to enable the appropriate number of junctions for each group to be connected. Fig. 2 is a trunking diagram of the arrangement.

the direction of the current in the 60 ohm winding is reversed.

The impulses of the second digit are repeated to the selector repeater at Tandem by A 11/12

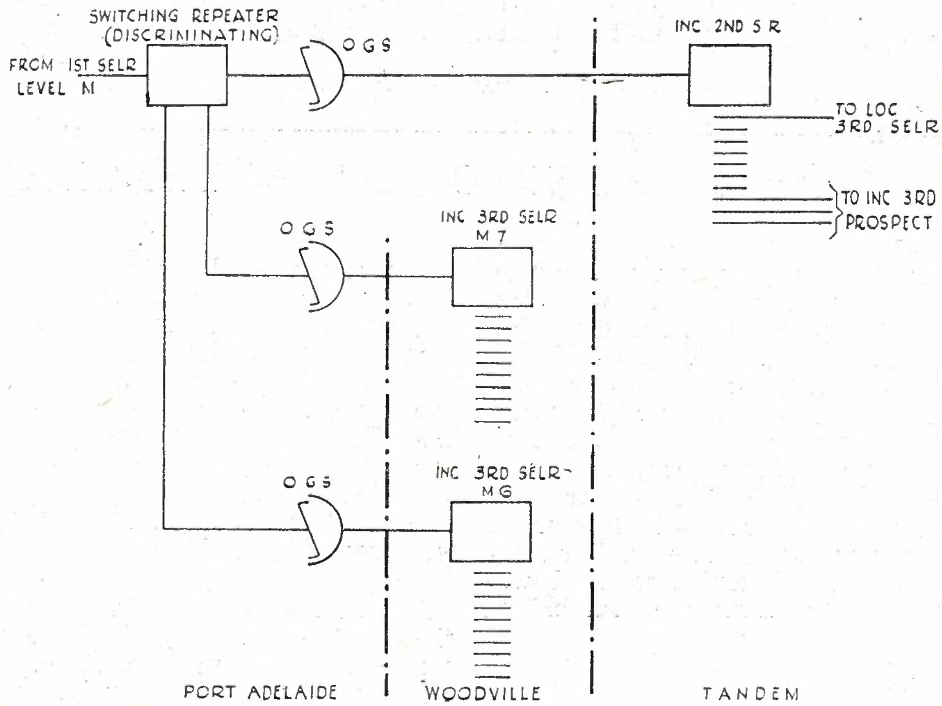

Fig. 2.—Trunking of Pt. Adelaide Level "M" Traffic.

The switch is divided into two parts—a modified auto-auto repeater and a discriminating circuit consisting of three relays and a uniselector. The ideal arrangement would be to fit the discriminating uniselector and relays on a jack-in relay set base mounted on the repeater trunk board immediately below the associated repeaters. Bases were not available, however, so a light iron frame of similar dimensions to a repeater shelf was constructed and the relays and uniselectors mounted thereon beneath the repeaters.

The circuit is shown in Fig. 3, the operation being as follows:—The switch is seized when the first selector cuts through after stepping to the M level. Relay A operates to the subscriber's loop extended from the first selector and completes a circuit for relay B at A 2/3. A also completes a loop forward at A 11/12 to seize an incoming second selector repeater at Tandem. B operates and applies earth to the private wire at B 2/3 to busy the relay set and hold the previous switches. B 14/15 prepares a circuit for the operation of relay C and the discriminating uniselector driving magnet. B 11/12 completes the circuit of relay G and the 1900 ohm winding of relay F. G operates and prepares the metering circuit. F does not operate until if there is a free junction and to the local discriminating switch driving magnet by A 2/1. The discriminating switch thus drives to the corresponding contact and prepares for the operation of one of the switching relays. The circuit of relay C is completed at A 2/1 when A releases for the first impulse. C operates and at C 2/3 shortcircuits the bridging relays to improve impulsing to the distant exchange, the 2000 ohm non-inductive resistance across C 1/2 preventing a false impulse being given during the change-over. C 11/12 opens to prevent operation of a switching relay before the digit is completed. C releases at the end of the impulse train and allows the appropriate switching relay to operate.

If the call is for a Prospect or an MO number the second digit will be 1, 2, 3 or 0 and relay SC will operate and lock to earth at SC 1/2. SC 11/12 breaks the circuit of the discriminating uniselector driving magnet and A 11/12 repeats all subsequent digits to Tandem. If the second digit is 6 or 7 relay SA or SB will operate on the release of relay C and lock up to its own 9/10 contact. Contacts 4/5 open the driving circuit of the discriminating switch and contacts 1/2/3, 11/12/13 and 6/7/8 switch the negative, positive and private trunks respectively to an outgoing secondary line switch with outlets to junctions terminated in incoming third selectors in the appropriate thousand group at Woodville. The junction to Tandem is open-circuited and the selector repeater at that exchange released. In this case the second digit is absorbed and the last three digits repeated to Woodville.

When the called subscriber answers the direction of the current fed back from the final selector in the distant exchange is reversed. The 60 ohm winding of relay F now assists the 1900 ohm winding and relay F operates. Earth at F 6/7 operates relays D and H. D 1/2/3 and D 11/12/13 reverse the current to the calling

from bank and wiper DS 4 applied to the private by contact B 1/2. The switching relays may flicker as wiper 2 passes over the associated bank contacts while homing, but this has no harmful effect.

The auto-auto relay sets used are of the standard B.G.E. pre-2000 type. 3000 type relays were not available for use as switching relays, so B.G.E. type relays were used and the older type relay set was chosen for the sake of uniformity.

The circuit modifications made to the repeater were as follows:—

(a) Two make contacts on the B relay were replaced with change-over contacts (B 1/2/3 and

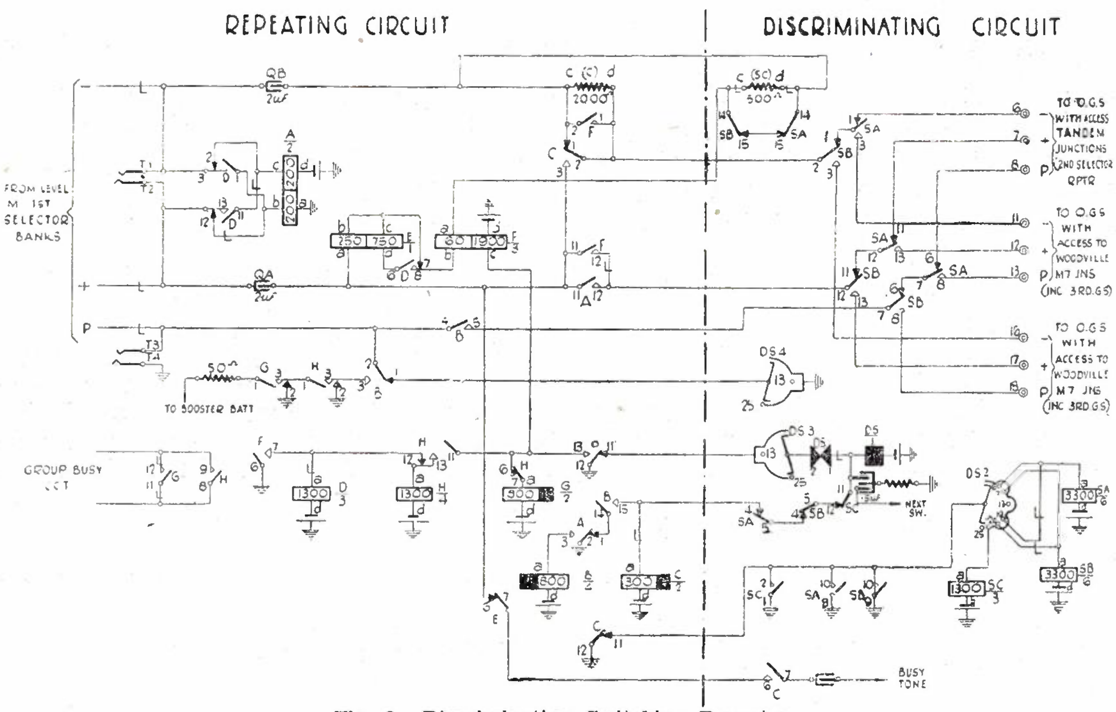

Fig. 3.—Discriminating Switching Repeater.

subscriber to give correct operation of public telephones or, if the call originated in a branch exchange, to operate the F relay in the repeater in that exchange. D 6/7/8 switches in the 750 ohm winding of relay E to increase the impedance of the bridging loop and so reduce the transmission loss in the switch. H 11/12/13 changes the holding circuit of H from earth at F 6/7 to earth at B 12/13 and H 6/7 breaks the circuit of relay G. H 1/3 applies 50 volt positive battery to the private to operate the calling subscriber's meter during the slow release of relay G.

When the calling party restores his receiver relay A releases, followed by relays B and H. B 11/12 applies earth to the homing bank of the discriminating switch and the switch drives by self-interruption to the home position. During the homing period of the uniselector the switch is guarded against seizure by an earth

B 11/12/13). The back contact was in each case brought out to a contact on the switch plug and wired to the discriminating circuit.

(b) Contact B 4/5 was moved from the negative wire, where it was serving no useful purpose to the private wire. This was necessary to prevent the associated outgoing secondary line switch on the Tandem junctions from driving continuously when the repeater was busied out by earthing the private. The B 4/5 contacts were brought out to contacts on the switch plug so that if it ever became necessary to restore the repeaters to normal use only a simple strapping alteration on the U jacks would be required to revert to the original circuit.

(c) The non-inductive resistance SC was connected in series with the 60 ohm winding of relay F to limit the current when the repeater is switched to the shorter junctions. The value of the resistance is chosen to equal the difference between the resistances of the two sets of junctions. When the longer junctions are in use the resistance is short-circuited, but it is switched in by the operation of SA or SB when a short junction is used. The polarised relay F, therefore, operates reliably under all switching conditions.

(d) A break contact was added to the retard E to control the application of busy tone, as explained later.

As the repeater precedes the outgoing secondary line switch instead of following it as is usual, the chain contacts G 11/12 and H 8/9 are not used. Special group control arrangements are necessary to give correct application of busy tone when all junctions in the required group are busy. A chain relay is connected to each junction and when all junctions in the particular group are engaged these complete the circuit of a Group Control relay. The GC relay operates a congestion meter and also operates an SR relay which breaks the battery feed to all outgoing secondary line switch driving magnets to prevent continuous rotation of the uniselector.

On the two groups of Woodville junctions the SR relay also feeds back busy tone in lieu of earth over the positive wire of all disengaged outgoing secondary line switches in the group. When the switching relay cuts through on completion of the second digit the calling subscriber therefore receives busy tone if all junctions in the group are engaged, and further dialling is ineffective.

A different arrangement is necessary on the Tandem group of junctions to prevent the subscriber receiving busy tone before dialling the second digit when all Tandem junctions are engaged. In this case the SR relay disconnects the earth from the positive wire in the outgoing secondary line switch and neither relay E in the repeater nor relay L in the outgoing secondary line switch can operate. The second digit is repeated to the discriminating switch and if the call is for a Prospect or MO number relay SC operates when C releases. SC 6/7 connects busy tone to the positive wire via E 6/7. Had a free junction been available battery and earth fed back from the selector repeater in Tandem would have operated relay E and busy tone would not be connected.

It will be noted that the discriminating switch has home positions on both contacts 13 and 25. Twenty-five point uniselectors were used as they were readily available and the two halves of the arc were used to minimise driving of the switch when homing.

This switch can be adapted to meet various requirements by modifying the discriminating circuit. It can be arranged to absorb the first two local digits and switch a subscriber's uniselector direct to a local third selector. In this form it is an attractive substitute for the switching selector repeater in small branch exchanges of less than 2000 lines' capacity. Both capital cost and maintenance charges should be considerably less than for the switching selector repeater.

Measurement of Relay Operate and Release Times

O. C. Ryan

Relay operate and release lags have been measured since the early days of automatic telephony, and as the circuits of the various automatic switches became more complex, the problems associated with timing became more acute, and the need for a simple method of timing relays during the maintenance of automatic equipment became important.

Practically the first instrument to be used for measuring the timing of relays was the Electro-Magnetic Oscillograph. This instrument has a high degree of accuracy, and is used in some instances as a standard, but the time which elapses between making the test and obtaining the developed oscillograms excludes its use for making extensive tests in the field. This instrument, which is mostly used in the laboratory and factory, lacks portability.

The Phonic Chronometer is regarded as the first really portable timing set. It consists of a phonic motor driven at constant speed by an electrically maintained tuning fork. Within a few mils of the motor fly-wheel is a small friction wheel which is brought into contact with the fly-wheel by means of a magnet controlled by the contact of the relay under test. The spindle of the friction wheel is extended to carry a pointer which moves over a dial suitably graduated to read in milliseconds. By means of keys the circuit may be preset to read operate or release lags. The pointer is reset by hand between successive tests. In a later development the tuning fork was replaced by an electrically governed D.C. motor, and the dial pointer electrically reset.

Other timing devices include the use of adjustable pendulums, calibrated reeds, condenser bridges or calibrated relays.

Messrs. Siemens Brothers' "Lagometer" is one of the modern type timing sets. It is a portable, robust instrument, designed for measuring short intervals of time such as relay operate and release lags. The principle employed is to charge a condenser through a resistance during the measured interval of time and then to measure

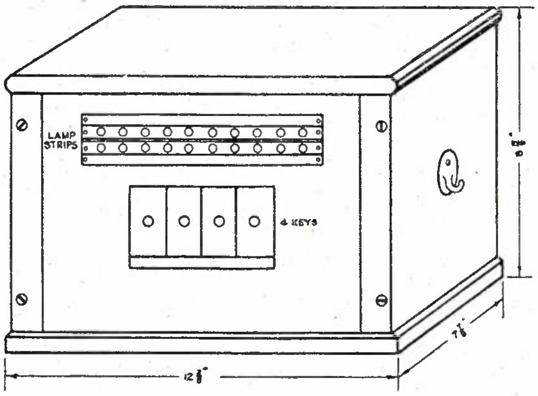

Fig. 1.

the voltage across the condenser by means of a galvanometer and potentiometer, the latter being varied until a balance is reached. In the standard instrument the potentiometer is fitted with a dial calibrated so that the time interval in milliseconds may be read direct. Other scale ranges may be up to 50, 500, and 1,000 milliseconds. In operation, tests are repeated while

Test Set No. 22. The Release Time Test Set No. 22, Drawing CE. 96 was designed primarily to provide a quick and economical means of measuring the release lag of B relays associated with group selectors, final selectors, repeaters, etc., in Automatic exchanges.

The Test Set is enclosed in a portable wooden cabinet $12\frac{3}{8}$" x $8\frac{5}{8}$" x $7\frac{7}{8}$". (See Fig. 1.) The front of the cabinet, to which a horizontal sub-panel is fixed, may be removed by withdrawing four lock screws from the face of the cabinet, making all components readily accessible. The lid is hinged at the rear. Fitted to the face of the cabinet are two strips of 10 lamp sockets and four vertical lever keys, and on the sub-panel, relays, uniselectors, etc., are mounted.

The method employed in the test set is to rotate uniselector wipers over the associated bank contacts at the rate of 60 revolutions per minute during the interval of time being measured. This is accomplished by completing the drive circuit of the testing uniselector over the private of a switch earthed by the "B" relay under test. On restoring, the "B" relay contacts open the drive circuit and the time in milliseconds is directly indicated by lamps. Release times between 20 and 980 milliseconds may be measured

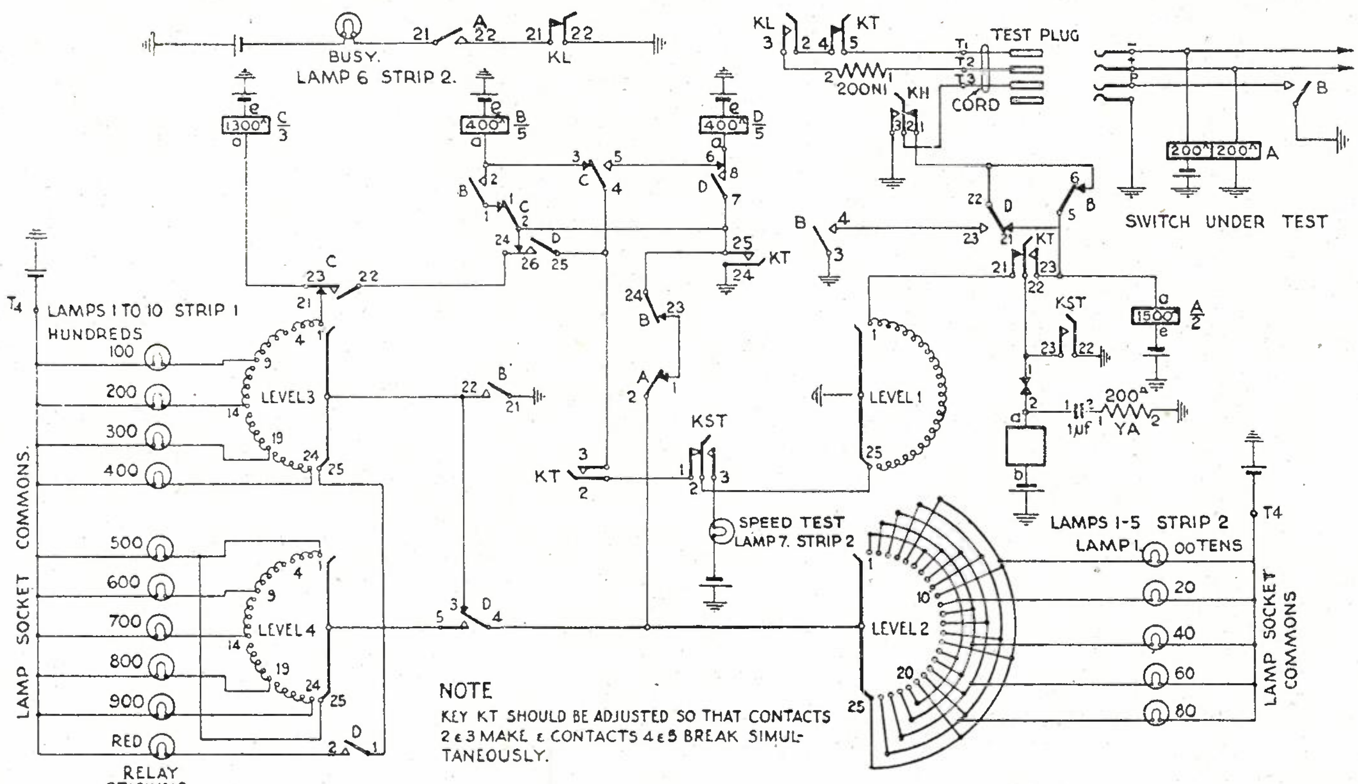

Fig. 2.

the potentiometer dial is adjusted for no deflection in the galvanometer. The time interval may then be read direct on the dial. The instrument is designed for 50 ± 8 volt working.

in 20 m.s. steps. Should a relay exceed this time the "Relay sticking" indicator lamp (red) lights.

Referring to Fig. 2 the method of testing the release time of a "B" relay associated with a bimotional switch or a repeater is:—

(a) With all test keys normal, connect the test plug associated with the test set to the test jack of the switch under test. If the switch is busy, relay "A" will operate. A 21-22 complete the circuit for the busy lamp, indicating that the switch under test is busy. A 1-2 is not required at this stage.

(b) If the switch is disengaged, operate the loop key, KL. KL. springs 2-3 close the circuit for relay A of the switch under test via the test plug and 200 ohms N.I. resistance. Relays "A" and "B" in the switch under test operate and earth is returned over the "P" wire of the test circuit. KL. 21-22 open the busy lamp circuit.

(c) Relay "A" in the test set operates via the earthed Private. A 1-2 disconnects earth from the indicator lamps during rotation of the wipers. For operation of A 21-22, see (a).

(d) Operate the Test Key, KT. KT. 2-3 close the circuit of relay B to earth at wiper level 1. KT. 4-5 open the loop circuit to the switch under test. Relay "A" of the switch under test restores and opens the circuit of relay "B" which restores after a time lag. KT. 22-23 close the circuit of the drive magnet to earth at relay "B" of the switch under test. The uniselector commences to step. KT. 24-25 prepare locking circuits for relays B, C and D.

(e) Relay "B" operates and locks to earth via KT. B 1-2 close its locking circuit via C 1-2 and KT. 24-25. B 3-4 prepare an earth circuit for busying the switch under test after completion of the test. B 5-6 remove the shunt from D 21-22. B 21-22 connect earth to wiper 3. B 23-24 disconnect earth from uniselector wipers in the "Relay sticking" position.

(f) When wiper 3 reaches Contact 1, level 3, relay "C" operates to earth at B 21-22 and locks up via C 22-23 operated, D 24-26 normal, to earth at KT. 24-25. C 1-2 open the circuit of relay "B" which restores. C 4-5 prepares the circuit of relay "D."

(g) If the earth be removed from the Private of the switch due to the "B" relay under test restoring within the time taken for the wipers to traverse 25 bank contacts ($25 \times 20 = 500$ milliseconds) relay "A" in the test set restores and the uniselector stops rotating. A 1-2 normal, close the circuit for the indicator lamps via wipers 2 and 3 and the release lag time is shown by the particular indicator lamps glowing. For example, if the uniselector wipers stop on Contact 14, the 200 millisecond and the 80 millisecond lamps will glow, indicating that the release lag time of the "B" relay under test is 280 milliseconds.

(h) Relay "D" operates. Should the uniselector wipers reach the 25th contact before the relay "B" under test restores, relay "D" operates via D 6-8, C 4-5 operated, KT. 2-3, KST. 1-2, contact 25 level 1, to earth at wiper 1. Relay "D" locks via D 7-8, to earth at KT. 24-25. D 1-2 prepares the "Relay sticking" indicator lamp circuit. D 4-5 switch earth from wiper 3 to wiper 4 for the indicator lamps (500 to 900). D 22-23 prepare the switch busying circuit. D 25-26 transfer the locking circuit of relay "C" from earth on KT. 24-25 to earth on wiper 1 via the 25th contact to prevent "C" restoring should the wipers stop on contact 25, first round.

(i) If the armature of the "B" relay under test fails to restore within one second, the uniselector wipers rotate to contact 25 (second round), relay "B" in the test set re-operates and B 5-6 open the drive magnet circuit. The "Relay sticking" lamp lights. Earth is connected to the Private to prevent seizure of the switch under test should adjustments be necessary.

(j) Restore the test key KT. All relays restore and the drive magnet circuit is completed via level 1 and wiper to earth. The uniselector wipers are rotated to contact 25 (home position).

The uniselector should be adjusted to rotate at 60 r.p.m. to enable wipers to pass contacts at the rate of 20 milliseconds per contact. To check the speed, operate the Speed Test Key, KST. and count the flashes, two per revolution, on the Speed Test lamp, as wiper 1 passes contact 25. Where difficulty is experienced in detecting the flash, a 24 volt lamp has proved satisfactory.

A Hold Key, KH., is provided to busy the switch at any time during test. The operation of KH. disconnects the timing circuit and connects earth to the Private.

The test set may be used to measure operate lags by arranging a break contact unit to disconnect earth from the Private on operation of the relay.

Where a contact unit is fitted to re-apply a guard earth on the private wire during switch restoration, the contact should be insulated.

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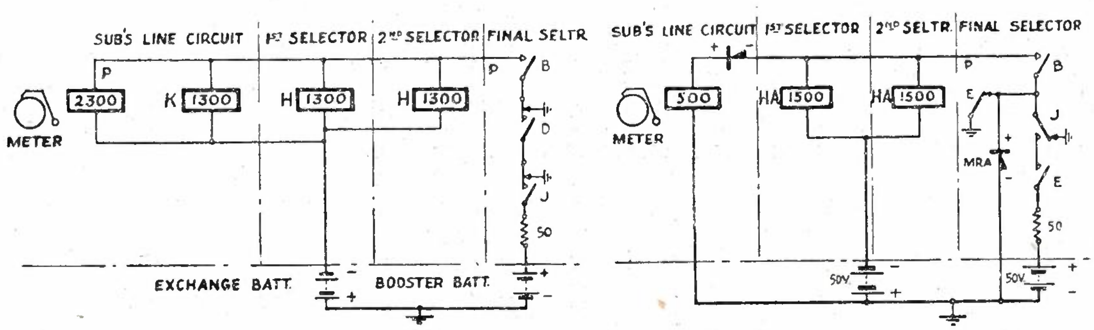
POSITIVE BATTERY METERING

W. B. Wicking

With the advent of 2000 type automatic equipment in exchanges in the Commonwealth, a change in the method of operating subscribers' meters was introduced. The new system, known as the Positive Battery System, is not very different from the Booster Battery system from which it has been evolved. A rectifier is an essential part of the circuit and the development of the dry plate rectifier in a form suitable for use in circuit design, contributed largely to the practical development of the system.

The metering schemes employed prior to the introduction of 2000 type equipment included the use of a double-wound polarised meter which operated on the reversal of the line current in one winding of the meter, and a modification of this system, using a polarised relay in the line circuit to operate one winding of a 1300 ohm meter in a local circuit. Both of these methods were displaced by the booster battery system in the latter pre 2000 type exchanges, and booster metering is now in its turn being displaced by positive battery metering. Because of the similarity of certain features in these two last-mentioned systems, it will be useful to draw comparisons between them from time to time, and for this purpose schematic diagrams of the two systems, showing the conditions during the metering pulse, are shown in Fig. 1.



Booster Battery Metering Circuit. Positive Battery Metering Circuit.

Fig. 1.

From an examination of the circuits shown in Fig. 1, it will be seen that both systems actually provide for the application of a pulse of positive battery to operate the meter. In each case the meters are connected to the release trunk; in the booster system directly and in the positive battery system via the rectifier MRA. Both circuits provide the metering pulse during the release lag of J relay in the Final Selector, i.e., for approximately 300 milliseconds. The principal difference is that no current normally flows in the meter in the positive battery system because of the rectifier MRA, and consequently the meter operates only during the positive battery pulse and releases immediately it ceases, whereas in the booster system the meter once operated remains held until the conversation is completed and the switches are released. The operation of the meter only during the meter pulse has the advantage that it permits multiple metering by arranging for the desired number of positive battery pulses to be applied by the Final Selector. Irregular metering, due to the called subscriber operating his switch hook, is safely guarded against by the release of the J relay in the Final Selector. An additional interesting feature is the provision of a rectifier in the final selector to provide a holding ground on the release trunk for the HA relays in the group selectors thereby permitting the use of an ordinary change-over instead of a make before break springset on the J relay, and at the same time obviating the momentary short circuiting of the meter battery which occurs with booster metering.

As would be expected, the battery provided for metering is the same for positive battery as for booster metering exchanges, and in each case a 50V. battery of small capacity glass type secondary cells is used, the negative pole being earthed. The charging arrangements are also

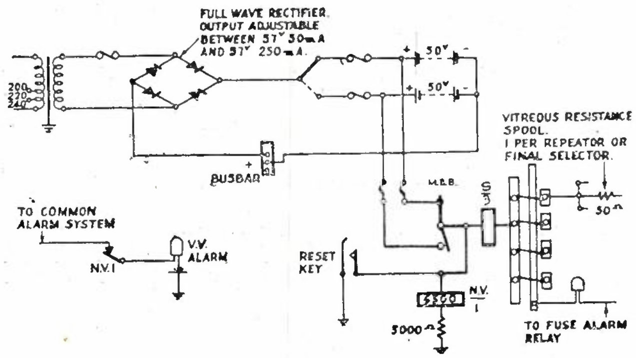


Fig. 2.

similar in the two systems, the battery being floated across a small dry plate rectifier directly connected to the public supply, or alternatively, charged from the main battery. The charging arrangements are generally in accordance with those shown in Drawing C.486, but the distribution arrangements vary slightly in 2000 type exchanges to conform to the local distribution and alarm system. Fig. 2 shows a typical arrangement. In this instance two batteries are employed, with facilities for charging or discharging either battery as desired. In many instances only one battery is provided. To safeguard against failure of the booster battery the 6500 ohm no voltage relay is included in the circuit. This relay is normally held, and releases only when the voltage drops below a safe margin, its release introducing an audible and visible alarm.

Although in some instances cells of larger capacity have been installed, the capacity of the positive battery is usually 10 A.H. at the 50 hour rate. The cells are specially designed with thick electrodes to give a discharge at low rates over a long period. The charging rectifier is also of low output, usually 250 mA. This combination of 10 A.H. cells and rectifier has proved very satisfactory, and although the capacity of the cells may at first sight appear low, actually the battery provides a safe margin over the normal requirements of even large exchanges as a reserve against failure of the public electric supply.

The approximate positive battery requirements for a main exchange of 5000 subscribers are as follows, based on a calling rate of .05 TU. per line, a holding time of 2 minutes per call, and with a ratio of busy hour to daily load of 1 : 7—

Total originating busy hour traffic = 5000 × .05 = 250 TU.

Total number of busy hour calls = (250 × 60)/2 = 7500.

Daily calls = 7 × 7500 = 52,500.

Total time occupied daily by meter pulses, assuming duration of each pulse period is 300 milliseconds:—

$$\frac{52500}{3600} \times \frac{300}{1000} \text{ hrs.} = 4.375\text{, say } 4.5 \text{ hours.}$$

The meter has a resistance of 500 ohms, therefore the current drawn from the positive battery to operate it is approximately:—

$$\frac{50\text{ V}}{500\Omega} = 100 \text{ mA.}$$

but additional current is taken by the holding relays in the selector circuits due to the boosting effect of the positive battery. The additional current required for this purpose will depend on the average number of group selectors employed in the connection. Assuming an average of two selectors, the additional current is approximately 100 mA. The total positive battery drain per meter registration, therefore, is 200 mA. and the daily battery drain will therefore be:—

$$\frac{4.5 \times 200}{1000} = .9\text{, say 1 ampere hour.}$$

On this basis the positive battery capacity of 10 A.H. would be sufficient to meet the requirements of this exchange for a period of 10 days. For a larger exchange the reserve period would be correspondingly shortened, but the main battery reserve is usually sufficient for approximately 24 hours, and no benefit is gained by providing positive battery reserve greatly exceeding that of the main battery. It will be appreciated from the foregoing that even in the largest exchanges a 10 A.H. battery should be ample. As a matter of interest, the positive battery discharge in one of our busiest main exchanges averaged 3 A.H. per day, when observed over a period of several weeks. The number of lines connected was in the vicinity of 7000 and the busy hour calling rate about 0.1 TU. per line.

Another feature which must be taken into consideration, particularly in connection with the distributing arrangements for the meter pulse, is the number of meter operations likely to occur simultaneously in any group. This is important, as, should the number be large, the potential drop within the distribution system might be sufficient to cause failure of the meters. Normally a 50 ohm limiting resistance is connected in series with the positive battery lead to each group of final selectors and repeaters, so that a short circuit occurring in one group will not impose a drain on the battery sufficient to cause failure of metering in other groups. These resistances are of the vitreous type and are usually supplied on the basis of 1 per rack, but in some instances the provision is 1 per shelf, and for repeaters 1 per switch. The inclusion of this safeguard for groups of switches introduces the possibility of the positive battery voltage available to a group being reduced by varying amounts due to the 1 R drop in the 50 ohm resistance should two or more meters in the group served by a particular resistance operate simultaneously. For 1, 2, 3, etc., meters operating simultaneously, the drop in volts would be approximately = 10 V, 16 V and 24 V, respectively.

It will be appreciated, therefore, that should more than two simultaneous registrations occur in a group, operation of meters would probably become unreliable.

The probability of simultaneous registrations occurring is remote, as will be seen from the following:—Taking the busy hour calls at 7500, and the duration of the meter pulse at 300 milliseconds. The total meter pulse traffic for the exchange is:—

$$\frac{7500}{3600} \times \frac{300}{1000} = .6 \text{ meter pulse hours during the}$$

busy hour. Assuming that 25% of this traffic terminates locally and that 200 line final selectors are used, the actual time of meter pulsing to each group of final selectors would be:—

$$\frac{.6}{4 \times 25} = .006 \text{ pulse hours.}$$

This represents the occupation time of one positive battery lead, and is equivalent to an occupancy of 22 seconds in the busy hour. It may be compared to traffic offered to a trunk group comprising a single trunk, which from standard tables will carry a traffic of .005 TU. with a loss of 1 in 200. In view of the similar conditions prevailing in the positive battery lead to those contemplated in connection with the single trunk, it will be appreciated that the probability of two registrations occurring simultaneously in any 200 line group is remote, while for practical purposes the occurrence of 3 or more simultaneous registrations may be completely disregarded.

AUXILIARY GROUPS OF FINAL SELECTORS IN UNIT TYPE AUTOMATIC EXCHANGES

A. W. Emery

The disappearance of the normal margin of exchange capacity through interruption of supplies of line units has naturally given rise to some problems. One of these is how to make use of the full uniselector capacity of exchanges using line and final units without having recourse to the very objectionable practice of re-allotting the numbers of cancelled services which are listed in the current Directory. This difficulty is, of course, brought about by the local and the multiple capacity of this type of exchange being identical — an important distinction between it and exchanges in which the line switches and final selectors are mounted on separate racks, thus facilitating the provision of a margin of multiple over local capacity. It is a matter for some regret that when C.B. multiple exchanges with their comfortable margin of multiple capacity were replaced by unit type automatic equipment this admirable feature was dropped. Fortunately the case for these exchanges is not hopeless, and the object of this article is to describe the method adopted for meeting these conditions in the Adelaide Network. The first exchange dealt with was Glenelg, in which there are 18 line units and where the need for an additional unit was very pressing. West Adelaide with 25 units was another similar case, and in each of these exchanges an auxiliary unit (see Fig. 1) was installed. These units, which are similar in dimensions to a line and final unit, were fabricated locally and mount one shelf of final selectors, 6 or 7 plates of No. 10 subscribers' registers with wiring for 10, and terminal blocks for the bank multiple and M.F. cables, and for tie cables running to the line unit suites.

The uniselectors thrown spare by disconnections still in the directory are jumpered to the other end of these tie cables and also to the multiple on the auxiliary unit, which was given the number of the next unit to be installed. It was thus possible to allot new numbers up to the total uniselectors available. The multiple capacity has thus been increased by 100. In large exchanges where the aggregate of numbers thrown spare during the currency of a directory through disconnections and removals to other

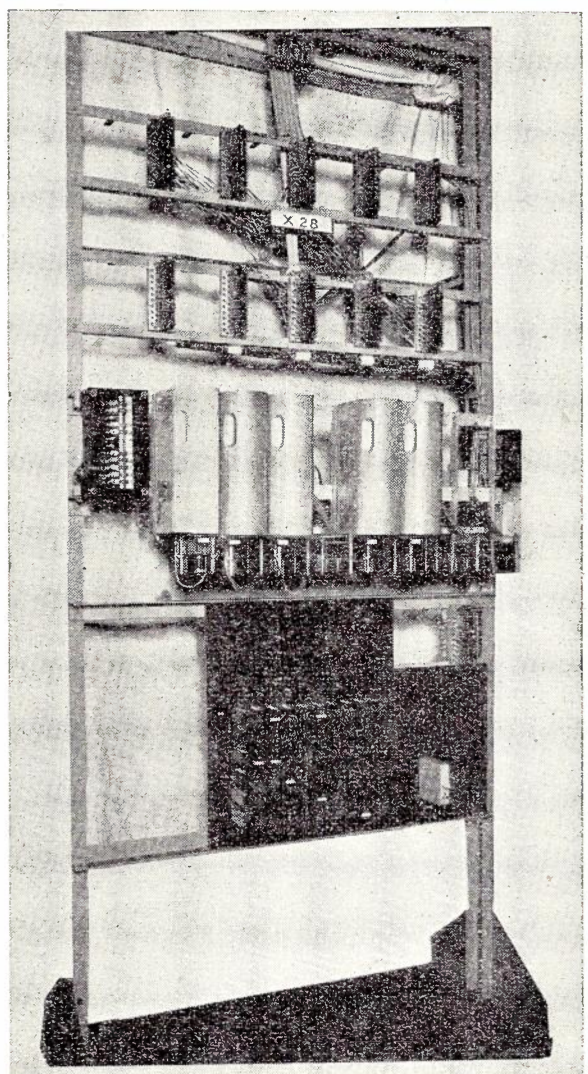


Fig. 1.—Glenelg Exchange Auxiliary Final Selector Unit.

areas normally exceeds 100, two or more auxiliary units could be used. The M.F. cables for these units were terminated at a distance from the last ordinary unit to avoid hampering development, and as each additional line unit is installed the auxiliary will take a new unit number and the subscribers on it will be rejumpered to the extension. With the issue of each directory a fresh lot of disconnected numbers is made available for allotment, and as these are allotted they are "straight" jumpered to their normal uniselectors after the auxiliary numbers using them have been rejumpered to others just thrown spare.

When all the straight line units in an exchange are fully allotted it becomes necessary to encroach on P.B.X. unit numbers if no extension equipment is available. Street P.T.'s and other silent lines easily changed are usually connected to spare circuits on P.B.X. units, but especially in a business or industrial area where several P.B.X. units are installed these are not sufficient to utilise available spares and numbers which should be reserved for new P.B.X. groups or extension of existing ones have to be allotted to straight line subscribers. The existence of an auxiliary unit enables these spare uniselectors to be used without allotting the P.B.X. numbers.

For economy reasons auxiliary groups of final selectors have been installed without special racks in some other exchanges. For example, at Norwood a selector repeater shelf was mounted on a spare selector trunk board and adapted to final selector wiring. Group selector banks with the normal grading terminals were used and jumpered to the terminal strips of tie cables run to the T.D.F., whence existing tie cables run to each line unit suite. In two other cases use was made of the alternative shelves for multiple splitting on P.B.X. line units, to mount the auxiliary finals. These alternatives are only regarded, however, as war-time expedients.

Although this general method of slightly increasing exchange multiple capacity has been adopted to meet war-time restrictions, there appears to be a permanent field of usefulness for it. While there is no need to resort to it in an exchange with a working margin of spare circuits, it will be seen that it enables the installation of further line units to be deferred until the exchange is almost 100 per cent. full.

From the point of view of the subscriber, especially the business man who may have his number displayed on premises and vehicles and printed on letterheads and leaflets, there are very sound objections to having this number changed. If circumstances necessitate the temporary withdrawal of line units from exchanges, the number changes previously regarded as unavoidable can be avoided by the installation of auxiliary groups of final selectors taking the numbers of the units withdrawn and providing a means as already described of jumpering from spare uniselectors scattered around the exchange. For this purpose the cables from the auxiliary group to the M.D.F. are connected to the same terminals as the unit withdrawn, thus avoiding disturbance of M.D.F. jumpering.

Another aspect which may have increasing importance is that the auxiliary group method enables available units to be withdrawn without regard to the issue of the Directory, and as future issues during the war period may become less frequent while the need for withdrawals may increase, this may conceivably dictate its adoption.

CALL FEE INDICATORS: MELBOURNE TRUNK EXCHANGE

A. J. Linton

To keep in step with recent developments, whereby automatic switching and Voice Frequency signalling equipment are associated with Trunk line operating, it became necessary to design a Time Check to give independent operation in each switching circuit and with a control mechanism small enough to fit into the keyshelf space for such circuit. It was also apparent that there were many other desirable features which had not previously been met. A Time Check developed jointly by the B.P.O. and the Automatic Telephone and Electric Company, known as the B.P.O. Clock No. 44, now fulfils modern requirements, and it is proposed in this article to describe the clock and associated equipment as installed at the Melbourne Trunk Exchange.

B.P.O. Clock No. 44. — The Time Check is shown from two elevations in Fig. 1. The proing circuit is connected to a looped line, and stops when the calling subscriber restores the receiver. In the normal position the clock displays the figures 9.9, so that the first impulse changes the reading to zero (0.0 mins.) and subsequent impulses, received at the rate of one per 6 seconds, are recorded by the rotation of the drums. The right-hand drum moves a step at each impulse and the left-hand drum is engaged and moved a step each tenth impulse; therefore, as 6 seconds is 1/10th part of a minute, the reading represents minutes and decimal parts thereof. The maximum reading of the clock is 9 minutes; therefore it is necessary to reset the clock to time calls of greater duration. The reset is instantaneous at the convenience of the operator. Accidental resetting during the progress of a call is safeguarded by the construction of the start and reset key assembly which requires the control key to be turned to the stop position before the reset key may be operated. The time check is designed for mounting with the face plate in a horizontal position on the switchboard keyshelf. The space occupied, $2\frac{1}{8}''$ x $1\frac{1}{8}''$, is identical with the standard key plate. This permits it to be mounted as an integral unit with the operator's speak key, and therefore directly associated with the connecting circuit on which it is operated. In Fig. 2, the clock and its connections are shown, the cams and indicator drums being extended to show the relationship between the name and numerals.

Time Check Operation.—A through connection having been established, the relevant "Time Check" start key is operated, thereby connecting the time check magnet via contact AS.1/2 of the answering supervisory relay (not shown) and SP.23/24 to the 6-second pulse lead. The time check records 1/10th minute each time its

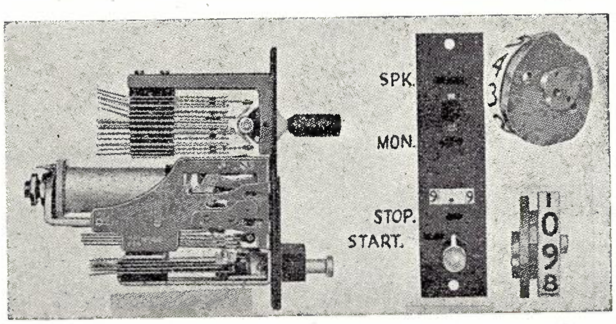


Fig. 1.

gressive duration of a call in minutes and tenths of minutes is indicated on the left and right-hand numerals respectively. Operation of the time check commences when the start key is operated and the answering side of the connect-magnet is energised by the 6-second pulse.

At 2.8 minutes the time check spring sets are operated by cams as indicated by the circuit, consequently the time check lamp lights and a circuit is completed for relay TC via the "Pip-Pip" control. The "Pip-Pip" control contact closes for three periods of approximately 150 m.s. during the 3 seconds immediately following the 6-second pulse. Relay TC responds thereto and its contacts connect 900 cycle tone to the line wires to announce the approaching completion of 3 minutes' conversation.

At 2.9 minutes the 1/10th minute springset disconnects the circuit of TC, but retains the lamp circuit. At 3.0 minutes the lamp is extinguished. At 5.8-6.0 minutes and 8.8-9.0 minutes the foregoing is repeated. At 9.0 minutes, however, both springsets rest on the lower part of the cams and complete a circuit for relay SP via the time check lamp. Relay SP completes a holding circuit for itself, disconnects the time check magnet circuit and connects the time check lamp to "flicker earth." Further timing of the call depends upon the resetting of the time check by the operator, by which action relay SP is released and the time check functions for a further period, as previously described. It should be noted that the time check ceases to function when the answering supervisory relay releases consequent upon receipt of a clearing supervisory signal. The 1000 ohm shunt across contact AS.1/2 prevents any possibility of false timing should the contact flick.

The time check driving magnet is wound to a resistance of 800 ohms and requires a minimum of 44 m.As. for satisfactory operation. The movement of the drums is of the "reverse" action principle, i.e., by the release action of the armature. A ratchet wheel is attached to each drum and the armature is fitted with two pawls; one engages with the ratchet of the 1/10th minute drum, whilst the second pawl is permitted to engage with the minute drum only upon the completion of each ninth impulse. The tenth impulse rotates both drums. Also attached to each drum are two sets of cams, one of phosphor bronze and one of steel. The former is used to control springsets which effect circuit changes as required, whilst the second set of cams seen in Fig. 1 as making a "heart-shaped" pair, is used to return the clock indicators to the normal position.

In resetting the clock, the start key is first returned to normal, and when the reset key is depressed the operating pawls, ratchet, and cam springs are lifted clear, and an X-shaped lever engages the heart-shaped cams and drives the display drums to normal. They may be returned from any display and move either forward or backward, whichever is the shorter distance. This instantaneous mechanical resetting action is a most ingenious feature of the B.P.O. Clock No. 44 and is accomplished by pressure applied to any portion of the periphery of the heart-shaped cam, which accounts for its peculiar shape and its construction of steel. The start key or indicator mechanism may be removed separately, which is required for maintenance purposes. As the time check should be quite silent in operation, a leather disc is fitted to the pole face, which effectually softens the blow at armature operation. The auxiliary springs of the start key are for use in subsidiary circuits if required, such as "Tone Machine Start" leads, etc., or for use on sleeve control circuits.

As there are more than 500 time checks installed at this exchange, special equipment is necessary to provide for the generation and

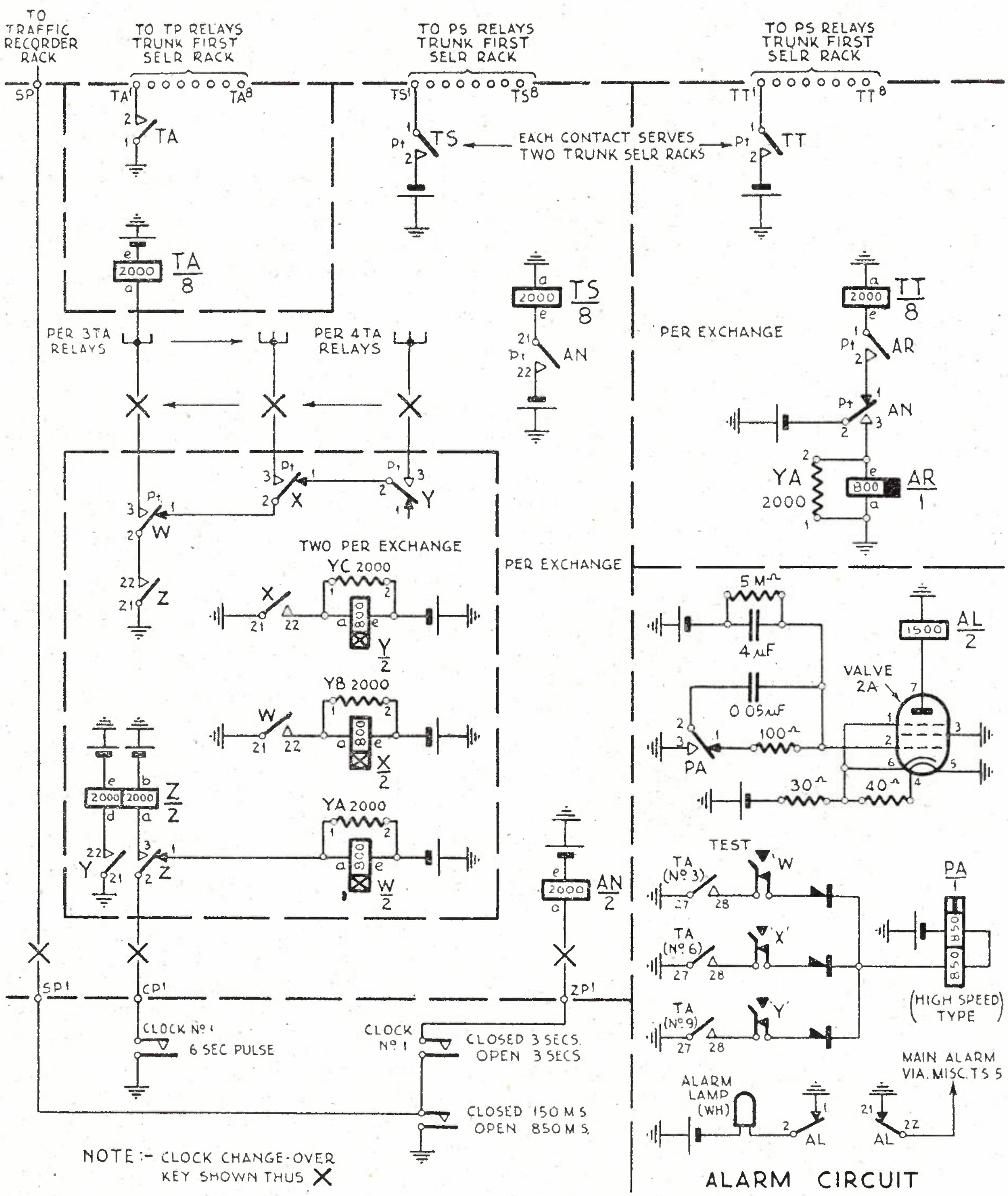


Fig. 3.

Pulse Alarm Circuit.

distribution of the pulses necessary to step the time checks and provide signal tones at the appropriate time. Pulse production is effected by a master clock designated B.P.O. Clock No. 46 and the pulses are distributed by sets of relays. With the exception of relays directly associated with the position circuits, this equipment is installed in duplicate.

Master Clock B.P.O. No. 46. — The master

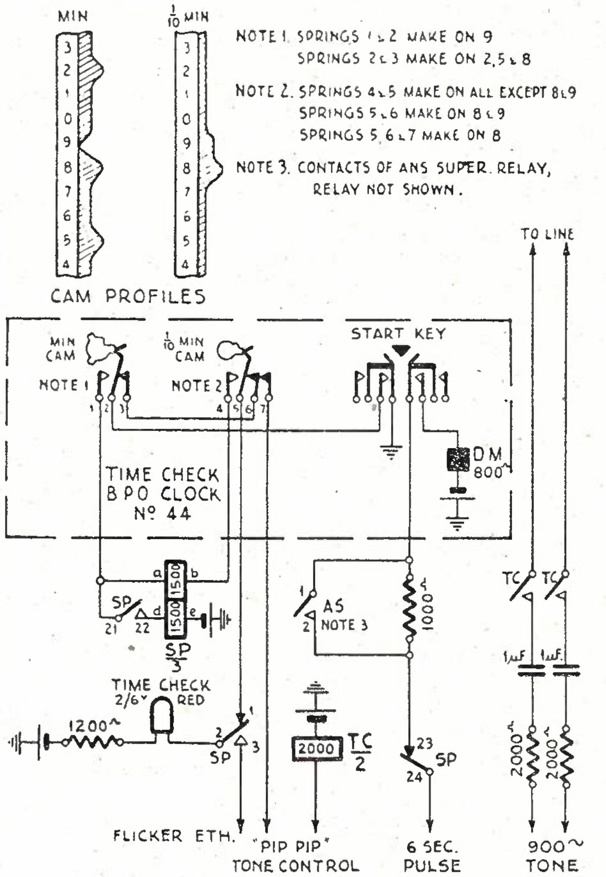


Fig. 2.

clock is essentially a producer of accurately timed impulses. It is pendulum controlled and electrically operated from the 50-volt exchange supply. The pulses produced are:—

(i) A pulse of 500 milliseconds every 6 seconds.

(ii) The "Pip-Pip" pulse of 150 milliseconds produced each second for the 3 seconds immediately following the 6-second pulse.

(iii) A pulse of 150 m.s. each second which is used for traffic recording purposes only.

Distribution Relays. — These are provided to distribute the pulses so as to smooth out the battery load and avoid simultaneous operation of the time checks in use. This system also reduces switch-room noise. The arrangement of the relays is shown in Fig. 3, from which it will be seen that the 6-second pulse generated by the master clock is used to operate a group of relays W.X.Y and Z which divide the 500 m.s. pulse into three parts, each of which operates consecutively a group of TA relays. In all, there are 10 TA relays, each of which is fitted with eight "make" springsets, each of which controls the operation of a relay TP associated with the operating position equipment. When circuit conditions are appropriate, the springsets of TP relays complete the circuit for the driving magnets of the time checks. The relay AN repeats the "Pip-Pip" pulse to relay TS, the contacts of which operate relays PS in the position equipment. Relay PS prepares the circuit of relay TC in the trunk connecting circuit which, when required, i.e., when the time check reads either 2.8, 5.8 or 8.8 minutes, injects into the connecting circuit 3 "pips" of 900 p.p.s., as a signal tone, to warn the caller of the approaching expiry of unit fee time.

Pulse Alarm Circuit. — As the time pulse distribution is of importance in the recording of the pay time of trunk conversations, an alarm circuit has been devised to indicate failure of distribution. The components used in the circuit, inset in Fig. 3, are:—Pentode valve (Mullard 36C), a standard 3000 type relay, a Siemens High Speed relay 85F, two condensers and a 5 megohm resistor. The earth pulses from the three groups of distributing relays are equally spaced, therefore the high-speed relay PA has three distinct operating and releasing cycles during each 6-second impulse generated by the master clock. Relay PA operating, charges the 0.05 μF limiting condenser, also partially charging the 4μF reservoir condenser, which places a positive potential on the grid element of the valve, which would produce plate current flow to operate relay AL. When PA releases, its contacts place the 100 ohms shunt across the 0.05 μF condenser and a second operation builds up the positive potential on the grid. Three successive operating cycles of PA accumulate a charge of such value on the 4μF condenser that relay AL will remain operated during the interval between the 6-second pulses. During this time the 5 megohm resistor tends to discharge the reservoir condenser and restore negative bias to the grid circuit. Should either of the W.X.Y. distributing relay pulses fail, the 4μF condenser will not be sufficiently charged, thereby allowing relay AL to release. In the event of a fault condition holding a TA relay, the "leak" across the reservoir condenser again "swings" the grid to negative and relay AL releases. The release of AL completes a local alarm lamp circuit and also operates the exchange alarm system.

Keys of the "push-button" type provide for a regular maintenance routine; the operation of any key simulates a fault condition. The alarm circuit can be tested periodically thereby.

NEW MELBOURNE TRUNK EXCHANGE: THE TRAFFIC ASPECT

R. Moore

In order that the traffic problems associated with the establishment of the new Melbourne Trunk Exchange may be appreciated, it is necessary to consider the relative locations of the old Trunk Exchange and the new.

The new exchange is on the 4th and 5th floors of the City West building—the switchboards on the 5th floor controlling the automatic apparatus on the 4th floor. The old Trunk exchange consisted of two exchange rooms located on the 1st and 2nd floors of the Central Exchange building, which sits back to back with the City West building. The 1st floor contained 40 trunk (delay) positions accommodating about 200 two-way trunk lines, 9 Trunk Recording positions and the Trunk Inquiry positions. A suite of 26 Demand positions (Combined Line and Recording) accommodating about 100 one-way trunks was installed on the 2nd floor. Calls to country and interstate exchanges served by the delay positions on the 1st floor were booked on the Trunk Recording positions (dialling code M.071). Subscribers dialled M.076 for a demand service to 36 country exchanges connected to the Demand (C.L.R.) positions. Service from the largest of the country exchanges to Melbourne was obtained via direct dialling lines (80) and/or one-way trunks terminating on special "In" positions (40) or a Trunk "B" position (20), which were also situated on the 2nd floor. A multiple appearance of certain Demand trunks on the Delay positions and junctions between the two exchange rooms provided for the connection of Through calls.

The Interstate Cutover.—The first section of the new Melbourne Trunk Exchange was established on Monday, 2nd September, 1940, when 40 Interstate trunk lines were transferred to the new Interstate suite of 18 positions (subsequently increased to 24).

From a traffic point of view, the major considerations prior to the cutover were:—

(a) To provide adequate communication between the new Interstate suite and the intrastate trunk lines in the old Country Trunk Exchange;

(b) To extend the Trunk Inquiry service to the new exchange;

(c) To provide facilities for transferring trunk line dockets between the old Country Trunk Exchange and the new;

(d) To select and train the operating staff and supervisory officers.

Access to the trunk multiple of intrastate trunks was provided by 14 junctions from the Interstate suite via trunk selectors and terminating on two specially equipped trunk positions in the old Country Trunk Exchange. These were designated the "980" positions as Interstate telephonists obtained access to the special junctions by punching up "980" on the key strip. Because of the inability of a telephonist on the "980" positions to originate calls back to individual Interstate trunk positions, connections from the Interstate positions to the "980" positions were held intact until a trunk line to the required country exchange had been secured. In order to facilitate the disposal of Interstate trunk line calls extended to country districts, Interstate telephonists were given priority on intrastate trunks. Arrangements were made, therefore, for the telephonists on the "980" positions to effect connections to intrastate trunks on Demand wherever possible. Where this was not practicable, the first free line to the required country exchange was made available to the Interstate telephonist. Connections were established on a 4-wire basis wherever practicable.

A comprehensive survey of the Trunk Inquiry traffic was made. Neither the new Trunk Inquiry positions installed in the new exchange room nor the old Trunk Inquiry positions which were located in the old Country Trunk Exchange could be adapted to meet the new conditions. An analysis of the traffic showed that slightly more than 50% of the normal Trunk Inquiry traffic could be completed to finality within the new exchange room and, having regard to requirements when the new intrastate trunk positions were cut into service, a new Trunk Inquiry system was devised. A suite of six operating positions was installed temporarily in the new exchange room. Junctions and order wires were provided from the positions to subsidiary posts in each of the three exchange rooms. The positions and subsidiary posts were made in the Departmental Workshops. The Trunk Inquiry suite is mainly a filtering point and in most cases the calling subscriber is connected to a further point at which the inquiry is finalised.

In order to facilitate the transfer of trunk dockets between the old Country Exchange (1st floor) and the Interstate positions, a carrier tube was installed between the two buildings. This tube was partly constructed from an old disused tube system which ran along the back of the "A" positions in Central Exchange to the Test Room. The installation was carried out by Standard Telephones & Cables Ltd., in conjunction with the larger installation on the 5th floor. The air supply is obtained from the blowers associated with the pneumatic tube system installed in the new Melbourne Trunk Exchange. A carrier loaded with trunk dockets travels between the exchanges in about 25 seconds. The direction of the air flow in the tube, viz., suction up and pressure down, is controlled from the 5th floor (see Fig. 8, Page 214, Vol. 3, No. 4) and the P.D.P. telephonist is careful not to operate the changeover switch whilst a carrier is in the tube —otherwise the carrier is ejected backwards with considerable noise.

The first steps in the staff training scheme were to write the operating instructions and to select and train a Training Class Supervisor. A training class itinerary was then prepared on the basis of an initial period of one week's instruction with a subsequent period of two days. Further instruction was given wherever necessary in individual cases. About 100 telephonists and Monitors were trained in groups of eight, which is the maximum number that can be dealt with adequately for this type of instruction.

A training class switchboard for demonstration purposes was made in the Departmental Workshops. The keyshelf was a replica of the new Interstate positions. The lamp operation was provided by manipulating a series of plunger type keys with which the lamps could be made to flicker, flash, glow or extinguish as required. It was a most ingenious contrivance and with its aid the operating staff learned to operate the Interstate switchboards. Later on, when battery was available on the new Interstate positions, a few Interstate trunk lines were connected temporarily each day and traffic was connected under actual working conditions.

The requisite operating instructions were issued to all other staffs concerned, including those at country exchanges, Metropolitan manual exchanges and the old Country Trunk Exchange.

A review of the notes concerning the miscellaneous matters shows that they are too numerous to explain at length. Suffice it to say that traffic requirements were studied and an intercommunication system linking up the new exchange and the old was devised; miscellaneous equipment, including Suspense, Pricing, Directory and Traffic Officers' tables, a Routing position, a Suspense position, a Delay post and two Monitor posts, were designed, built and installed; furnishings and fittings for a Lounge Room, Dining Room and Sick Bay were bought; a Cafeteria was opened; a new Sortergraf, telephonists' chairs, head and breast sets, lockers and 17 exchange clocks were obtained; a rotary index for the Routing position was purchased and more than 3000 cards were typed; notices were prepared for bulletin panels; a fire alarm system was installed and fire drill rehearsed; routine tests to be performed by telephonists and a fault recording procedure were devised; the lessees of T.L. lines were advised that T.L. lines (which terminated in the old Country Trunk Exchange) would not be available for Interstate calls; groups of automatic exchange lines were installed at Attended Pay Stations to replace manual junctions; the Trunk Inquiry staff was trained; staff rotas were drawn and the personnel allotted to shifts.

The technical arrangements were so perfected and the operating staff so well versed in their training that the cutover was commenced at 7.30 on a Monday morning and completed by 8 a.m. At 9.30 a.m. the new Interstate suite was carrying a full load of traffic. The new temporary Trunk Inquiry system had been established a week before.

Plans for the Intrastate Cutover.—The possibility of transferring the whole of the intrastate trunks to the new exchange in one cutover was contemplated. Owing mainly to the difficulty of ensuring that mechanics with the requisite technical experience would be in attendance at all Group Centres on the date of the cutover the idea was dropped in favour of a partial cutover.

Having regard to the installation difficulties and to traffic requirements, plans were made to—

(a) establish as Group Centres the exchanges served by the Demand (C.L.R.) positions (excepting Ballarat and Geelong, for which special equipment is being obtained);

(b) transfer the 20 Trunk Recording junctions (M.071) and the 60 demand service junctions (M.076) to the new equipment;

(c) retain Ballarat and Geelong trunks in situ until suitable accommodation could be made available on the 1st floor.

The principal problems from a traffic point of view in connection with the establishment of the Demand Section of the new Melbourne Trunk Exchange were—

(i) to provide adequate communication with the old Country Trunk Exchange;

(ii) to train the operating and supervisory staffs at Melbourne and at the selected country exchanges;

(iii) to plan effective terminations for V.F. trunk lines at country exchanges.

The method of completing trunk line calls between exchanges served by the old Country Trunk Exchange on the one hand and exchanges served by the new Melbourne Trunk Exchange on the other, was given a great deal of consideration. The obvious scheme was to continue the practice of obtaining access to the old Country Trunk Exchange multiple by means of special "980" junctions. This system was well tried during the previous year from the Interstate section of the new Melbourne Trunk Exchange. The "980" junctions are efficient and reliable and, when properly used and supervised, provide a speedy and effective service. A study of the traffic requirements, however, indicated that it would have been necessary to provide approximately 40 junctions to meet maximum requirements during the transition stages of the cutover. The provision of 40 "980" junctions would have necessitated utilising five trunk delay positions (with eight cord circuits per position) exclusively for inter-exchange communication.

A further scheme would have been to construct a two-position switchboard equipped with a trunk multiple and 40 cord circuits. The cost of a suitable switchboard with the requisite facilities would have amounted to about £600. It seemed unlikely that the switchboard would be adaptable for use elsewhere, and as the residual value would be small the loss would have been substantial.

Both these schemes would have involved transferring Through dockets from the old Country Trunk Exchange to the V.F. Through positions. When dockets are placed in the carrier to be sent via the pneumatic tube from the old exchange to the new they are curved into a semi-cylindrical shape. The "sail" of a docket treated in this way is creased and the docket is unsuitable for insertion in the rectangular-shaped tubes of the new Melbourne Trunk Exchange. Consequently, it would have been necessary to employ docket runners between the P.D.P. and the V.F. Through positions.

The plan adopted is more economical from the equipment and staffing viewpoints. Portion of the minor trunk equipment was used to provide junctions from the old Country Trunk Exchange to the V.F. Through positions. Three trunk line positions (T.31, T.32 and T.33), which are known as the Magneto Through positions, are equipped with a rotary group of seven automatic exchange lines, two miscellaneous service lines and 20 junctions to the V.F. Through positions. Dockets for all calls between exchanges served by the old Country Trunk Exchange and the Group Centres are transferred to the Magneto Through positions, which are charged with the responsibility of completing the calls. The "980" links are reserved for use exclusively from the Interstate positions except during slack hours (e.g., all-night duty and Sundays), when telephonists employed on the V.F. Through positions are allowed access to them.

The training class instruction was divided into two distinct phases—

(i) A study of the traffic plans;

(ii) Actual manipulation of the equipment.

Practically every telephonist in the State was affected by the traffic plans for this cutover, particularly as regards calls routed through Melbourne. Operating instructions were, therefore, written respecting the following:—

- Demand positions;
- V.F. Through positions;
- V.F. Suspense positions;
- The tube system and P.D.P.;
- The old Country Trunk Exchange;
- Magneto Through positions;
- Central Exchange;
- Manual branch exchanges;
- Country exchanges which would be established as Group Centres;
- Country exchanges which would not be cut over.

A training class switchboard similar to a Demand trunk position was built in the Workshops. The common key and lamp equipment and three connecting circuits are provided. The keyshelf is hinged in front for demonstration purposes and, as in the case of the Interstate training switchboard, the lamps are hand-operated. Advantage was also taken of slack hours on the Interstate positions to demonstrate the common key and lamp equipment which is similar to that installed on the Demand positions.

Approximately 100 Monitors and telephonists were trained prior to the cutover. The training was conducted on similar lines to those followed previously in connection with the Interstate cutover. In addition, about a dozen Traffic Officers and Supervisors were given detailed instruction.

In order to ensure that telephonists at Group Centres were adequately trained in the correct method of operating V.F. trunk lines and also that they should gain a proper appreciation of the facilities being provided in Melbourne, a Travelling Supervisor visited all the exchanges prior to the general cutover. At exchanges converted to V.F. working subsequent to the general cutover, the Travelling Supervisor has attended the exchange on the date of the cutover. The necessity for these visits is exemplified by the fact that in some of the more remote centres the telephonists had not seen a dial. The Travelling Supervisor attended the V.F. Through positions for a week after the cutover.

The trunk jack fields of standard magneto "A" positions and standard magneto trunk positions have somewhat limited space on the face of the boards and, as provision must be made for three jacks and two lamps for each appearance of a V.F. trunk line, it was necessary, on many occasions, to visit Group Centres in order to contrive a satisfactory rearrangement of the trunk lines. In some cases it was necessary to cut away the panel beneath the jack field to provide space for the Busy and Call lamps, whilst in others the space in the section occupied by the subscribers' jacks and/or indicators was used. Having regard to the jack space available on country switchboards, the V.F. terminations were arranged in the sequences shown in Table 1:—

(i) With 5 jack strips:

	Me.1	:	Me.2
Net jack	+	:	+
Out jack	+	:	+
Busy lamp	+	:	+
In jack	+	:	+
Call lamp	+	:	+

(ii) **With 3 jack strips:**

Me.1		:	Me.2	
Net	Spare	:		
+		:	+	
Out	In	:		
+	+	:	+	+
Busy	Call	:		
+	+	:	+	+

(iii) **With 2 jack strips:**

	Me.1		:		Me.2	
Net	Out	In	:			
+	+	+	:	+	+	+
Spare	Busy	Call	:			
	+	+	:		+	+

Table 1.—Terminations of 2-V.F. Trunks at Group Centres.

The principle followed was that V.F. trunks, dials and dial keys were within reach of each telephonist at a Group Centre. In many cases the layout of the trunk lines on positions and the internal Trunk to "A," "A" to Trunk, and "A" to "A" transfer junctions were completely recast in order to fit the facility to the best advantage within the jack space available. Drawings were made of the switchboards at Group Centres showing the required arrangement of the trunk terminations, and copies were sent to the Superintending Engineer for the guidance of the installation staffs.

In some of the smaller Group Centres it has not been practicable, owing to the limited building accommodation available, to place the V.F. equipment in a separate room. The noise made by the working of the V.F. equipment is irritating to the more temperamental telephonists, and it is placed in a separate room wherever possible.

One great advantage of the V.F. installations at the larger Group Centres is that a greater number of ancillary appearances of the Melbourne Trunks was possible. Under magneto conditions our traffic difficulties were accentuated at large exchanges owing to the limitation of the number of appearances of magneto trunks that could be successfully provided. At the Bendigo Exchange, which serves a large provincial centre, seven appearances of the V.F. trunk lines were installed and provide a flexible arrangement which enables a Demand service to be given from the whole of the operating positions.

A number of trunk lines from Melbourne to exchanges beyond certain Group Centres was cut at the appropriate Group Centre; the Melbourne Group Centre portion of the trunk being converted to V.F. working and the remaining portion of the line being used to augment the Group Centre Terminal exchange group of trunks. For example, the Melbourne-Maffra trunk was cut at Sale, thereby providing a third Melbourne-Sale V.F. trunk and a fourth Sale-Maffra Magneto trunk.

A comprehensive survey of the traffic to and from the Trunk Exchange was made and, in order that the best possible use could be made of the junctions available, an estimate on the following lines was prepared for the guidance of the installation staff:—

(a) The number of outgoing automatic junctions required as at the date of the cutover—
 (i) on the new equipment;
 (ii) from the Ballarat and Geelong positions;
 (iii) from the old Country Trunk Exchange;

(b) The number of junctions that could be released from the old Country Trunk Exchange and the Ballarat and Geelong positions for re-use on the new equipment at the date of the cutover; and

(c) The estimated traffic on outgoing automatic junctions when the transfer of the whole of the Group Centres to the new equipment is effected.

The preliminary wiring was done and a few days prior to the cutover a number of junctions was released and transferred to the new equipment. The loss of the junctions in the old Country Trunk Exchange was offset to a large extent by providing a number of the remaining outgoing junctions with ancillary appearances on the old demand (C.L.R.) positions and on the Trunk (delay) positions.

The Intrastate Cutover. — The cutover commenced at 1 p.m. on Saturday, 27th September, 1941, and 108 trunk lines were transferred to the new equipment that day. Seventy-eight (78) trunks were cut over on the following day. With 40 Interstate channels already being worked there, approximately one-half of the trunk lines terminating in the Melbourne Metropolitan area was then accommodated in the new Melbourne Trunk Exchange. Coincident with the cutover, the M.076 junctions and the M.071 (Trunk Lines) junctions were transferred to the new exchange and additional M.071 junctions cut into service.

The progressive cutover created minor traffic difficulties, but close supervision of the traffic and of the transfer of trunk line dockets obviated any interruptions or delays to trunk calls.

The new equipment brought into service is:—

Demand Positions	54
V.F. Through Positions	7
Suspense Positions	3
Monitor Posts	2*
Delay Supervisors' Positions	2
Pneumatic Distribution Position	1
Delay Post	1*
Demand "B" (B.10) Position	1
"Magneto" Through Positions	3

* Two-position posts.

The 54 Demand positions were not needed initially. The installation of the equipment is completed, however, and it is practicable to use any of the positions in Display Fields Nos. 1 and 2 and, of course, the four Link positions. The third Display Field (viz., Demand positions 110, 112, 114 and 116) has not been cut into service because they are some distance away from the centre of activities on Display Fields Nos. 1 and 2. They would be, in effect, "isolated" positions with all their disadvantages of uneconomical or wasteful staffing and supervision.

The appearance of the room is most pleasing. The low desk type switchboards have many advantages over the old type of trunk switchboard, which measured upwards of 6 ft. in height. The low boards do not materially interrupt the air movement within the exchange. It is practicable for a person of average height to stand at the back of the boards and supervise, instruct or coach telephonists doing their work and/or take whatever special records may be necessary from time to time. Sound absorbing material on the ceiling helps to keep the room noise at a low level. The panels on the keyshelves are fitted with rhodoid, a transparent material, which, because of its lower heat conductivity, is preferable to glass in this position.

Special Trunk Recording junctions from manual branch exchanges and Pay Stations and Trunk Local lines from subscribers' premises were discontinued, as no provision is made in the new equipment for calls to be routed to the call queues via manual junctions excepting, of course, those from Melbourne Central Exchange.

Calls from Central Exchange to the new Demand positions are routed via a Demand "B" position in Central Exchange. The method of completing calls from Central to Trunk Lines is as follows:—

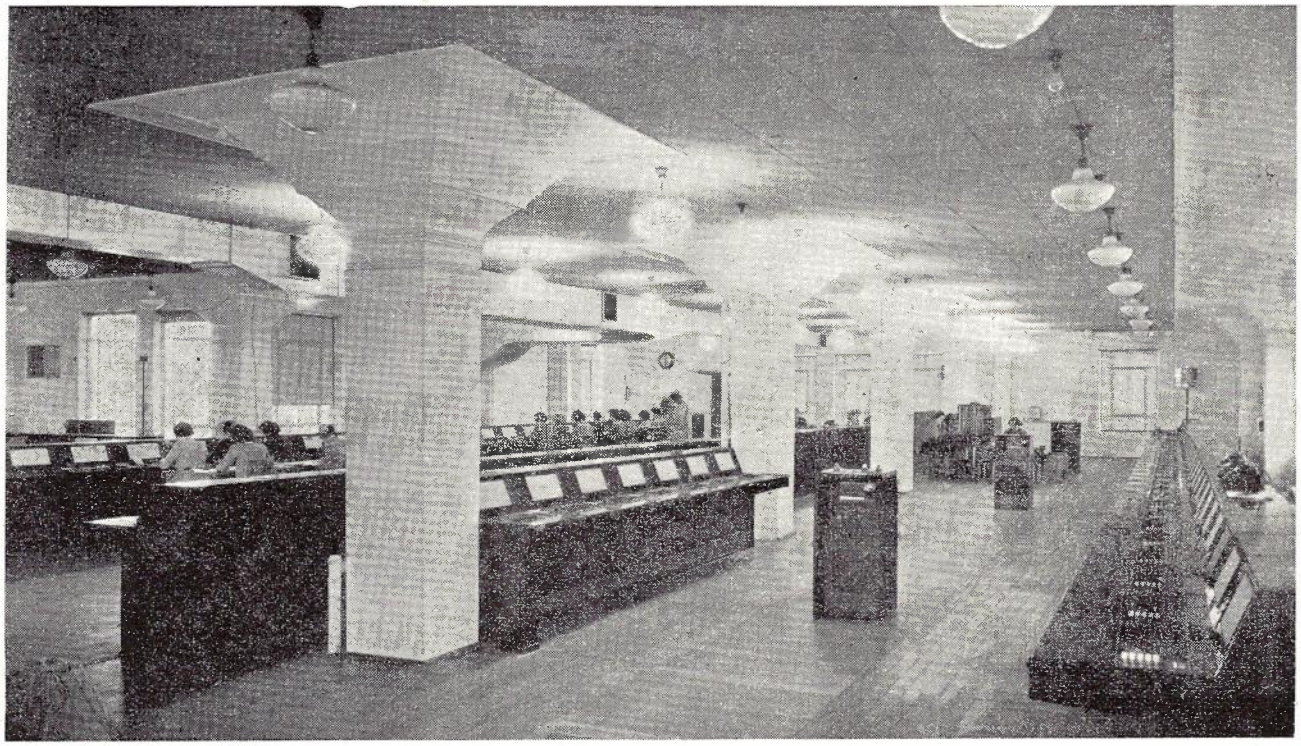
(a) Upon receipt of a request from a Central subscriber for trunk line service, the central "A" telephonist depresses the order wire key to the Demand "B" position and quotes the Central subscriber's number, e.g., "Central 1234";

(b) The Demand "B" telephonist repeats the subscriber's number and selecting a free connecting circuit plugs into the multiple;

(c) The "A" telephonist operates the L. & R. key forward, waits until the beginning of the tone which indicates that the call is connected to the call queue, meters the call and takes down the connection.

The advantage of this scheme is that the traffic does not pass through City West automatic exchange and the consequent saving in selector equipment is appreciable.

The tube system has many advantages, and dockets are distributed within the exchange with a speed and efficiency which could not possibly be done with any system of "docket runners." In order to ensure that the dockets pass through the P.D.P. with a minimum of delay, four telephonists were trained specially for P.D.P. work.



New Melbourne Trunk Exchange.

Dockets in respect of calls to be completed over trunk lines terminating in the old Country Trunk Exchange are transferred by tube system to the 1st floor. Trunk line dockets for calls to Ballarat and Geelong, which had remained temporarily on the old M.076 suite, were elevated by a conveyor belt from the 1st floor to the 2nd floor.

Supervisory officers ensure that dockets in transit do not lie at any point for more than a few seconds and the time lag in transferring dockets between the old exchange and the new is cut to the minimum.

The trunk line dockets used in the new Melbourne Trunk Exchange are made from a special quality paper which was obtained from Great Britain. In order to ensure the effective operation of the pneumatic tube system, it is important that the dockets be of uniform size and weight and that the paper be tough, rigid and free from dust. Standard Telephones & Cables Ltd., who installed the tube system, stipulated in their tender that their guarantee comprehended the texture and quality of the paper used for dockets should be equal to that used by the British Post Office.

For reference purposes in these notes—

(a) Country exchanges which have been cut over to the new system of working are referred to as "Group Centres."

(b) Country exchanges which are not provided with trunk lines to Melbourne and whose calls to or from Melbourne are switched at Group Centres are referred to as "Terminal Exchanges."

(c) Country exchanges which continue to be served by the old Country Trunk Exchange are referred to as "Magneto Exchanges."

The main functions of the suite of 7 V.F. Through positions installed in the new Melbourne Trunk Exchange are—

(a) to complete Through calls between
  (i) Group Centres;
  (ii) Group Centres and Terminal Exchanges;

(b) to record Through calls from Group Centres (and Terminal exchanges) to Interstate and Magneto exchanges;

(c) to assist to the fullest possible extent in establishing connections from the Magneto Through positions to Group Centres and Terminal exchanges;

(d) to assist in the completion of MX calls (i.e., via two or more switching points) from Melbourne Metropolitan subscribers to Terminal exchanges.

The Magneto Through positions are responsible for completing calls from—

(a) Magneto exchanges to Group Centres;

(b) Magneto exchanges to Terminal exchanges (via Group Centres);

(c) Group Centres to Magneto exchanges;

(d) Terminal exchanges (via Group Centres) to Magneto exchanges.

Dockets for these Through calls are passed to the Magneto Through positions.

Calls between Magneto exchanges are not handled on the Magneto Through positions.

Notwithstanding any difficulties which may be encountered in securing trunk line channels to Group Centres, to Terminal exchanges or to Magneto exchanges, the telephonists employed on the Magneto Through positions are responsible for completing the Through calls mentioned above.

In view of the unusual equipment arrangements which are necessary in the Melbourne Trunk Exchange during the transition period of the cutover, telephonists at country exchanges have been instructed that they must pay special attention to calls routed through Melbourne and offer the closest co-operation with the Melbourne Trunk Exchange.

Calls from Group Centres to other Group Centres via the V.F. Through positions are completed mainly on demand. The V.F. Through positions are regarded most favourably by country telephonists who now have contact with Melbourne telephonists whose functions concern only the establishment of Through calls and who zealously look after the interests of the Group Centres.

Magneto exchanges equipped with loop dialling lines to Melbourne, notably Geelong and Ballarat, are able to obtain a large proportion of calls to Group Centres on demand by dialling M.071. The call appears in the call queue on the Demand positions and, wherever possible, is extended on demand to the required Group Centre. Should the trunks to the wanted Group Centre be congested, the details are recorded and the Through docket is passed to the old Country Trunk Exchange, from whence it is completed from the Magneto Through positions via the V.F. Through positions.

The standard method of completing MX trunk line calls (viz., calls which pass through two or more switching stations) is briefly as follows:—
The details of the call are passed by the Out station to the first switching station. Each switching station in turn passes the details onwards until the In station is reached. The In station is then responsible for building up the connection to the Out station. The Out station secures the caller and assumes control of the call.

In the absence of In positions, MX calls are built back to the V.F. Through positions. The Demand telephonist who books an MX Out call, therefore, passes the details to the first switching station only and transfers the Out docket via the P.D.P. to the V.F. Through positions. The relative Out docket is held on the middle of the seven Through positions. The incidence of these calls is only about 2% in Melbourne and, so far, this method of handling has been practicable without any undue difficulty. As the volume of MX traffic grows with expansion of telephone facilities in rural districts, it may be preferable from a traffic point of view for these calls to be reverted to a specially provided "In" position rather than to the suite of Through positions, which also will have to be extended beyond the seven positions now installed.

Consideration was given to the possibility of building back MX calls to the Suspense positions which are equipped with tube inlets. The Suspense positions, however, will be fully loaded when the whole of the 78 selected Centres are connected to the new exchange and would not be capable of carrying the added burden of the MX calls. Provision, however, has not been made for incoming tubes to the V.F. Through positions. Whilst the need for this will be reduced gradually as more exchanges are cut over to V.F. working, there is a real need for tubes to the V.F. Through positions during the transition stages of the cutover.

The Routing position, which is an essential adjunct to the Trunk Exchange, is equipped with a rotary index fitted with frames containing approximately 3000 cards on which are recorded details of the routing station, the hours of service and the basic "day" rate for trunk calls in respect of—

(a) each trunk line office in Victoria and Tasmania;
(b) exchanges in the Riverina district of New South Wales and in the Mt. Gambier district of South Australia;
(c) the more important exchanges in other States.

A schedule showing at any time of the day the estimated delays to traffic booked to take effect after 8 p.m. (the commencement of the half-rate period) on each trunk line route is provided. Other miscellaneous information, to which quick reference is necessary in the working of the exchange, is also contained in the frames. The Routing position is, in effect, an internal Information Bureau.

Order wires have been provided from all trunk line positions and the Trunk Inquiry positions to the Routing position, which is staffed from approximately 7 a.m. to about 11 p.m. daily. The telephonists employed on the Routing position are specialists who have retentive memories. They were given an intensive course of training in Victorian geography and are now able to satisfy a surprisingly large percentage of queries without reference to the frames.

Calls to "Information" and Trunk Inquiry are free and subscribers' meters do not operate when answered by Information (M.073) or Trunk Inquiry (M.072) telephonists. A unit (local) call fee, however, is chargeable for each effective trunk line call. The circuit arrangements in force in Melbourne provide that a local call is debited to subscribers who call or dial "Trunk Lines" (M.071)—battery reversal takes place on the trunk telephonist answering. In order to obviate overcharges to subscribers who call or dial "Trunk Lines" (M.071) concerning Trunk Inquiry matters, a special rebate record is maintained on the Routing position. Requests for rebates are passed by Demand telephonists by order wire to the Routing position saying, e.g., "Rebate one call to M.6789." The telephonist on the Routing position acknowledges the request, e.g., "M.6789 rebate one call," and makes the necessary notation on the rebate record.

Similarly, a special debit record is maintained on the Routing position to facilitate the recording of additional unit fee calls. For example, where a subscriber books, say, two trunk line calls at the same time, advice respecting debits for the additional unit fee call is passed to the Routing position. The Demand telephonist says, e.g., "Debit M.7890 with one call." The telephonist on the Routing position acknowledges the request, e.g., "M.7890 debit one call," and records the debit.

Two Trunk "B" positions equipped with plug-ended junctions have been provided to handle traffic from the new Melbourne Trunk Exchange (by telephonists operating the keystrip and punching up the digit "B") and from Group Centres (who dial "B"). In effect, the Trunk "B" positions are Automatic "A" positions, which are exclusive to the new Melbourne Trunk Exchange and Group Centres.

Charts for the bulletin panels were printed in black on buff-coloured paper (Abermill Buff Bond). Tests made with printers' ink on about a dozen papers of divers colours and shades and viewed through the special glass of the bulletin panels showed that the best results were obtained by this combination when backed by two or three sheets of clear white paper. The details on the bulletin panel include—

(i) List of dialling codes for Group Centres;
(ii) List of dialling codes for Metropolitan Branch Exchanges;
(iii) The telephone numbers of Attended Pay Stations and other miscellaneous services;
(iv) Notes regarding Double Ticket stations.

A satisfactory procedure of fault recording was devised in collaboration with officers of the Superintending Engineers' Branch, and routine tests which could be done by telephonists were formulated. The incidence of equipment faults is relatively small.

The principal advantage derived from the establishment of the new Melbourne Trunk Exchange is the grouping together of all trunks to each Group Centre into a consolidated group of lines. For example, where previously two one-way trunks were provided from the Demand positions to a Group Centre, and two one-way trunks from the Group Centre to Melbourne, there is now a group of four two-way lines. With the greater carrying capacity of the group, the disposal of traffic has been facilitated in both directions and the delays have correspondingly been reduced.

The call storage facility has added to the carrying capacity of the groups, although the actual extent has not so far been estimated. The operating staff appreciates the "free" trunk being offered to them, thereby obviating the necessity, under the old conditions, of continually testing the jacks in order to secure a free line.

In order that the utmost value may be obtained from the alternative routing equipment, a detailed analysis of the trunk line traffic was made and a comprehensive routing scheme was devised. The advantages of the alternative routing equipment will not, of course, be obtained fully until the whole of the Group Centres has been established. Nevertheless, it is apparent from our experience so far that the automatic routing of calls via alternative routes will very effectively increase the carrying capacity of the exchange as a whole.

The advantages afforded by positive supervision is appreciated by telephonists at both ends. It is an undoubted advantage to trunk telephonists to receive a signal when the distant exchange or called subscriber answers. It may not be generally known that under magneto conditions a trunk telephonist spends more time in waiting for someone to answer than in any other phase of her work. The facilities for recalling over V.F. lines and the disconnect signals are operating aids which tend to reduce the telephonists' manipulative time with a corresponding increase in the availability of trunks for paid time.

All positions in the new exchange are equipped with a timing clock associated with each connecting circuit. The clocks are B.P.O. Type 44 which register the time in tenths of a minute. The circuit arrangement provides for the time check lamp to glow 12 seconds before the 3 minutes, 6 minutes and 9 minutes' intervals. Synchronously with the lamp commencing to glow, the parties on the line receive three short pips to indicate that there are only 12 seconds left before another 3-minute period commences. Although trunk telephonists ask the caller at the expiration of each 3-minute period whether an extension of the call is desired, subscribers generally appreciate the warning pips of tone and many compliments have been received respecting the innovation. The clock stops when the calling subscriber hangs up, and consequently the timing of trunk line calls has been improved immeasurably.

Two special whistles are provided at Group Centres for use in case of power failures, viz., a "short" one giving a 750-cycle note for calling the Through positions, and a "long" whistle giving a 600-cycle note for cancelling irregular set-ups. To establish a call under emergency working conditions, the telephonist plugs into the Out jack, throws the cord circuit Speak key and, with the "short" whistle held close to her transmitter, blows two short toots each about half a second long and with about one-second spacing. This causes the call to appear in the call queue on the V.F. Through positions. If, when blowing the "short" whistle, the notes produced are not steady, or if they are not pure (as might be caused by blowing too hard), further attempts to produce two "good" notes should not be made until the "faulty" notes are cancelled. This is done by first blowing the "long" whistle steadily for about 3 seconds. The whistles are packed in a box and located in a convenient place in the exchange room. To preserve the whistles from damage by itinerant use, the box is bound with string and the knot sealed in such a way that the string or the seal must be broken to remove the whistles from the box. An entry must be made in the exchange Journal every time the whistles are used. The whistles were made in the Workshops from patterns which were supplied by Siemens Bros. & Co. Ltd.

The Delay Supervisor's position, which was explained in a previous article in the Journal (Volume 3, No. 4, Page 211), provides a ready indication of the volume of traffic incoming over the trunk recording junctions and of the staff conditions within the exchange. It affords a ready reference to the volume of the traffic offering on each trunk route, the number of trunk groups in delay, and facilitates the assessment of delays to trunk line calls when it is necessary to revert traffic due to trunk line routes becoming congested.

A traffic recording device has been installed as a supplementary facility on this position. As the calls are taken from the call queueing equipment and transferred to connecting circuits, a meter associated with the relevant Display Field is operated. Another summation meter registers at intervals of three seconds the number of calls waiting in the queue. The traffic waiting to be answered is thus measurable in T.U.'s and, as the calls are counted as they are taken from the queue, it is possible to ascertain the average speed of answer for any given period. Keys to start and stop the meters are provided and the "speed of answer" is recorded by the Delay Supervisor at selected times.

Whilst the whole of the statistics relating to the performance of the trunk lines under V.F. dialling compared with dialling facilities provided prior to the establishment of the new exchange are not readily available, a comparison of the results of a number of trunks taken at random shows that the incidence of faults per line is slightly greater under V.F. conditions. The proportion of wrong number and no progress calls, however, has been reduced and the percentage of calls completed O.K. at the first attempt has been increased appreciably.

The training of telephonists was a problem that presented many difficulties. Although the preliminary training given to telephonists was as thorough as possible under training class conditions, and telephonists had no doubts to what should be done, nor how it should be done, it was found under actual traffic conditions that the operating staff was a little hesitant in manipulating the new keyshelf. About a week elapsed before they got the "feel" of the keyshelf and were able to operate the various keys confidently. During the first few weeks the operating force was augmented temporarily by relief staffs normally used to provide recreation leave and leave in lieu of Sunday duty.

In view of the ease with which Melbourne telephonists can secure a trunk line from call storage (i.e., on receipt of a "free trunk" signal) some concern was felt as to whether Melbourne would not have an undue advantage over the telephonists at Group Centres and exclude them from access to the V.F. trunk lines. In practice, however, the chances at either end are approximately equal and telephonists at Group Centres are able to obtain a fair share of the trunk lines to Melbourne.

On a typical day during Easter week, 11,367 Out calls were booked. Of these, 3,699 were transferred to the old Country Trunk Exchange, 6,019 were completed on the new Demand positions, and 1,649 on the Interstate positions. Assuming the normal day's business is completed between 8.30 a.m. and 10.30 p.m., a total of 3,052 channel hours (viz., 218 trunks × 14 hours) was available on the new Demand positions for the disposal of traffic. Channels were in delay for an aggregate of 528 hours. That is to say, 83% of channel hours was available for traffic under Demand or Storage Clear conditions. The maximum number of trunk lines in delay at any one time was 62 and the average duration of delay working per group was 3 hours 1 minute.

One of the difficulties from the staffing point of view is economically to provide staff adequate to dispose effectively of the volume of traffic offering and at the same time to provide a prompt speed of answer. From observations to date, it seems that the two are incompatible. That is to say, a staff which is just sufficient to connect the calls offering during the busy hour is not capable of providing a prompt speed of answer during surges of traffic. On the other hand, where sufficient staff is employed to give a prompt speed of answer, it is found that the staff provided is more than is necessary to connect the volume of traffic booked during the hour and that at times telephonists are unavoidably idle for relatively long periods. Doubtless, there is a happy medium between the two ideals, and efforts in determining the ideal staffing arrangements are being continued.

The extent of a Demand service should be restricted only by the traffic carrying capacity of the trunk lines. That is to say, trunk lines to Group Centres should not remain unoccupied whilst calls are waiting connection, and, as a general rule, the speed of answer should be a secondary consideration.

During periods of exceptionally high traffic, and with the staff depleted owing to supernormal wastage, it has been necessary to have telephonists concentrating on booking calls only in order to keep the call queues within due bounds. This, however, should be regarded as an expedient.

With the improved operating aids available on the new Demand positions, the output in calls per telephonist per hour has been increased appreciably compared with the old Demand (C.L.R.) positions. The best results to date show the following maximum loads for experienced telephonists:—

(a) Calls recorded only (i.e., subscriber answered, details recorded on an Out docket, subscriber advised of delay and docket inserted in tube) .... 129 calls
(b) Out calls reverted direct to Group Centres (completed on demand at the Group Centres) .... 43 calls
(c) Out calls reverted through Group Centres to Terminal exchanges (completed on demand at the switching stations) .... 36 calls

(N.B.: In (b) and (c) above the calls were not recorded by the telephonist under trial.)

As the recording of calls for exchanges served by the old country Trunk Exchange is also done on the Demand positions, it has not been practicable to establish the maximum load for booking and completing calls on Demand to Group Centres. Nevertheless, an expert telephonist has booked and completed 24 calls on Demand to a Group Centre and booked 57 other calls in one hour.

The capacity of the call queue associated with each Display Field is limited to 10 calls, and calls above this number, that is, those arriving at the exchange when the queues are full, do not necessarily enter a queue in order of their arrival. Whilst it is essential from a service point of view that the queues should not be unduly long, it is thought that the capacity of the call queues could be extended with advantage. It is a relatively common occurrence for the queues to be temporarily overloaded for a few minutes. For example, assume 8 calls are in a queue and say 7 more arrive within a few seconds, only two of these enter the call queue. The other 5 wait for places in the queue as calls are transferred to connecting circuits. Normally calls are taken from the queue in a steady flow, and if the telephonists concentrate on completing calls (at the rate of 24 calls per hour) it may take about 1½ minutes before the "15th" call was answered. It is possible, however, for this "15th" call to be beaten for its place in the call queue by other calls which may arrive a few seconds later, i.e., whilst the queue is still full. It would not be necessary, however, to extend the ladder of lights on the Demand positions beyond the present limit of 10 calls.

The flashing lamp at the top of the queue indicating that the first subscriber in the queue (referred to locally as the "oldest inhabitant") has been waiting 20 seconds, has a great psychological effect on the staff. Telephonists generally respond promptly to a flashing signal and when the lamp at the top of the queue begins to flash the operating staff puts forth its best effort in answering subscribers.

Four Link positions are provided for balancing the loads over the three Display Fields. Two of these are associated with the third Display field, which temporarily is not in use, and the other two are effective as Link positions between Display Fields Nos. 1 and 2. If the telephonists on the Link positions are required to concentrate on completing calls as distinct from booking calls, a relatively long period is sometimes necessary to equalise the loads. It is expected that the position will be improved when the third Display Field is cut into service, but for installations with only two Display Fields it would be an advantage to provide more than two Link positions.

One of the outstanding features of the new Demand exchange compared with the old Country Trunk Exchange is the increase in the average holding time per trunk call. This is due to several factors:—

(a) The higher proportion of calls completed on Demand has resulted in a greater number of trunk lines being held whilst the Out telephonists obtain the Particular Person on outward calls. Here it may be explained that where a group of trunks is worked in delay under advance working conditions (back to back) the telephonist at the "In" end obtains the Particular Person in advance and has him standing by. Where, however, calls are completed on Demand at the "In" station or where direct dialling lines are used, the responsibility for obtaining the Particular Person rests entirely on the "Out" telephonist.

(b) The proportion of calls completed on Demand via a switching station has increased appreciably. In this case the time taken by the Through station (viz., the Group Centre) to establish the connection over a second trunk to the Terminal Exchange adds to the occupancy of the Main Trunk.

(c) Under Storage Clear conditions the calling subscriber is released and the telephonist remains in storage for the trunk line. When the trunk becomes free, the Group Centre invariably answers before the Out telephonist has had an opportunity of securing the attendance of the caller. Consequently, the trunk line is held whilst this is done.

The efficiency of keystrip sending as compared with dialling is greatly appreciated by telephonists and the advantage is reflected in the following manipulative times:—

(a) Average time taken to dial six digits .... = 9.5 seconds

(b) Average time taken to operate keystrip—i.e., depress the "Send" key, wait for sender taken lamp to glow—depress prefix "O," six digits and the Finish key .... = 3.5 seconds

Another very interesting review was made of the junction line traffic from automatic exchanges to the Trunk Exchange. An interesting sidelight of this analysis showed that approximately two-fifths of the trunk line traffic is originated by subscribers in the "M" group.

A problem to which a great deal of thought is being given concerns the stage at which a group of trunks should be changed from Demand to delay working. It depends, of course, upon the volume of traffic offering compared with the size of the group. Messrs. Siemens Bros. & Co. Ltd. have suggested a basis covering groups of from one to five trunks. As many of our groups exceed this number, steps were taken to formulate a basis for groups of more than five.

The following assumptions were made by the company:—

(a) Groups are fully operated on a both-way basis;
(b) The outgoing traffic approximately equals incoming traffic;
(c) The average holding time per call is 5 minutes;
(d) The occupancy per trunk is .8;
(e) Permissible waiting period for calls in storage for the smaller groups of trunks (1-5) does not exceed twice the average holding time.

The basis shown in Table 2 was introduced on trial.

Our investigations show that the ratio Out to In traffic and the holding time on calls varies appreciably on groups of similar size. Some modification of this basis has, of course, been necessary in individual cases, particularly at Group Centres serving large districts and at which the volume of Through business is relatively high. Typical cases are Bendigo, Hamilton and Morwell. On the other hand, the scale seems adequate on routes where the traffic mostly terminates at a Group Centre.

The Storage Clear and Delay scale is used with discretion and groups are not placed in delay merely because of some transient overflow or temporary peak in traffic. When the number of calls stored on a Group reaches the Delay datum point, the Delay Supervisor contacts the Group Centre and ascertains the number of calls waiting at that end. Similarly, the Group Centre advises the Delay Supervisor when the number of calls on hand reaches the figure appropriate to the particular route.

Having regard to the complexities experienced in delay working and the difficulty of ensuring perfect team work between the Out and the In station, the manipulative effort required on the part of an Out telephonist to complete a call under advance working conditions (back to back) is almost 50% greater than under demand conditions. Consequently, one of the greatest hazards, from a traffic handling point of view, is to be forced to place a very large group in delay and on occasions special measures have been taken to continue working large groups under demand conditions, whilst dockets for a small percentage of the calls were set aside for completion later on. Experience to date confirms that on a large group where the capacity for a demand service is relatively high (in T.U. per line) traffic is disposed of quicker under demand conditions despite the higher holding time on demand calls.

For many years prior to the cutover a demand service had been provided between Melbourne and Ballarat and Geelong. It was decided to restore the demand service by cutting back the M.076 level (Demand) junctions to prepared positions in the old Country Trunk Exchange as soon as practicable. The first step, of course, was to transfer the bulk of the demand traffic from the M.076 to the M.071 level. The relevant entry was made in the November, 1941, Telephone Directory and subscribers were advised through the press to dial M.076 for Ballarat and Geelong only and call M.071 for all other intrastate calls. Additional M.071 level junctions were provided to meet the first impact of the changed traffic conditions, and as the traffic was gradually transferred from M.076 to the M.071 level, 4th selector equipment was adjusted accordingly.

No. of lines in Group	No. of calls in Storage when changed from		No. of lines in Group	No. of calls in Storage when changed from	
	Storage Wait to Storage Clear	Storage Clear to Delay		Storage Wait to Storage Clear	Storage Clear to Delay
1	1	2 ⎫	14	3	11
2	1	3 ⎪	15	4	12
3	1	5 ⎬ Siemens	16	4	12
4	1	6 ⎪	17	4	12
5	2	7 ⎭	18	4	13
6	2	7	19	4	13
7	2	8	20	4	13
8	2	8	21	5	14
9	3	9	22	5	14
10	3	9	23	5	14
11	3	10	24	5	14
12	3	10	25	5	15
13	3	11			

TABLE 2.

The numbering scheme for Main Trunks, viz., 10 to 98, will permit the number of Group Centres to be increased from 78 to 88. The ten Group Search numbers, which are being reserved, were carefully selected so that when the requisite equipment is made available a further ten Group Centres may be fitted into the main list in their proper alphabetical sequence.

To date 247 trunk lines serving 51 Group Centres have been converted to V.F. working.

This article completes the series on The New Melbourne Trunk Exchange. Previous articles appeared in Vol. 2, pages 201, 298 and 357, and Vol. 3, pages 211 and 280.

The Board of Editors much appreciates the assistance rendered by Messrs. C. L. Hosking, R. Moore and L. Paddock in completing the work commenced by the late Mr. C. McHenry. Special features of the Trunk Exchange equipment such as Call Fee Indicators —see page 10 of this issue—and the associated 2 V.F. Signalling System are being covered by separate articles.

CHROMIUM PLATING

A. B. Greig

INTRODUCTION.—Chromium is a metal that has come very much to the fore in recent years. It belongs to the same group of elements as sulphur, selenium and tungsten. It was known to exist as far back as 1797, but it was not till 1894 that fairly pure chromium was prepared. It is a fairly abundant metal which is found in South Africa, Russia, the United States, India and elsewhere.

The preparation of the metal from chromite is a long and complicated business. The mineral after being washed is finely ground with lime and potassium carbonate, and is then roasted. Potassium Chromate is thereby produced. It is soluble in water and the solution is then converted to potassium dichromate by adding sulphuric acid and recrystallising it.

The potassium dichromate is next reduced to chromite by heating it with starch or some other reducing agent, and, by washing, chromium sesquioxide is obtained. All the soluble chromites are decomposed by water and this chromium sesquioxide is the source of the metallic chromium of commerce.

Chromium is a hard whitish-grey metal which melts at about 1920° C. and has a boiling point of 2200° C. It is exceedingly stable in the air, which makes it so valuable as a plating metal. It has to be heated to 2000° C. before it will combine with oxygen.

Chromium forms important alloys with iron, nickel, cobalt and copper and it also forms amalgams. Added to steel it makes that metal hard and tough, and alloys containing a large percentage of chromium remain permanently bright in moist air.

USES OF CHROMIUM PLATING.—The applications of chromium plating are wide and varied. Gauges, tools and machine parts are plated to increase their surface hardness and to give longer life.

Taps, reamers, milling cutters, slitting saws and drills when used on bakelite, hard rubber, bronze, aluminium, fibre, asbestos, copper, cast iron, steel of various composition, wood and other materials, give greatly increased wear life and operate easier when plated.

As a "putting-on" tool and salvaging medium in the machine shop, chromium plate has no equal. Shafts, arbors or spindles accidentally machined or worn undersize may be quickly, easily and effectively brought back to normal. Likewise holes in gears, cutters, bushings or dies may be reduced in diameter by almost any amount. On expensive parts, salvaging with chromium plate usually represents only a small fraction of the replacement cost and is much quicker.

Mechanics' tools and other items of hardware such as micrometers, calipers, scales, drills, saws, feeler gauges are greatly improved by a coating of chromium (0.00002-0.00003 inches) directly on the steel base. Drawing dies and mandrels give 3-5 times the life of bare dies and mandrels in drawing copper, steel, nickel, gold, silver, platinum and their alloys. Moulds for various plastic materials, porcelain, glass and rubber benefit greatly by a deposit of chrome. The bright finish is preserved much longer and the plastic material does not stick to the mould, while pitting is reduced or entirely eliminated. The mould wear is reduced and in general the moulded product has a better appearance. It is claimed that the economics which are obtained by the chromium plating of machine tools alone, can pay for the equipment in short time.

Chromium plating will not tarnish and requires no polishing to keep clean. So long as it is occasionally wiped with a damp cloth to remove dust or dirt the original polish is undimmed. Thus the advantages of decorative chrome plating are self-evident.

CONSTRUCTION OF THE PLATING VAT.—The chromium plating vat requires special design. The tank should be constructed of welded mild steel. It is imperative that the tank be lined with 6-lb. 8% antimonial lead to prevent decomposition of the solution and corrosion of the tank.

It is also absolutely essential that the tank be provided with loose glass sides and bottom. Reinforced glass sheets ($\frac{1}{4}$" wired cast glass) should be used and held in position by lead clips welded to the lining of the tank. Glass lining is necessary to prevent the tank (owing to the proximity of the anodes) becoming anodic to the article being plated and causing a burnt or satin finish to those pieces close to the sides or bottom. It also eliminates the possibility of short circuit should one of the articles touch the sides or bottom.

As the temperature of the solution must be controlled the tank is enclosed in a water jacket. The height of water in the jacket should not be above the height of solution in the tank and should have a half-inch surface film of steam cylinder oil. The use of a jacket entirely of oil is not recommended, as it results in "patchy" distribution of heat. The water with a surface film of oil allows rapid convection currents and an even distribution of heat. Immersion heaters are used to raise the temperature of the water jacket. The temperature is controlled by a thermostat with a differential no greater than 5° F.

EXHAUST SYSTEM. — The fumes given off from the chrome solution have a corrosive action on the skin and clothing, particularly affecting the mucous membrane of the nasal organ. With a properly designed exhaust system the working of the plant is not in the least hazardous or dangerous so long as ordinary care is exercised by the operator.

Fume ducts should run either side of the vat into a condenser. The inlet to the fume ducts should be eight inches above the "chrome" solution. The ducts should have a fall of 1 in 50 towards the condenser and the condenser should have baffle plates and a draining cock. The fan should be as high as possible above the vat with a vertical discharge at least four feet above the roof and a weather hood over the vertical discharge. The exhaust system must produce a velocity of 1000 cubic feet per minute at least for drawing off the fumes.

THE ANODE.—Anode plates should be made up of 8% antimonial lead. The herring-bone shape is widely used and has the following advantages:—

1. It can be readily cast.
2. Has large discharge surface for weight of metal used.
3. Cost is moderate.
4. Voltage drop between hook and solution is low.

When casting, to minimise crystallisation and porosity and to lengthen the life of the anode, a blow-torch flame of oxygen and hydrogen is played over small sections of the surface of the anode. Intense heat applied to small portions of the metal penetrates deeply and the small area which contacts the flame (needle shaped) is heated to melting point. The flame is then passed to another area, each space being heated to melting point and the flame quickly removed. The surrounding metal and atmosphere cause rapid cooling and result in compact fine crystalline structure with the surface distinctly showing waves left by the flame. This resultant smooth and homogeneous structure increases the anode's resistance to breakdown.

Anodes are often made up of 10-lb 8% antimonial lead with a copper bar or rod burnt in to make contact with the anode rod. On no account must improvised anodes bent around the anode rod be used. Lead sulphate forms on the anode rod and results in a bad electrical connection.

"Chrome" solutions have poor throwing power, i.e., will not plate into deep recesses. Therefore with pieces of irregular shape it may be necessary to use anodes approximately the same shape as the piece to be plated. All portions of the article being plated should be the same distance from the anode—about nine inches—and the article must be six inches down in the solution. It is essential that intimate contact of the article be made with the cathode rod.

METHOD.—Chromium should always be applied over nickel, although it may be applied to hardened steel and other surfaces. The following is the method to be followed:—

1. Clean in alkali cleaner with or without the use of current.
2. Rinse in water.
3. Dip in hydrochloric acid (18% by volume).
4. Rinse and immediately place in chrome bath while still wet.

If a polished chrome surface is required the article should be polished and buffed before cleaning.

When chroming over nickel it is necessary to keep the hydrochloric acid dip from becoming contaminated with copper, otherwise a thin film of copper will form over the surface of the nickel and the chrome will not adhere perfectly.

It is believed that optimum results will be obtained from the following conditions:—

1. A low concentration of chromate radical (CrO_3) such as 200-300 grams per litre (31-45 oz. per gallon) of water.
2. A low sulphate content of $CrO_3/SO_4 = 100$.
3. Current density 150-200 amps. per square foot.
4. Temperature 50-60° C. (122-140° F.).

These conditions require 6 volts.

The current density and the temperature are the two important variables.

If the current is too high a burnt or satin finish results, while the current too low gives a bluish plate or fails to cover.

Conditions found to yield the best throwing power are:—

1. CrO_3 150-250 gms. per litre (20-33 ozs. per gallon of water).
2. Sulphate content $CrO_3/SO_4 = 200$.
3. Current density 325 amps. per square foot.
4. Temperature 55° C. (131° F.).

Reference

Technological papers and articles of the Australian Standards Association.

RE-ALLOCATION OF CHANNEL FREQUENCY FOR THE TYPE "B" TELEGRAPH CARRIER SYSTEM

F. E. Ellis

One of the first types of carrier equipment put into operation by the Department was the type "B" Telegraph Carrier System. With the exception of Hobart, the capital cities of Australia are linked by these systems, which, when fully equipped, each provide 10 duplex high-speed channels. They have given valuable service over a number of years and are still doing so.

The carrier frequency allocation of this system is shown in Fig. 1, together with the frequencies of the 3-channel telephone and 18-channel V.F. telegraph systems. It will be seen that the type "B" telegraph system makes use of the frequency spectrum, especially in the A to B direction in a manner which is regarded as extravagant according to present practice. The B to A channel frequencies require a transmission band approximately 3.25 to 5.58 kC/sec. = 2330 cycles wide, and the A to B frequencies require a band approximately 6.42 to 10.08 kC/sec. = 3660 cycles wide.

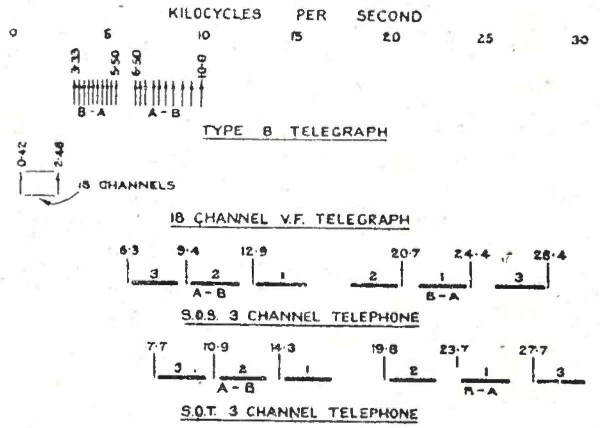


Fig. 1.—Frequency Allocations of Telegraph and Telephone Carrier System.

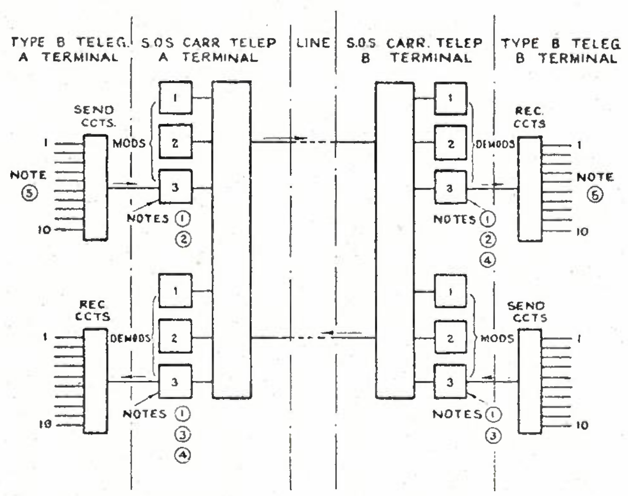
The marked increase in the number of carrier telephone systems in this country in recent years has left, on the main line routes, very few pairs of line wires suitable for the operation of further 3-channel telephone carrier systems to cope with expanding traffic demands. In some cases, if the wires carrying the Type "B" telegraph system could be made available for a telephone system, the erection of additional wires could be postponed, re-transposing of portions of the 10 kC line for 30 kC operation perhaps being necessary only. However, the telegraph system or some other system equivalent to it in traffic handling capacity would still have to be accommodated on the route, and it is interesting to examine the possibilities in this regard.

Reference to the frequency allocations shown in Fig. 1 will show that the deletion of the A to B direction of channel 3 of the SOT system would make available sufficient space in the frequency spectrum for the Type "B" system to operate on the same pair as the remainder of the SOT system; but, in order to operate the two systems in this way, a pair of separating filters would be required at each terminal and two pairs at each repeater. Filters of this kind are not available as a standard item and it would be uneconomical to procure them.

The trend in England in providing large groups of telegraph channels between widely separated points is towards multi-channel V.F. telegraph systems of sizes up to 18 channels per system, each channel usually accommodating a teleprinter circuit. The 18-channel system requires a transmission band approximately 380 c.p.s. to 2500 c.p.s. = 2120 cycles wide for each direction of transmission. When the V.F. telegraph system is operated over a carrier telephone channel, the actual frequencies passed over the line are a band of frequencies produced by modulation and side-band selection in the carrier telephone system.

It should, perhaps, be pointed out that the oscillators and filters of the type "B" system do not lend themselves to being tuned to the voice frequency range, and further, the other components of this system are not designed for voice frequency operation. However, if the B to A group of frequencies of the type "B" telegraph system could be translated up into the pass range of the modulator band filter and demodulator band filter of a carrier telephone channel, then transmitted over the channel and translated down to the original type "B" telegraph frequencies, a means would be to hand of operating the telegraph channels in a somewhat similar manner to that for a V.F. telegraph system. The side-band transmission range of the telephone channel, of course, would have to be at least 2330 cycles wide and the V.F. transformers of the modulator and demodulator would be required satisfactorily to handle frequencies from 3.25 kC/sec. to 5.58 kC/sec. These requirements would be met by most of the 3-channel systems operated by the Department. The A to B group of frequencies of the type "B" telegraph system could not be accommodated on the 3-channel systems in the above-mentioned manner, as it requires a band width of approximately 3660 cycles. But, since the oscillators and filters of the type "B" system are readily tunable to any of the frequencies within the system, the A to B group can be re-tuned to the frequency allocation of the B to A group and so made to occupy the narrower band of approximately 2330 cycles wide.

Considering the B to A group of the telegraph system, a method of translating the channel frequencies which suggests itself, is to group modulate them in a special modulator to reduce them to the voice frequency range so that they could be injected into a telephone channel in the same manner as is done with a V.F. telegraph system. A group demodulator could restore the channels to their original frequencies at the receiving end. This method would be ideal if suitable equipment were readily available. Two modulation processes would be involved, the group modulator and the telephone carrier modulator at the sending end, also two demodulation processes at the receiving end. This would require very close synchronism between each modulator oscillator and its respective demodulator oscillator, as differences, if additive, would impair the telegraph operation. This aspect seems important when it is remembered that the oscillators and filters of the telegraph system itself are required to be stable and a frequency drift here could add to that in modulators or demodulators. It is doubtful whether the provision of group modulating and demodulating equipment would be economical considering the possibility that future development may lead to a re-arrangement of the type "B" systems respecting the routes over which they operate.



NOTES:—

(1) Channel 3 of S.O.S. System as typical case.

(2) Modulator Oscillator and Demodulator Oscillator A to B altered from 6.3 kc/s. to 12.1 kc/s.

(3) Modulator Oscillator and Demodulator Oscillator B to A altered from 28.4 kc. to 31.6 kc/s.

(4) Demodulator Output Filter removed.

(5) Telegraph Channels retuned to 3.33 kc/s., 3.33 kc/s.-10 kc/s. band.

Fig. 2.—Operation of Type B Telegraph System over a Carrier Telephone Channel. Elements of circuit arrangements.

A very simple scheme is possible, however, in which the existing equipment can be manipulated to give the desired result at practically no cost. This can be achieved as follows:—

(1) Re-tune the 6.5 kC/sec. to 10 kC/sec. directional band of channel frequencies to the frequencies of the lower band, i.e., 3.33 kC/sec. to 5.5 kC/sec.

(2) Re-tune the modulator oscillator and demodulator oscillator of a selected telephone channel to such a frequency that when modulated by the telegraph channel frequencies, one of the side bands produced will be transmitted by the band filters of the modulator and demodulator of the telephone channel.

(3) Remove the demodulator output filter from each end of the selected telephone channel and connect voltage limiters to the modulators of the other two channels, if they are not already equipped with them.

(4) Transmit the telegraph frequencies over the telephone channel on the four-wire principle by connecting the send side of the telegraph system to the modulator input and the receive side of the telegraph system to the demodulator output. The telegraph channel frequencies will appear at the demodulator output and will be selected by their respective receiving filters.

(5) If there is an alternative route between two of these telegraph terminals it would be desirable to provide on a channel on the alternative route facilities to enable rapid retuning of the oscillators of the modulators and demodulators to accommodate the telegraph systems in the event of a failure on the normal route. This could be provided by means of keys.

The scheme has been demonstrated by laboratory tests, field trials, and in one case by operation for approximately 18 months on working equipment, to be practicable. A block schematic showing the elements is shown in Fig. 2. The details present no real difficulties and do not call for comment.

A telegraph system operated in this way has not the flexibility of a V.F. telegraph system and it is not suggested that additional carrier telegraph equipment should be provided for operation by this method, but, as an expedient, to utilize existing equipment, the scheme has advantages. It will be seen that the telegraph carrier repeaters now in operation would be deleted with this arrangement, thus reducing battery current drains at the stations concerned and also reducing the man-hours spent on lining up and general maintenance.

FLINDERS ISLAND: TASMANIA RADIO LINK

C. H. Brown

Ultra High Frequency Radio links are used extensively in other countries where the cost of normal land-line or submarine cable proves prohibitive. The quality of the Flinders Island-Scottsdale link, which was opened to traffic on 11th January, 1942, indicates the reliability of this type of channel, provided that the transmission path is above the horizon, i.e., along the optical path.

Flinders Island, the largest of the Furneaux Group of islands, has an area of 513,000 acres. The population of the group is over 1000, and 85% of the people reside on Flinders Island. The only means of communication was by boat, plane or radio-telegraph, a service operating off a fixed schedule.

The telephone network on the island consists of seven exchanges and approximately 50 subscribers, and their appreciation of the radio link was demonstrated by the traffic flow to various parts of the main Commonwealth network on the opening day.

SITE LOCATION AND SURVEY

The sites for the terminals were selected to obtain an optical path for the radiated signal. This means that the direct line between the terminals is above the horizon. The frequencies used under this condition are not affected by

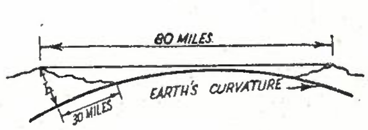


Fig. 1.

fading or atmospheric conditions, and, therefore, the equivalent of the circuit remains reasonably constant.

It is often difficult to obtain suitable sites for long point-to-point transmission, particularly for distances exceeding 60 miles. The average distance between the suggested sites in this case being 75-80 miles, it was remarkable to find that there were many locations available.

The choice of the most suitable of these sites was determined by the following considerations:

(1) Distance to the horizon, together with nature of the intervening country.

(2) Elevation of the radiated beam at various points along the path.

(3) Nearest main trunk route and telephone exchange.

(4) Proximity to good road and low tension power supply.

The mainland terminal is located on a main road, has an elevation of 1900 feet above sea-level, and, as shown in Fig. 1, the height of the radiated signal above the intervening land is such that interference and absorption losses should be a minimum.

The major sources of interference at the frequencies used are ignition systems of cars, motor boats, and petrol engines in general. It is apparent, therefore, that the site selected, although it is desirable to have it adjacent to a good road, should have a steep grade to enable the angle between the radiated path and the contour of the country beneath to be of maximum value. The height being 1900 feet, the distance to the horizon is 53 miles. Knowing the total point-to-point distance, the minimum height of the other terminal then equals

$$\frac{(a-53)^2}{1.488} \text{ Feet}$$

where a = the distance between terminals in miles. The minimum height is therefore 490 feet.

A very convenient site within two miles of the Whitemark Exchange was chosen for the island terminal. The height of this site is 500 feet and the angle between the slope of the hill and the beam path is in the region of 30-40 degrees. The type of country on the higher peaks on the island is very rugged and rocky. Fig. 2 shows the windmill and equipment cabin at Flinders Island.

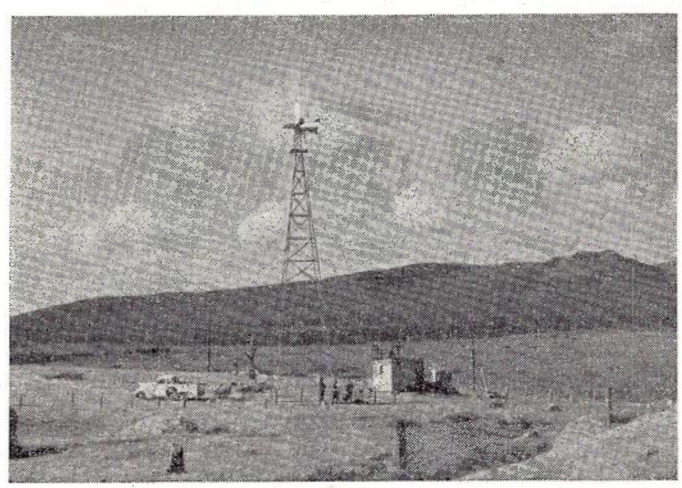


Fig. 2.—Equipment Cabin and Windmill, Whitemark, Flinders Island.

EQUIPMENT

The equipment consists of a 5-watt transmitter combined with a 6-valve superhetrodyne receiver suitable for duplex operation at a fixed frequency in the band 30 to 45 megacycles.

A single piezo-electric crystal controls both the transmitter and the receiver, the receiver

A.V.C. controlling a relay for bell ringing on the incoming calls.

Power is supplied from a 12-volt battery and vibrator unit, the charging source being a wind-driven generator.

The windmill driving the generator is the type that maintains a reasonably constant speed having variable pitch blades.

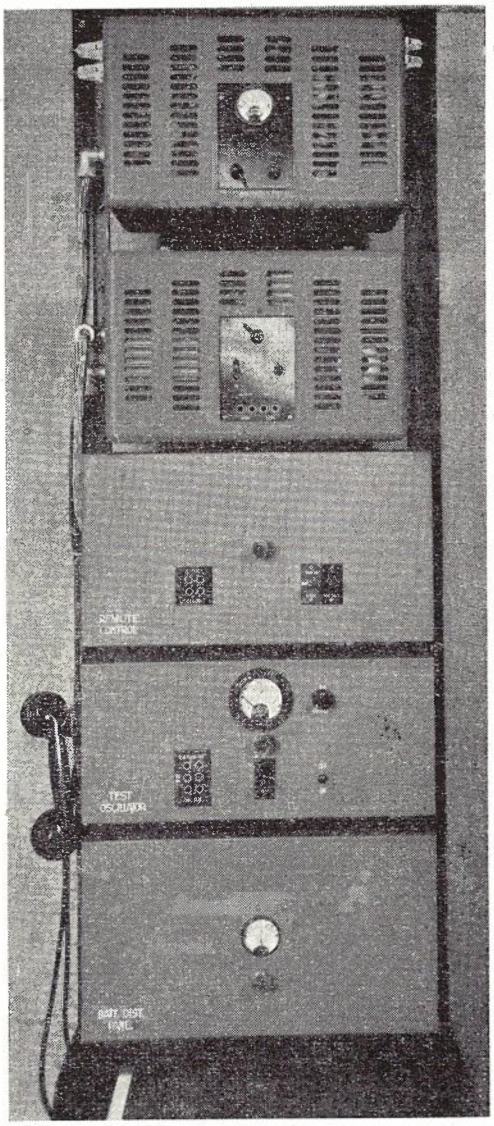


Fig. 3.—Terminal Equipment Panel.

REMOTE CONTROL

The terminals in this case are located some distance from the telephone exchanges and are controlled by relays over the voice frequency line. Although a radio circuit, this may be regarded as a new type of trunk circuit, as normal carrier line-up methods are adopted when lining-up levels, while calling and answering facilities are provided at the telephone exchange as for any normal trunk line.

DESCRIPTION OF EQUIPMENT AT ONE TERMINAL

The equipment consists of five units mounted on an angle iron rack 5 feet high and 21 inches wide which will accommodate standard panels. Fig. 3 shows the equipment rack complete with all the units mounted. The units are designated and mounted as follows from the bottom:—

(1) Battery distribution panel.
(2) Test Oscillator panel.
(3) Remote control panel.
(4) Power converter panel.
(5) Transreceiver panel.

Units of 4 and 5 were purchased from Amalgamated Wireless (A'sia) Ltd., this being their standard 5-watt duplex set.

Units 1, 2, and 3 were designed and manufactured by the P.M.G. Department to provide remote control from a telephone exchange or subscriber. These units also include the hybrid transformer for extending the four-wire circuit

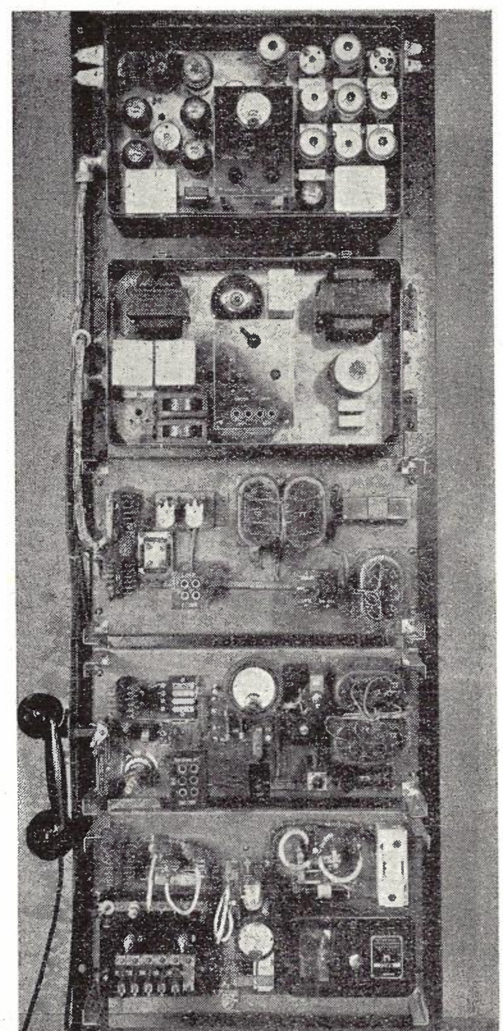


Fig. 4.—Equipment Panel—covers removed.

at the radio terminal to the two-wire voice frequency line and telephone network.

The control circuit is derived from the cailho on the voice frequency line. It was found on this installation that modifications to the original control circuit were necessary. These will be described when dealing with the circuit operation.

In Fig. 4 the dust covers have been removed to show the layout of the various components. On unit five the five valves on the left-hand side are the transmitting valves with the 600 ohm output terminated on the two insulators on that side. The tuning coils are very small and are located between the valves. A typical coil for 40 megacycles at low power would be about eight turns of 16 S.W.G. wire having a length of about 1½ inches and a diameter of 1 inch. The receiving valves and associated coils are shown on the right-hand side. A milliammeter for reading the anode current of the transmitting valves is shown in the centre. Shunts are provided in each anode circuit, so that the circuit is not broken when switching the meter in to read the current. The meter panel also accommodates the meter switch, sensitivity, volume, and bell-ringing controls.

Unit 4 comprises a vibrator, associated transformer and filter. The vibrator converts the 12 volts d.c. to 350 volts d.c. to provide the necessary potential for the anodes.

Units 1, 2, and 3 are shown in Fig. 5 to give a clearer view of the component parts and their layout. Unit 1 consists of a fuse panel of the standard rat-trap type, differential ammeter, and all relays associated with the battery charge, discharge, and distribution to the various circuits. Rat-trap pilot fuses are connected in parallel with the large fuses to provide the fuse alarm.

Unit 2 comprises the test oscillator, level meter and test jacks, together with a handset telephone wired up as a four-wire unit. This permits levels to be lined up from Exchange to Exchange, and when speaking from the radio cabin with the handset the circuit remains stable. The receiver can be used as a monitoring receiver in the normal way.

Unit 3 shows the two remote control relays A and B, the hybrid transformer consisting of 2/4012A transformers, and test jacks.

TRANSMITTER

The frequency source is a crystal of the ambient temperature type, operating on 6.65 megacycles at one terminal and 6.95 megacycles at the other. The anode circuit of the oscillator valve is coupled to a 6V6 valve operating as a frequency multiplier. The output of this stage, which is tuned to select the third harmonic of the oscillator, drives the modulated amplifier.

The anode circuit of the modulated amplifier (an 807 beam valve) is tuned to the sixth har-

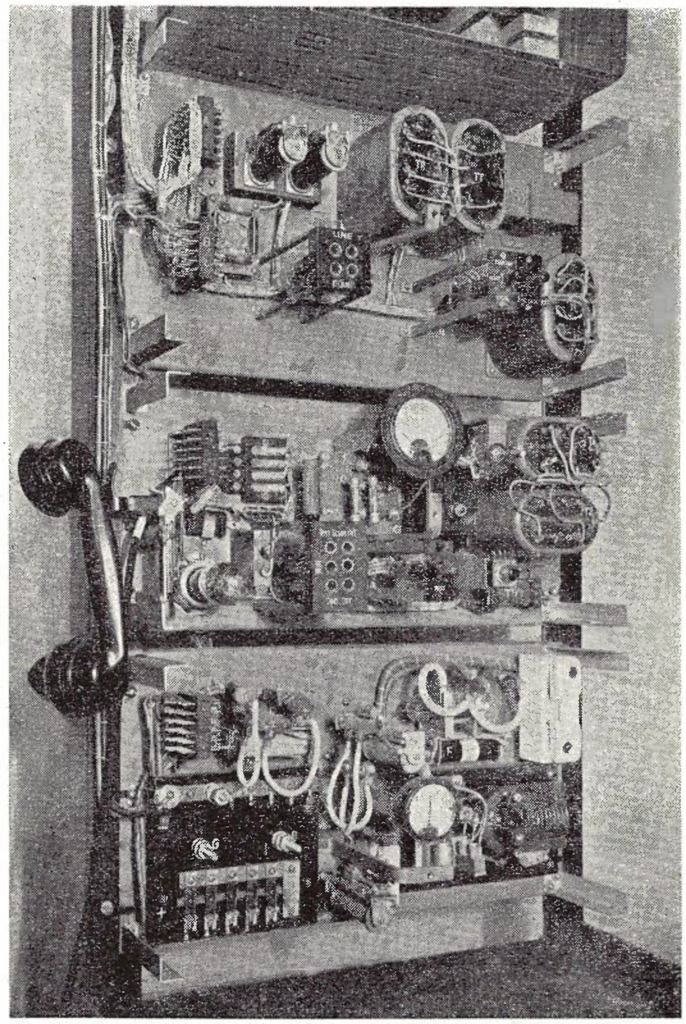


Fig. 5.—Close-up of Units 1, 2 and 3.

monic of the crystal frequency, i.e., it is working as a frequency doubler. This eliminates the possibility of any instability and it is not necessary to neutralize any of the high frequency stages. The modulated amplifier delivers 5 watts of carrier power into a 600 ohm line, which feeds the radiating system.

The carrier frequencies transmitted in each direction are:—

Send 39.9 megacycles; and
Receive 41.7 megacycles;

the difference being 1.8 megacycles, this difference being the frequency which the intermediate frequency amplifiers are tuned to select. The modulator comprises two 6V6G valves in push-pull and is designed for input from a 600 ohm line. A power level of 6 milliwatts at 1000 cycles per second is required to modulate the radio frequency carrier 100%.

The transmitter-receiver units supplied were designed to operate as 4-wire units, hence, as hybrid coils were used to connect to the 2-wire exchange line, it was necessary to provide a stage of amplification between the hybrid and the modulator. The gain of this stage was adjusted so that a level 10 db below 6 milliwatts from the V.F. line to the hybrid would modulate the transmitter 100%.

RECEIVER

The receiver comprises:—

1 radio frequency stage;
1 frequency converter;
2 intermediate stages, detector and audio frequency amplifier.

The input to the receiver is from a 600 ohm line feeding from the receiving array.

The special features of the receiver are:—

(1) The use of the transmitting crystal oscillator as the local signal generator for reception; and
(2) a bell-ringing relay controlled by the A.V.C. voltage.

FREQUENCY CONVERTER

The local signal is obtained by supplying energy through a very small condenser from the output of the frequency multiplier of the transmitter. This frequency, 19.95 megacycles, has enough second harmonic content to beat with the incoming signal, which is 41.7 megacycles. Frequencies in the output of this stage will be 39.9, 41.7, 81.6, and 1.8 megacycles, neglecting, of course, all the harmonics. The intermediate frequency amplifiers select the lowest frequency, 1.8 megacycles, which is fed through and rectified in the normal way. The detector stage is a 6G8G diode amplifier. One section of the diode supplies the automatic volume control voltage.

The A.V.C., in addition to controlling the gains of the high frequency stages, also controls the grid of a 6V6G tube as shown in Fig. 6. It will be seen that the 6V6G tube forms one arm of a bridge circuit, whilst R1, R2 and R3 form the other three arms. The bridge is balanced by adjusting R1 with the incoming signal at zero. When balanced, the potential difference across the relay is reduced to a minimum. If the incoming carrier is switched on at the sending terminal, the voltage developed on the A.V.C. feed will change the current flow through the 6V6 tube. This unbalance on the bridge will energise the relay, the voltage developed across the relay being proportional to the strength of the received signal. In this circuit the voltages on both relays are of the order of 7 to 10 volts, the variation probably being due to supply and impedance variations on the R.F. transmission lines.

Connecting a meter across this relay and checking all tuning stages on the receiver provides a simple routine for lining up the receiver.

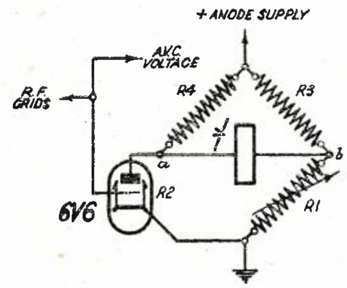


Fig. 6.

The fact that the crystal provides the source for the local oscillator frequency means that the lining up of the I.F. stages is a simple adjustment.

POWER SUPPLY AND TESTING EQUIPMENT

The primary source of power is a windmill driving a generator, which is connected across the battery. The windmill, together with the generator, is mounted on a lattice steel tower. The generator on this unit has an output of 40 amperes at 18 volts. A description of a similar type of windmill and plant appeared in Telecommunication Journal, Vol. 3, No. 2. Provision has been made on the later types of windmills for regulating the charging rate by varying the field current. In the Scottsdale-Flinders Island installations, however, this is achieved by a variable resistance in the output leads.

An audio frequency oscillator, giving an output of 6 milliwatts at 1000 cycles per second into 600 ohms, is included at each terminal. A copper oxide level indicator is mounted on this test panel, together with a speak-test key. A milliammeter, switch and suitable shunts in each anode feed is provided to read anode currents on the various stages.

ARRAYS

Both transmitting and receiving arrays are of the multi-element type and in each case consist of 16 half-wave vertical elements. These are arranged in two groups of eight and are all connected in parallel. The lateral spacing between the arrays is also half a wavelength. A further groups of half-wave elements arranged immediately behind the radiating arrays serve as reflectors and concentrate the radiation towards the distant terminal. The spacing between the array and the reflector is one-tenth of a wavelength. The gain of an array of this type over that of a single half-wave dipole is 13 db. Fig. 7 shows an outline of the general arrangement and indicates the simplicity of this type of radiator. Open wire transmission lines of nominal impedance 600 ohms are used to connect the equipment to the arrays.

Although, because of the small dimensions of the elements at ultra high frequencies, the arrays are of reasonably simple construction, it the transmission line are reduced to a minimum, it is possible to line up the transmitter to deliver maximum power to the radiating system, the major losses on the line being those due to heat.

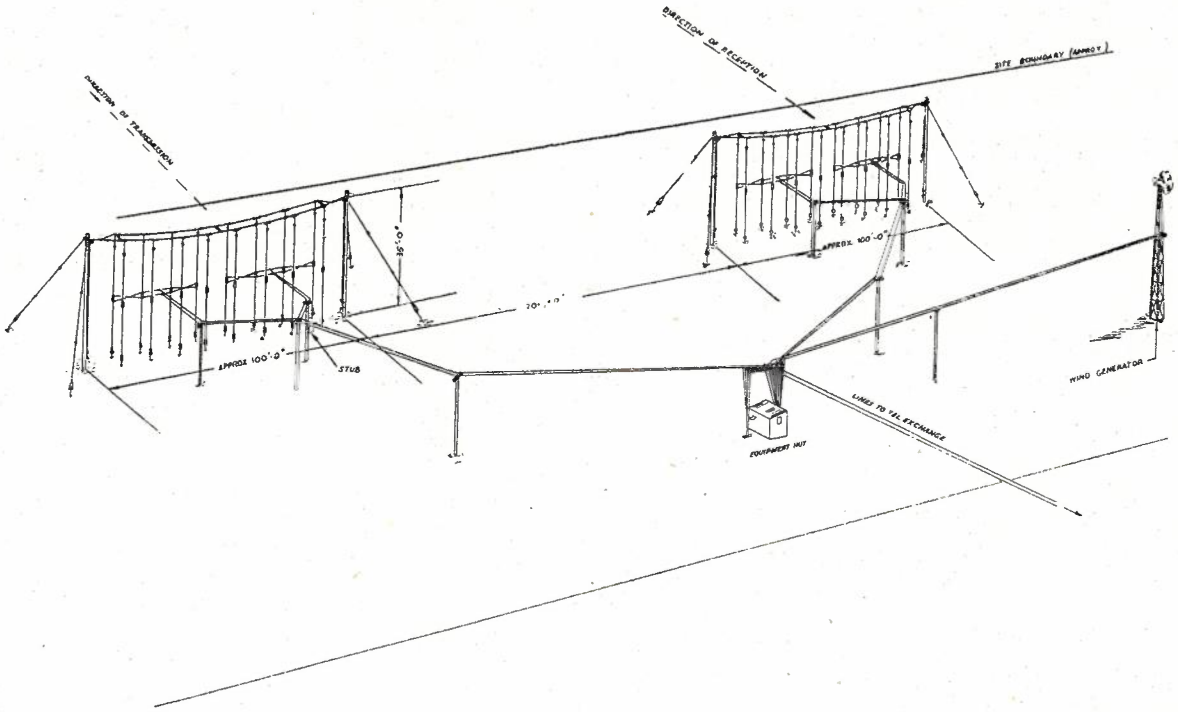


Fig. 7.

should be stressed that the margin of error is correspondingly small and great care is necessary when designing and surveying for direction.

For example, the stub in this case is a short-circuit stub only 25 inches long and is placed 24 inches from a current antinode on the array side. Without the stub the standing wave ratio (i.e., the ratio of maximum and minimum currents along the transmission lines) was 5/20. Connecting the stub changed this ratio to 8/11. The final adjustments were made by varying the stub length and position 2 or 3 inches on either side of the calculated position.

IMPEDANCE MATCHING

The input impedance of a half-wave dipole is approximately 2400 ohms. With the connections correctly phased, the eight dipoles in parallel should have an impedance approximately equal to 300 ohms. This would introduce a mismatch, when connected to the 600 ohm line. This may be corrected by measuring the standing wave ratio (i.e., minimum to maximum currents along the transmission line) and connecting a stub at the junction of the transmission line and the array feed. This stub may be either an open stub or a closed loop, its length and position being determined by calculations and the standing wave ratio. When the standing waves on

OVERALL EQUIVALENT

The overall equivalent 2-wire to 2-wire is 4 db. It is possible to line up to a zero circuit, and 4 db tolerance allows for variations in gain that may occur, due to supply or changes of the characteristics of R.F. transmission lines at each terminal with a resulting impedance change. These changes compare with those that occur on any normal open wire trunk throughout the day. The transmission lines in each case are 6 to 10 wavelengths long, hence the comparison with an open wire V.F. line.

The line-up of 4 db is made with 1000 cycles and the circuit then tested for stability with the receiving end opened at the line jacks, this condition simulating that of the telephonist placing a plug in the line with her listening key normal. The circuit is quite stable under this condition. Transmission tests conducted from various telephones in Launceston indicated that this level would be satisfactory, provided that the telephone output level was comparable with that of a standard handset. No difficulty was experienced on calls extended beyond Launceston on normal carrier systems, and the insertion of a cord repeater compensates for the loss of level introduced when calls are extended beyond Launceston on normal voice frequency circuits.

SPEECH INVERSION

Units are being assembled and tested for inverting audio frequencies over the radio channel. This is necessary as it is possible for any radio set of the superhetrodyne type operating on the 20 or 40 megacycle band in close proximity to either terminal to pick up the signals. The 2nd harmonic of the local oscillator on the 20 megacycle band covers the 40 megacycle band.

CIRCUIT FUNCTIONS AND OPERATIONS

Fig. 8 is a general schematic of the control equipment with other units shown in block. It will be noticed that the Scottsdale control circuit is different to that at Whitemark. This is due to the proximity of an electric power line of 80,000 volts, the impedance of the condensers in the hybrid transformers being sufficient to cause an unbalance on the voice frequency line, which resulted in a high noise level.

The modified circuit at Scottsdale eliminates the noise, but has the disadvantage of requiring batteries at the exchange. It is proposed to carry out tests with marginal relays to permit all functions to be performed using the battery at the radio terminal.

Functions of Remote Control Circuit:

(1) Switch on receiver only (Standby).
(2) Set up ringing circuit when called.
(3) Switch on receiver and transmitter (duplex).
(4) Switch off equipment (off).
(5) Indicate the voltage of the battery at the terminal.

The functions at both terminals are identical, the method of energising the relays to perform them being different. The circuit operation at the Scottsdale end will be described; the remote key (K1) at the exchange is mounted in a convenient position on the trunk switchboard.

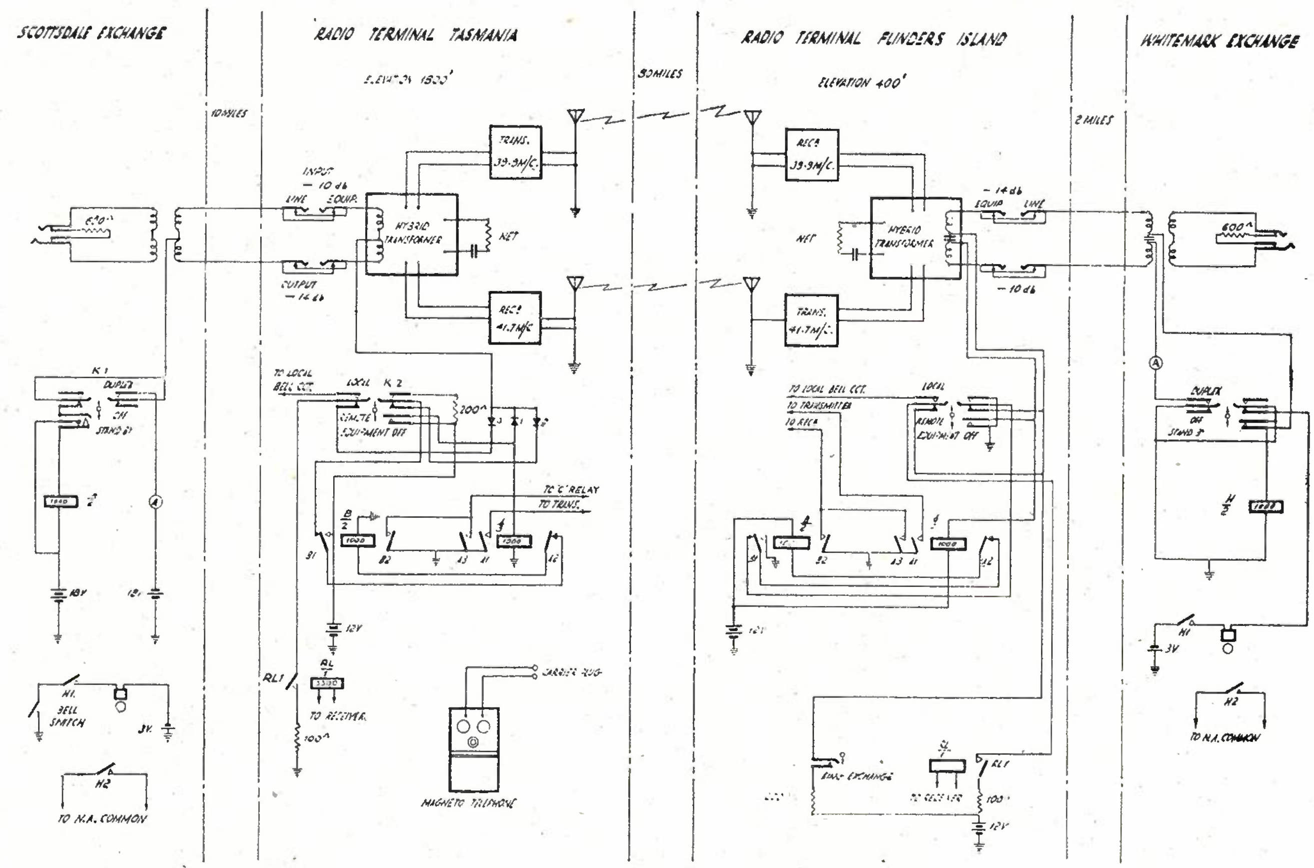


Fig. 8.

Function 1—Standby.—Key K1 is thrown to the standby position. The "make before break" contacts on K1 momentarily short circuit relay H and this allows B relay at the radio terminal to operate. B operates from ground, winding B, contacts A2, B1, K2 key, copper oxide rectifier 2, centre point of hybrid coil, cailho circuit over the voice frequency line, K1 springs, to positive battery and ground. B locks up via B1 contact to positive battery. Contacts B2 complete the circuit of relay C (not shown), which operates and supplies 12 volts to the heaters of all tubes and the vibrator unit. The vibrator supplies the anode potentials to the recevier and transmitter. The modulator and modulated amplifier cathodes are provided with automatic bias which reduces the anode currents practically to zero. The receiver is now ready to receive incoming signals or calls.

It will be noted that B relay, in locking up via B1, cleared the cailho circuit for the function 2.

Function 2.—Assuming that the far end (i.e., Whitemark) wishes to call, they would operate Key K1 to Duplex. This would switch on the transmitter and receiver at Whitemark, and, as the receiver at Scottsdale is on, the incoming carrier will operate the bridge relay RL. RL1 contacts close and complete the ring relay circuit as follows:—Ground, 100 ohms resistance, RL1, K2 springs, copper oxide rectifier 3, to cailho, K1 springs, winding H, + battery and ground. H operates and closes the bell circuit. H2 contacts provide the normal night alarm function.

Function 3.—To answer the call, Key K1 is operated to the "Duplex" position, clearing the ringing relay H at K1 springs, and feeding negative battery to the line instead of positive. Copper oxide rectifier No. 1 will now be conducting and will allow relay A to operate, from ground, winding A, rectifier 1, cailho to K1, milliammeter A and negative battery to ground.

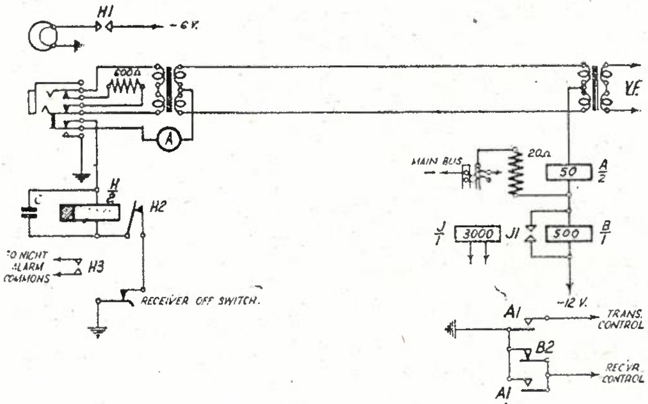
A operating, provides a holding circuit on C relay via contacts A3, and releases B relay via contacts A2. Contacts A1 short circuit all but the normal working bias on the modulator and modulated amplifier cathodes. This allows the transmitter to radiate a carrier to Whitemark, and the circuit is ready for duplex transmission. Each exchange connects to the line jacks and speaks. The 600 ohm resistance is necessary to provide the termination for hybrid balance.

Function 4—To Close Down. — K1 to normal closes down the transmitter and receiver by releasing A relay. It is always necessary to close down from the "duplex" position, otherwise B relay remains locked in.

Function 5 is only possible at the Whitemark terminal. As the operating current for the relays at Whitemark is provided by the 12-volt battery at the radio terminal, it is possible to determine approximately the condition of the battery at the terminal. The relay current is noted on the meter A by switching to "duplex" and then the drop in current as the equipment load is taken indicates whether the voltage is low or not.

ALTERNATIVE CONTROL CIRCUIT

Fig. 9 shows one method of performing the various functions over a single cailho or similar circuit. It has the disadvantage of using marginal relays, and would only be used when a second control circuit is not available. The circuit has the advantage of making the control operation at the exchange very simple, and eliminates the possibility of the transmitter being left switched on when not required. For ex-



FUNCTIONS:

1. Receiver on. A operated, J, B and H normal. (A operates in series with B and H.)
2. Receive call. Upon far end plugging into line jack, relay H is short circuited and operates B. Carrier then operates A.V.C. which energises J, at near end. J1 short circuits A, allowing B and H to operate in series. H lights calling lamp, and pulses by breaking own circuit. B, pulsing, provides ring tone back to caller.
3. To answer, telephonist plugs in, B operates permanently, and circuit is ready for conversation.
4. To clear, both ends take down cords.
5. Fuse operated will operate calling relays at both terminals. Upon contact faulty end will be indicated by meter reading A.

Fig. 9.

ample, where continuous working is required, it is essential that both receivers, when not carrying traffic, should be on "standby." This is necessary for the ringing function. Fig. 9 shows that this requirement is fulfilled automatically when the plug is taken out of the line jack.

The switch marked "receiver off" would be mounted on the test panel, as it is only required for test purposes. Where the working of the channel is on a half-hourly schedule or similar basis, this key has only two positions, and again there would be no danger of the transmitter being left switched on, as it is very unlikely that a plug would be left in the jack and forgotten. This is important as the transmitter load on the battery would increase the discharge rate by nearly 30%. It will be noted that the same functions are attained as in Fig. 8 and, in addition, a fuse alarm is provided, and a pulsing ring.

The inclusion of this circuit may serve to indicate that there are various ways of obtaining control functions over a single circuit, this one being more suited for short lines, as the marginal adjustments would be too fine where the circuit resistance approached a value of 300 to 400 ohms.

Where two control circuits are available, this would not present any difficulty as the marginal adjustment would not then be necessary.

Operation.—Relays H, A and B are all in series with the battery at the radio terminal. Relay H is adjusted not to operate in series with

B, and relay B is adjusted to operate in series with both A and B.

Relay A is adjusted to operate in series with B or H, but not in series with both.

The Functions are:—

(1) Standby.
(2) Receive call.
(3) Answer call.
(4) Clear.
(5) Call out.
(6) Fuse alarm.
(7) Provide ring tone.

Function 1—Standby.—As the receiver off switch is in the "on" position, relay B will be operated, but A and H will be normal. B being operated, the receiver will be on standby. It should be noted that the relay J on Fig. 9 and R.L. on Fig. 8 perform the same function.

Function 2—Call Incoming. — The distant end inserts a plug into the line jack, and this will switch on the transmitter and send carrier out. The incoming carrier operates relay J by unbalancing the bridge circuit. J operating short circuits B, and this allows A and H to operate. H operating, breaks the circuit and releases both A and H. Thus A and H will pulse and cause the ringing lamp to flash at each pulse until a plug is inserted into the jack. The condenser C increases the release lag of H. The pulsing of A will send out pulses of carrier to the calling end, so that pulses of signal and noise will give the effect of ring tone.

Function 3—To Answer.—When the called telephonist plugs into the line jack, the ringing relay H is cut off, and A is held in by the ground on the jack springs. A switches on the transmitter and duplex working can proceed.

Function 4—To Clear.—Each end restores plugs to normal. The first end to clear will receive the ring upon removing the cord from the jack, until the other terminal is cleared.

Function 5—Call Out.—Plugging into the line jack will short circuit relay H and allow A to operate. A operating, switches on the transmitter at A1 contacts and carrier is radiated.

Function 6—Fuse Alarm. — A fuse operating will short circuit B relay and operate the ringing relay H. H and A relays will pulse, as with an incoming ring and attract the operator's attention. When the operator answers, the fault will be apparent as the equipment will not operate.

CONCLUSION

In concluding, it is fitting to mention the excellent co-operation between officers in Sydney, Hobart, Launceston, Scottsdale, Whitemark and Melbourne on the opening day. All switching was carried out at Launceston, and the only hitch in the proceedings throughout the afternoon occurred when a black snake attempted to invade the cabin at Scottsdale. Its length apparently was elastic, as it varied, according to the party describing the incident, from 3 feet to 6 feet.

I wish also to express my appreciation and thanks to all officers for their assistance in compiling this article.

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SOME INFORMATION ON ROPE

A. V. McLaughlin

Rope is so universally used for hauling, lifting and binding that most people who are in the habit of using it determine from their past experience without conscious thought what size is required for any particular job, and the allowance needed to compensate for the age of the rope to be used if it is not new. Those who are not so familiar may consult a statement of standard practice for new rope giving breaking strength and safe working strength. The latter figure may be one-quarter of the former, while for secondhand rope under six months old the safe working stress allowable is generally one-half that of new rope, i.e., one-eighth the breaking strength. As this reduction is applied to sound rope, and there are many ways in which ropes can be made unsound unless proper precautions are taken, it is not surprising that an occasion sometimes arises when a rope fails under a stress which was easily handled previously by one of similar size. Some information regarding the nature of ropes and the care necessary to keep them in reasonable order might be of use to those who have not been acquainted with it.

The use of hemp by the Thracians for the manufacture of garments is recorded by Herodotus (Circa. 484-424 B.C.). It was in common use among the Romans in the first century for ropes and sails, etc. The more perfect methods of fibre extraction described by Pliny in the first century have varied little since then, except that machine methods have increased the speed of production. Whereas hemp fibre is extracted from the stems of Cannabis Sativa and is known as a soft fibre, the fibres generally used for rope and cordage are known as hard fibres and two typical ones in use for this purpose are briefly described.

Manila or Abaca fibre is derived from the plant Musa Textilis, which is almost indistinguishable in appearance from the banana plant during the period of growth. The fibre of the latter is, however, almost valueless for cordage. Musa Textilis is indigenous to the Philippine Islands and grows well on hilly volcanic slopes in moist, loose soil. Very little success is said to have been obtained in endeavours to raise it in other localities. The sheathing leaf stalks are cut off a few inches above the ground and split into widths of five to six inches. The stalks are beaten and scraped with suitable instruments by hand or by machine, with the object of completely removing the material surrounding the fibre, which is then well washed, dried and graded by experts into as many as 13 grades of fibre from A to M (with intermediate grades of varying colouration) in order of quality. This is known as the Philippine Islands grading system.

Sisal is produced from the fleshy pointed spine-margined leaves of plants of the order Amaryllidaceae and of the family known as Agave or Aloe. Several varieties are used, but the main Sisal fibre of commerce is obtained from Agave sisalana, which is grown extensively in South Mexico, Kenya, East Africa, and the Bahama Islands. In contrast to the Musa textilis the Agave plants are grown successfully on waste and arid land and require little attention after the preliminary clearing and planting out. As a result of the occupation of the Philippines by the Japanese the development of Sisal plants in areas under British and American control has been actively encouraged. Improved methods of cultivation and processing are producing Sisal, which is practically equal to high-grade manila. The leaves of the Agave may grow to a height from three to six feet. The mature leaves may be cut at from two to four years from planting and the others as they mature at intervals of six months, when the plant is cut down and the ground fallowed for a year prior to the introduction of a new plant.

The leaves are crushed and stripped in machines and the resulting fibre washed, dried, baled and graded. The object of the processes being to clean away the adherent pulp and dust from the fibre and to obtain a uniform product as white as possible. The fibre from the bales of manila or sisal is next set up in suitable proportions for the mixture to be made up and fed to a "Hackler and Spreader" between feed rollers. A series of hackles or pins moving faster than the feed passes through it and it is then drawn out through drawing rollers. The fibre may pass through a series of similar machines with the object of further equalisation and drawing until the fibre is finally delivered in the form of a thin, broad ribbon known as a sliver enclosed in a can known as a sliver can. In the spinning machine the fibres from the sliver are combed by gill pins and drawn through a ripping die to a flier from which it is wound on a bobbin. From the bobbins the ropes are made up in a rope walk, or small sizes up to 3 inches diameter may be made in full automatic "house machines." The principle in each is similar. In the rope walk the necessary number of yarns for each strand is drawn from the bobbins and passed in order through a number of holes in a register plate. A "traveller" draws out the strands while a rope gear rotates them. When a sufficient number of strands have been made they are given extra twist judged by experience, and the strands built up into rope by operating the "traveller." The above processes are adjusted to produce the correct hardness, lay and tension in the rope. From the "house machine" or rope walk the rope passes to coiling machines, where it is made up ready for despatch.

Ropes are designated usually by their circumferences in inches, and also by the number of strands, not including a heart if this is required. The length in which they are made up depends on the purpose for which they are used, but a common length for the smaller ropes is 120 fathoms. There is now an Australian Standard Specification (Emergency Series) for both Sisal and Manila Rope. The only difference between them are the plants from which the fibre is derived and the minimum breaking strength, which in the case of sisal is 20% less than the corresponding size of manila rope. The minimum breaking strength specified for five common sizes of manila rope, viz., 1 in., 1½ in., 2 in., 2½ in., and 3 in. are 10, 18, 30, 50, 70 cwt. respectively. The strength of rope is reduced by any of the following causes:—

(a) Repetition of ordinary stresses, overloading and sudden stress.
(b) Friction. Internal, by sharp bending; external, by rubbing over rough surfaces.
(c) Collection of sand and grit, which works into the rope and grinds the fibres to powder.
(d) Chemical — most commercial chemicals or wastes are injurious.
(e) Mildew—rope which has been wet should be dried promptly. Rope should not be stored in a damp place. The fibre is readily attacked by mildew, and if damp will rot rapidly. New rope which appears discolored should be viewed with suspicion.

An example of this damage was revealed recently, when a new 3-inch rope failed on a lift. There was no trace of acid or salt and an examination showed that over a section of about 3 feet there was a brownish discoloration present and a number of strands tested in tension broke at 10 to 20 lbs., whereas sound strands should have taken a hundredweight. A number of whitish spots were visible where the coils would have been touching before the rope was unwound and a microscopic examination showed the presence of mildew. It was decided therefrom that the rope had been wet at some time while in the coil and had been damaged by mildew. There are special treatments which can be applied to rope to proof it against water and rot. Many of them are applied to the fibre before being formed into rope and are proprietary processes. For ordinary purposes where rope can be kept dry or dried readily, the cost of special preservative treatment is not usually justified.

A summarised extract from some of the rules which a large overseas company require its employees to observe in handling rope is given below. It will serve to show the importance attached to careful maintenance. An examination of the external and internal condition of the rope should be made when rope is taken into charge. A weekly inspection of the external condition and a monthly inspection of the internal condition should be made. A check inspection should be made two to four times per annum. Defects to be looked for are as follow, and if there is any doubt regarding the safety of using the rope it should be exchanged for good rope.

Externally.

(a) Abrasion (broken fibres).
(b) Cuts.
(c) Too soft. (Badly worn rope which has lost its stretch is extremely soft.)
(d) Decayed or burnt by heat or chemical action.

Internally. Separate the strands at 3-foot intervals and inspect the inner part for—

(a) Broken fibres.
(b) Fine powder denoting the presence of grit.
(c) Mildew or mould.
(d) Change in colour of fibre.

New rope in the original coil should be stored in a dry place with free circulation of air until required for use. Used rope should be stored similarly or on reels. Rope which has become wet should be dried as soon as practicable by hanging it in loose coils on pegs in sunshine, or a warm room with a free circulation of air through the coils. Rope should never be placed over a hot radiator or too near a fire. Used rope when not placed on reels should be coiled by laying out the turns in a clockwise direction. When uncoiling used rope turn the coil over and draw from the top, that is, the first coil laid down. When uncoiling from a new coil remove the binding, secure the outside end to the adjacent turn, place the coil on the flat with the inside end nearest the floor, withdraw the inside end from the bottom up through the centre of the coil. Before cutting rope bind it with several turns of friction tape on each side of the cut, which should be done with a sharp tool. If rope has been covered with mud, sand or grit in hauling it should be dried as soon as practicable and then whipped up and down on a smooth, flat surface such as a paved road to remove embedded dirt, which will otherwise work in and grind away the fibres.

AERIAL LINE CONSTRUCTION

A. S. Bundle

PART 5 WIRES AND WIRING

This section deals with:—
- Types of Line Wires.
- Attachments
- Wire Spacing Problems.
- Erection.

TYPES OF LINE WIRES

The fundamental purpose of a telephone pole route is to support electrical conductors in the form of wires which will conduct electric currents between two stations. These wires must be good conductors and be insulated from earth and from one another, as well as having reasonably low inductance and capacitance so as to permit of the maximum transfer of electrical energy (in the form of oscillatory currents) from one station to another.

Solid circular wires are almost universally used for telephone conductors on pole routes. The materials commonly used are:—
- Galvanized Iron.
- Hard Drawn Copper.
- Cadmium Copper.

Iron, or galvanized iron wires were used for the early telegraph and telephone wires, and are still used in some instances where strength and economy are more important than attenuation. The material is actually a low carbon steel containing approximately 0.8% of combined carbon and this steel is galvanized with a virgin zinc spelter.

The most commonly used telephone wire material is hard drawn copper which is made from electrolytically-refined copper drawn cold through dies in order to get maximum strength. For the same weight per mile of wire, the resistance of hard drawn copper wire is about 1/6th that of G.I. wire, while its strength is approximately equal to that of G.I. wire. Its price is approximately five times that of galvanized iron. Thus, it will be seen that for the same line resistance, 1/6th as much copper is required as iron, and the cost is lower, being 5/6th that of the iron wire. Moreover, the capacitance of H.D.C. wire of equal resistance to iron wire will be very much lower as the capacitance depends upon the diameter. The inductance of iron wire is also appreciably higher and varies considerably with frequency, whereas the inductance of copper wire varies very little with frequency. There are, however, some circumstances where the smaller copper wire may not have sufficient strength to withstand the severe stress conditions, such as on a tree-sling line. If the stress conditions are severe and the length of the route is so short, that the transmission requirements are not great, then the heavier (and consequently stronger) iron wire would be used.

Where transmission requirements are important and the strength of hard drawn copper wire is **not** sufficient, cadmium copper wire (copper alloyed with 0.8% cadmium) is used. This alloy is 1.18 times the resistance and 1.47 times the strength of hard drawn copper. Its cost is about 1.28 times that of hard drawn copper. Hence, a cadmium copper wire having the same resistance as hard drawn copper would be 1.74 times stronger and 1.4 times dearer.

For trunk line purposes cadmium copper wires weighing 118 lb. per mile and 237 lb. per mile are used wherever cadmium copper is justified.

For the reasons given in the foregoing, the general uses for the different types of line wire are as follow:—

Subs.' Lines.

Condition	Types of Wire Used
(a) General.	Cadmium copper wire weighing 40 lb. per mile.
(b) Long Lines (Severe Conditions) or subscribers' routes of over 3-chain spans.	Cadmium copper weighing 70 lb. per mile.
(c) Short Lines (Severe Conditions, e.g., long spans, tree - sling routes, severe wind, overhanging branches.)	G.I. wire weighing 200 lb. per mile.

Trunk Lines.

Condition	Types of Wire Used
(a) General.	Cadmium copper weighing 70 lb. per mile. H.D.C. weighing 100 lb. per mile; 200 lb. per mile; 300 lb. per mile. (According to transmission requirements.)
(b) Long Lines (Severe Conditions).	Cadmium copper weighing 118 lb. per mile; 237 lb. per mile. (According to transmission requirements.)
(c) Short Lines (Severe Conditions).	G.I. wire weighing 400 lb. per mile.

Table 8 sets out useful data for the types of line wires in common use.

In U.S.A. a special composite wire is used where extra strength is required. This is known by the trade name of "Copperweld" and consists of a steel core surrounded by a thick skin of copper.

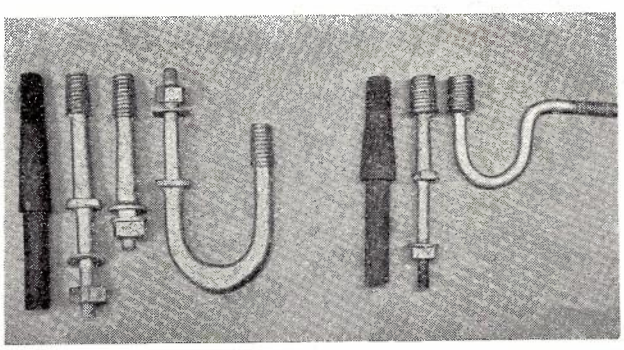
TABLE 8.

LINE WIRE DATA

Usual Title	Weight in lb./mile	Diameter inches	Resistance per mile ohms	Minimum Breaking Load lbs.	Approximate attenuation in db. per mile			
					1 kC./sec.	10 kC./sec.	30 kC./sec.	42.5 kC./sec.
40 lb. Cadmium Copper	40	0.050	27.48	200	0.4			
70 ,, ,, ,,	70	0.066	15.7	345	0.3			
100 ,, Hard Drawn ,,	100	0.0791	8.8584	330	0.12	0.151	0.260	0.304
118 ,, Cadmium ,,	118	0.086	9.36	550	0.12			
150 ,, Hard Drawn ,,	150	0.0969	5.8999	490	0.09			
200 ,, ,, ,, ,,	200	0.1119	4.4206	640	0.069	0.112	0.205	0.249
237 ,, Cadmium ,,	237	0.121	4.68	1040	0.069			
262 ,, Hard Drawn ,,	262	0.128	3.3712	830		0.102	0.189	0.230
300 ,, ,, ,, ,,	300	0.137	2.9413	945	0.05	0.096	0.181	0.220
400 ,, ,, ,, ,,	400	0.1582	2.2017	1250	0.04	0.088	0.167	0.203
600 ,, ,, ,, ,,	600	0.1937	1.4649	1800	0.03			
200 ,, Galvanized Iron	200	0.124	26.64	600	0.25	1.07	1.87	
400 ,, ,, ,,	400	0.171	13.32	1200	0.20	1.57	1.57	

ATTACHMENTS

On normal open-wire construction the wires are attached to vertical insulators which in turn are supported either above a crossarm or out from a pole by spindles. Cheaper and lighter insulators and spindles are used on the less important lines, such as subscribers' lines, than on the longer trunk lines since the insulation requirements per unit length of subscribers' lines are of the order of 1/10th those of trunk lines.



Left to Right: Spindle Trunk Wood L.S. (Tk. L.S.). Spindle Trunk Steel, ⅝" Tk., ⅝" L.S. Spindle Transposition. Spindle Trunk J.L.S. (Tk. J.L.S.). Spindle Sub. Wood. Spindle Sub. Steel, ½". Spindle Sub. Swan Neck, ½" (sub. S.N.).

Fig. 34.—Typical Spindles.

Spindles.—There are several types of spindles provided to meet the various requirements and Fig. 34 shows some of the spindles in common use.

Wooden spindles are used on crossarms if the pull is not likely to exceed 80 lb. Wood is used only for economy, the cost of wood spindles being of the order of 1/6th that of steel spindles. Wood spindles have the following disadvantages, however, which tend to nullify the economic advantage:—

(a) Shorter life; 10-20 years compared with 40-80 years for galvanized mild steel spindles.

(b) Greater fault liability. The wood spindles break more often and are not as securely held in the crossarm.

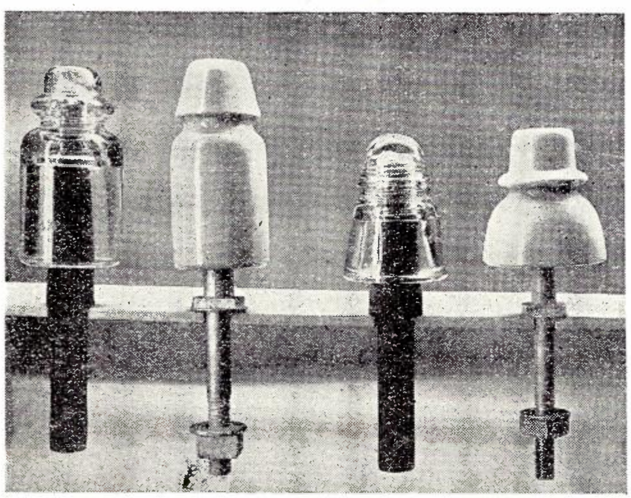
(c) Greater dielectric absorption and displacement current losses at high frequencies. These, moreover, vary with the weather conditions, and tend to make the circuit unstable.

(d) Limitation of efficient insulator design. The efficiency of an insulator is dependent upon the length and width of the insulating surface, which becomes a leakance path when dirty or damp. Hence the diameter, which controls the width, should be as small as possible. However, this is limited by the diameter of the spindle, which in turn is governed by the stresses imposed on it, its shape and length, and the strength and durability of the material of which it is composed. A wood spindle made to the same dimensions as a steel spindle would not have sufficient strength and so it has to be made larger with a consequent need for a wider insulator.

Wooden spindles are also used extensively in the U.S.A., but in Great Britain only steel spindles are used.

In Australia these spindles are usually turned from Spotted Gum or Iron Bark, obtained from N.S.W. and Queensland, these timbers being particularly strong and durable. Except in very dry climates, it is desirable to impregnate wood spindles with creosote in a hot tank, thereby pre-serving the fibres and discouraging termites. Where necessary the spindles are prevented from lifting out of the crossarms by passing a piece of wire through the fid hole near the bottom of the spindle.

Steel spindles are used in all cases where there is greater stress such as at heavy angles, terminations and transpositions or where special shapes are required as in the case of swan-neck or J-spindles. These consist of mild steel rod forked or bent into the desired shape with an antimonial lead head moulded at the top. This head has an external taper thread on which the insulator is screwed. It is usually secured to the spindle by jagging the spindle top with chisel cuts; the lead fills these voids and is thus keyed on to the spindle. A more recent development is to tin the upper end of the spindle and then mould the lead on while the tinning metal is hot, so that the lead unites with the tinning metal on the spindle. The steel spindles shown in Fig. 34 will withstand, without permanent deformation, loads of 800 lb., 830 lb., 800 lb., 250 lb., and 250 lb. respectively.



Left to Right: Insulator Trunk Glass Long Skirt (Tk. G.L.S.). Insulator Trunk Porcelain Long Skirt (Tk. P.L.S.). Insulator Sub. Glass (sub. G.). Insulator Sub. Porcelain (sub. P.).

Fig. 35.—Insulators in common use.

Insulators.—The insulators to which telephone wires are attached are designed to combine minimum leakance, minimum weight and minimum cost. Porcelain and glass are the only materials available in quantity to give high insulation at low cost with weather-resistant properties. Fig. 35 shows the types of porcelain and glass insulators now being provided for trunk and subscribers' lines in Australia.

Porcelain insulators are made from a mixture of quartz, feldspar and clay. These ingredients, in a finely ground condition, are suitably mixed with water and worked into rough shape, after which they are turned and polished into final shape, dried thoroughly, dipped in glaze mixture and baked. The feldspar, when heated to correct vitrifying temperature (1200-1300° C.), acts as a flux permeating the whole mass and binding the whole into a solid non-porous mass. After 36-48 hours' firing the vitrifying temperature is reached, after which the kiln is allowed to cool and the insulators are then removed, sorted, tested and packed. The firing temperature for vitrification is fairly critical. Underfiring results in a porous, non-vitrified mass, while over-firing results in the formation of gases which cause the insulator to swell and become "puffy," large pores being formed by the gases.

Australian glass insulators are made from various combinations of silica (sand) with soda and lime, together with quantities of potash, alumina, magnesia and lead oxide. The material is heated to temperatures of the order of 1200° C. according to the mixture, and allowed to flow from the furnace at a controlled rate. The flowing molten glass is cut in sections as it falls by automatic scissors. These sections or "dew-drops" fall into separate moulds into which dies are pressed to force the plastic dew-drop into the shape of an insulator. The "die" consists of a special block of the shape of the inside of the insulator and a mandrel which forms the thread. The mandrel is screwed out and then the rest of the die is withdrawn. The cherry-red insulator (then at about 1000° C.) is removed from the mould and placed in a "lehr" (annealing chamber), in which it is annealed by being raised to 1100° C. and then allowed to cool steadily over a period of five hours. Automatic machines are used, consisting of a rotating table carrying 12 moulds, each of which stops under the molten glass stream long enough to receive one "dew-drop" and then rotates to another position for moulding, extraction of mandrel, etc. The only hand operation is the transfer of the insulator from the mould to the lehr. The rate of manufacture on such a machine is about eight per minute.

Porcelain insulators are the most commonly used in Australia. Experience with glass up to the present has not been so satisfactory because of a much higher percentage of breakages and lower insulation, especially during wet weather. Ordinary glasses used for making bottles, jars, dishes and the like, contain a high percentage of alkali which will absorb moisture deposited on the surface of the insulator and form a leakage path over the surface. It is necessary, therefore, to use special glass with low alkali content or else to take some special action to remove the alkali from the surface of the insulator. The better quality glasses are borosilicates in which boric oxide replaces the sodium and magnesium oxides. However, borax (the mineral) is not found in Australia and so this type of glass is much dearer to produce. A special skin treatment has recently been introduced in the manufacture of glass insulators now being produced in this country, which removes much of the alkali from the surface. This tends to prevent the formation of a conducting film and also the subsequent pitting or roughening ("weathering") of the surface caused by the removal of tiny particles of alkali. A smooth surface serves to prevent the formation of a film of dirt over the surface, and even if such a film starts to form it can be readily washed off by rain, there being no tiny interstices to which the dirt can cling.

The greater tendency of glass insulators to break is attributed to internal stresses set up during cooling because of the different rates of cooling where the thickness of the glass changes. This calls for special care, both in design (to avoid sharp changes in thickness of glass) and in the annealing treatment during manufacture.

The transparency of glass gives it one important advantage over porcelain. The illumination of the inner surface of the insulator skirt discourages spiders from building their webs and so providing leakage paths, any single web possibly causing more leakage than hundreds of comparatively poor insulators. In some cases, spider webs are very frequent, but the trouble can be overcome to a considerable degree by using glass insulators.

In America and other parts of the world, glass is largely used for telephone insulators, but is of different grade (usually borosilicate) from that which has been available in Australia at reasonable cost. Good quality borosilicate glasses have lower dielectric constant, of the order of 5 compared with about 8 for soda lime glasses with correspondingly less power losses.

With good quality glass or porcelain the conductance through the material is considerably less than that over the surface of the insulator after it has been in service for several months. Careful design is, therefore, necessary to ensure adequate and stable insulation, the following considerations being important:—

(a) To have as long and narrow a surface as practicable, so as to offer minimum conductance.

(b) To have the maximum length of dry surface between wire and spindle, even during heavy rain—due regard being had for the splash effect from rain beating on the crossarm.

(c) To have the outer surface at such an angle as to prevent accumulation of dust on the surface and provide maximum washing by rain. This condition has been shown to be reached when the sides are vertical, or nearly so.

(d) Simplicity of design, low manufacturing cost and minimum weight.

From the above, it will be appreciated that for high insulation a long, narrow insulator with vertical sides is desirable, but length and width are limited by spindle size and by economy. The longer the insulator, the larger must be the diameter of the spindle to withstand the greater bending moments resulting from horizontal stresses applied by the wire.

High frequency considerations, on the other hand, demand low capacitance between the spindle and the wire, and the minimum leakance film on the insulator surface. High frequency losses can be considerable if there is a high resistance leakage path over the surface of the insulator. This path may be regarded as a series of resistance elements each of which has capacitance to the spindle. During wet weather the resistance of the surface is considerably lowered and appreciable displacement currents flow over the surface and through the capacitance to the spindle. It is, therefore, necessary—

(a) to limit the capacitance by having adequate spacing between insulator surface and spindle, and

(b) to maintain a surface of very high resistance such that displacement currents would be negligible.

The H.F. requirement (a) in its physical aspect conflicts with the D.C. requirements with regard to size, and the latest designs of Trunk Long Skirt (TK. L.S.) insulators shown in Fig. 35 represent fairly closely the optimum between these limits. They also combine simplicity of manufacture and lightness. A smaller diameter thread at the top of the spindle would serve to reduce appreciably the wire-to-spindle capacitance, but this is not practicable with a wood spindle and Australian practice is to use the same insulator, either with wood or steel spindles. Latest practice in the U.S.A. is to have separate insulators for use with wood and steel spindles and to use steel spindles on high-efficiency circuits. These spindles are also bonded together to obviate displacement current losses in the crossarms.

Because of the greater liability of breakage with glass insulators the present policy in Australia is generally to use them only on straight sections and to use porcelain insulators wherever there is appreciable stress such as at angles, terminations and transpositions.

WIRE SPACING PROBLEMS

The problem of wire spacing and sagging is fundamentally one of carrying a number of pairs of wires with the two wires of each pair as close together as possible without danger of them contacting with one another, yet avoiding the too frequent provision of poles. It is necessary also to avoid tensioning the wires too tightly so that they will not be liable to break. It should be pointed out here that the number of faults due to both excessive tension and fatigue increases with the tension of the wires, and it is therefore advisable to allow the maximum sag that is possible without danger of the wires contacting.

The primary conditions associated with the contacting of wires are:—

(a) wind velocity;

(b) sag;

(c) span length; and

(d) wire spacing.

Hence, to be able to determine the standards of span length, sag and wire spacing to which wires should be erected, it is necessary to know what are the wind velocities at which wires are liable to contact under various conditions of span length, sag and wire spacing.

Threshold of Contact Velocity is the term used for the wind velocity normal to the line, at which wires are likely to contact under a given set of conditions (b), (c) and (d). Information enabling this to be determined has been obtained by an elaborate series of experiments carried out at Chester, New Jersey, U.S.A., from January, 1929, to May, 1936, by the Bell Telephone Laboratories. The results are summarised in the nomogram in Fig. 36, which is constructed from the empirical expression:

$$V_w = 22.4 \left(\frac{L^{0.1} \, S^{0.3}}{d^{0.25}} \right)^{2.1} \qquad \text{(15)}$$

Where

V_w = Threshold of contact velocity (miles per hour)

L = Span Length (100 to 260 feet)

S = Wire Spacing (3 in. to 12 in.), and

d = Sag of wires at rest (4 in. to 45 in.).

Wind Gusts.—From a study of the frequency of maximum daily wind gusts in Australia per year, it has been found that 55 m.p.h. may be selected as a wind gust velocity which is exceeded so very infrequently that it is not necessary to design for higher contact velocities. It must be borne in mind that the wind velocity is completely effective only when normal to the line; in other cases the resolved component (normal to the line) of the wind being effective.

Wire spacing and span lengths are determined arbitrarily from:—

(i) Transmission requirements.

(ii) Cost of pole provision.

(iii) Transposition interval lengths.

(iv) Other factors, including the maximum tensile stress of the material used for line wires.

Wire Spacing.—For many years the standard wire spacing was 14 in. both horizontally and vertically for trunk lines and 7 in. horizontally and 14 in. vertically for subscribers' lines. With the advent of multi-channel carrier systems it was found advisable to reduce crosstalk coupling by changing to 9 in. spacing between pairs and a minimum of 19 in. between adjacent wires of adjacent pairs. The vertical spacing is also being developed to 28 in., particularly on new routes or between the more important arms of an existing route. Action is being taken to change the spacing to these newer standards in the most economical manner by taking advantage where practicable of reconstruction or re-poling works as these become necessary.

Assuming a maximum span length of 3 chains and minimum wire spacings that may be assumed to have been standardised at 9 in. for trunk circuits and 7 in. for subscribers' circuits, it is then necessary—

(a) to determine the maximum sag which can be provided to ensure freedom from contact, and

(b) to allow an adequate factor of safety on the minimum breaking load of the wires in the severest weather conditions, which combine heaviest wind loading and increased stress because of contraction of the wires at the lower temperatures.

From Fig. 36 it will be found that the maximum sag that can be fixed for these conditions is 21 in. With this sag, even for a 4-chain span, the Threshold of Contact Velocity is 45 m.p.h. It will be appreciated that this velocity is not likely to be reached often, when it is remembered that it is only the resolved velocity component **normal** to the wires which applies.

Weather Conditions Affecting Stress and Sag.—The weather conditions in Australia which control wire loading and sag are briefly summarised as follow:—

(a) The maximum air temperature which can be expected is 120° F. The temperature of the ground surface may, under windless conditions, reach 170° F., but even with a low velocity wind most exposed objects quickly reach the approximate air temperature, and this would not be exceeded during high winds.

(b) The minimum air temperature for which it is necessary to design is 20° F. At this temperature there is no likelihood of winds with a velocity of over 50 m.p.h.

(c) The maximum wind velocity which it is estimated may be expected once every 10 years is 75 m.p.h. Greater wind velocities are experienced during cyclonic disturbances, but these occur at relatively high temperatures and the stresses involved would be readily catered for by the factor of safety used.

(d) The minimum temperature at which maximum velocity winds can be expected is 44° F. This condition applies as far north as Newcastle, due to cold air movements from the south.

In general, the conditions outlined above apply to the coastal belt and the wind velocities decrease over the inland regions. As most of the open-wire construction is more or less near the coast, it is advisable to base design for coastal conditions.

Thus, from (a) it will be seen that the maximum sag of 21 in. would be expected to occur at 120° F. and from (b), (c) and (d) the maximum stress might be expected either at:

(i) 50 m.p.h. wind at 20° F., or
(ii) 75 m.p.h. wind at 44° F.

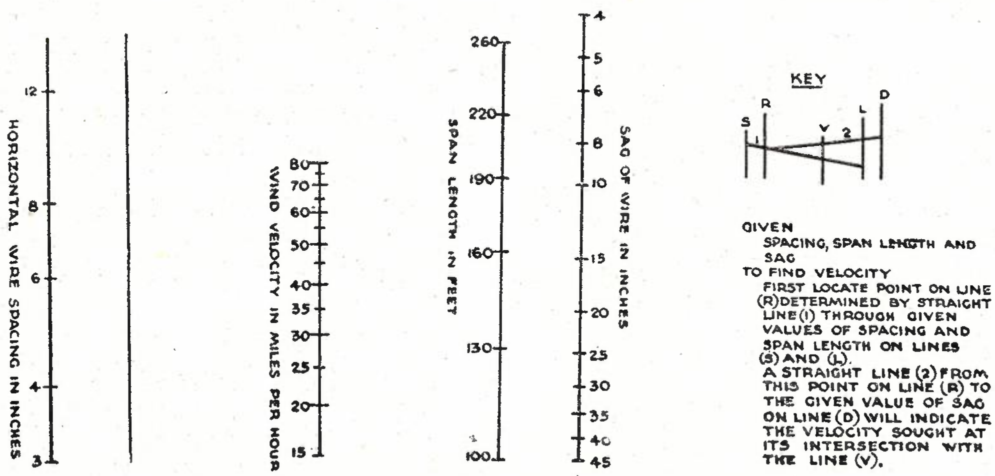


Fig. 36.—Nomogram for Determining Wind Velocity (Threshold) Normal to the Line, at which Wires of a pair begin to contact.

Wire Loading.—

The load on the wire—

$$= \sqrt{W^2 + P^2} \quad \ldots \quad (16)$$

Where W = weight of wire,
P = wind load which in lb. per sq. ft. of projected area of the wires
= $0.003V^2$ where V
= wind velocity in m.p.h.

Calculation of Stress in Wires.—When a wire is suspended between two horizontal supports it forms a curve which is called a catenary. Over the comparatively short normal spans between telephone poles this curve is for practical purposes equivalent to a parabola, and the parabola equations can be used for calculation in lieu of the more complicated expressions for the catenary curve.

A graphical method of using the catenary formulae has been devised in the form of curves known as the Thomas Chart, but for the comparatively short spans normally used for telephone work and in most cases where the sag is less than 10% of the span length, the plotting inaccuracies in the graphical method might be greater than the calculation from the parabola formulae.

The stress in a wire for a given sag may be calculated from:

$$f = \frac{l^2 dq}{8S} \quad \ldots \quad (17)$$

Where f = stress in lb. per sq. in.
d = weight per ft. per sq. in. (= 3.852 for H.D.C.)
q = ratio of weight of wind loaded wire to weight of wire in still air (= 1 for wire in still air)
S = sag in feet.

Thus for hard drawn copper wire in still air at 120° F. and a span of 66 yds. the stress will be 10, 787 lbs. per sq. in.

The stress under worst conditions of wind and temperature can be calculated from an extension of the parabola formula (see appendix 1) to ensure that an adequate factor of safety is obtainable. In this particular case the maximum stress occurs at 44° F. with a wind velocity of 75 m.p.h., the stress being 29,050 lb. per sq. in. Compared with the minimum breaking stress for H.D.C. of 65,000 lb. per sq. in., this allows for a factor of safety of 2.24 under worst conditions which might be expected to occur only at very infrequent intervals.

Preparation of Stringing Charts. — To enable wires to be erected in practice it is necessary to know what will be the sag of the wires for varying span lengths and varying temperatures. This information can be calculated and set out either in the form of graphs or tables.

Fig. 37 shows a chart calculated from the parabola formulae as shown in appendix 2, for sagging hard drawn copper wires. From (17) it will be seen that as d is constant for any one material the sag is proportional to the stress for the same loading (i.e., with q constant), so that all wires of the same material can be sagged to the same extent. Separate graphs are, therefore, required only for H.D.C., Cadmium Copper and G.I. wires for wire spacings of 7 in. and 9 in. For purposes of standardisation it is desirable that wires at 14 in. spacing be erected (or re-regulated if work is being done on existing wires) with similar sags to those at 9 in. spacing.

WIRE ERECTION

With the increasing use of multi-channel carrier systems and the generally improved grade of service (except possibly under war-time conditions) the proper erection of wires is an extremely important work. Not only does efficient carrier operation call for accurate and even regulation, but also for proper care in the handling and erection of the wire so as to obviate as far as possible the subsequent development of faults, each of which is liable to result in the interruption of numerous working telephone or telegraph channels. Rule-of-thumb methods are no longer satisfactory. This phase of the work should be regarded as of special importance, careful and correct erection being of greater importance than speed. The principal factor in obtaining speed is proper organization to avoid loss of time such as would occur in unnecessary retracing of steps.

The erection of wires may be divided into three stages, viz.:

(1) Erecting the wires on to the crossarms.
(2) Regulating the wires.
(3) Securing the wires—this is to be covered in a later section, "Attachment of Wires."

Scheme of Operation. — When erecting wires the general scheme is to terminate the new wire or join it to the existing wire at the starting

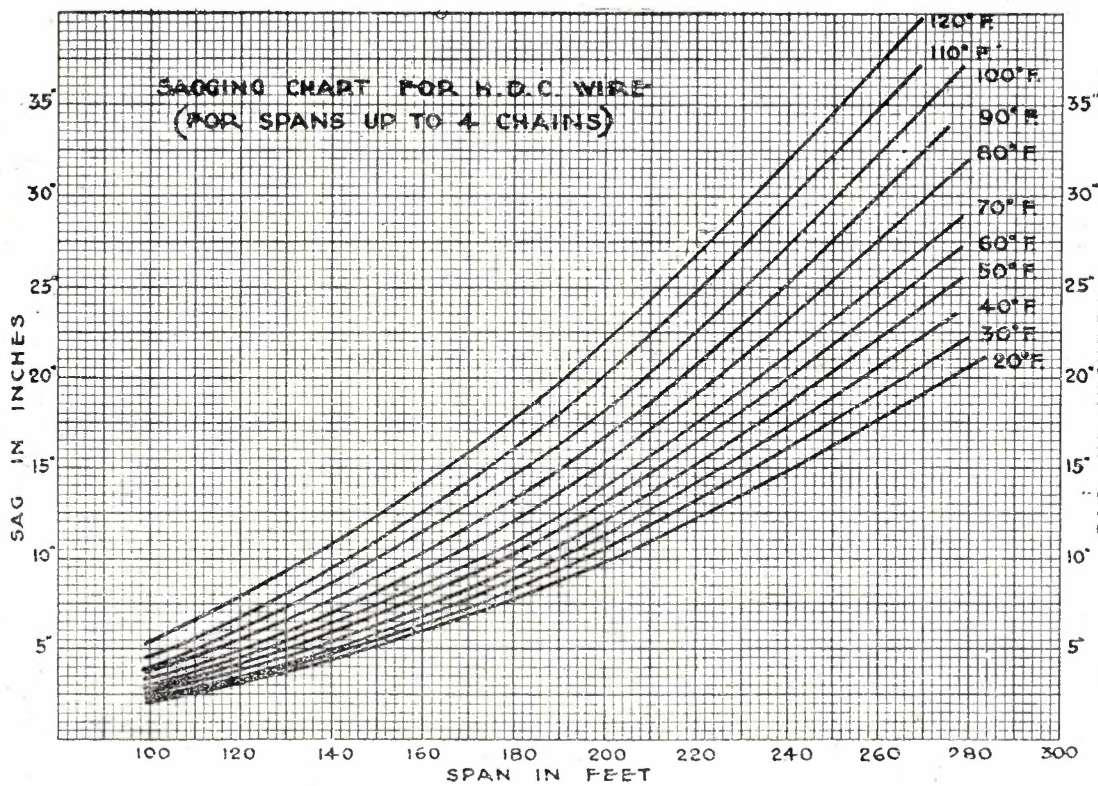


Fig. 37.—Sagging Chart for H.D.C. Wires (Spans up to 4 chains).

The calculation of the chart in Fig. 37 has been based on the application of the results of the Bell System Laboratories' experiments to the Australian weather conditions as enumerated above. Careful and accurate sagging (or "regulating") of the wires in accordance with this chart should allow minimum stress without danger of contacting and consequently result in fewer breakages from fatigue or over-tensioning. An important aspect often not appreciated as contributing largely to the contacting of wires is the creeping of angle and terminal poles in the direction of the resultant pull of the wires. The ground is compressed or displaced under pressure from the pole or stay plate under the severest loading conditions and allows the head of the pole to move towards the pull. Once a pole has moved in this manner it does not appreciably return towards its original position when conditions change and the loading is eased, so that in hot weather the sags in the wires become excessive, resulting in lower "threshold of contact velocity."

point and draw or run out the new wire to the full extent of the coil. If two or more wires are to be erected the full number should be run out at the same time, provided that sufficient equipment is available, as this saves time in retracing steps. When a coil is completed it is anchored temporarily until the wire has been regulated up to that point. This is to permit the joint to the wire on the new coil to be so adjusted that when the wires are tensioned the joint will be within reach from the pole. The wires are regulated every few (not more than eight) spans progressively, the tensioning points usually being transposition poles or angle poles, it being necessary to regulate at every transposition and at heavy angles. When the wires have been regulated and held at a pole near to the end of the wire the new coil is joined up, the end of the previous wire being cut off if necessary, to ensure that the joint will be within reach from the pole, but not within 1 ft. 6 in. of the insulator, when the wires have been regulated. The new coil or coils are then run out and the wires regulated as before.

The precise procedure must depend upon the conditions applying to each individual job, such as number of men and amount of gear available, number of wires to be erected, and the local conditions. The general policy where the staff is sufficient is to carry the work forward without going back over the route. If staff is limited one method is to run out and regulate for one day and on the following day to tie the wires into the insulators.

Handling of Wire.—The strength of every span of wire is only as great as the weakest point. Any nicks or kinks made in the wire decrease its strength and are liable to result in failure subsequently. Hence, it is important—

(a) to handle the coils carefully, keeping them wrapped until the last moment when everything is in readiness for the wire to be erected;

(b) to prevent the wire being trodden on or run over during erection; and

(c) to keep it taut enough to avoid excess loops which will result in kinks when the wire is drawn tight.

Coils of wire should be examined on the outside, especially at points where the wrapping may have become torn or rubbed through, to see that there are no nicks or scratches. Any such injured sections of the wire should be cut out.

Hard drawn copper wire becomes annealed when heated above 480° F. and loses much of its strength, so that it is necessary to keep the wire clear of fires or very hot objects. Line wires should not be soldered at any point where they will be under tension, as the melting point of 50/50 solder is about 417° F. and that of the solder now being obtained 480° F. It will be appreciated that the margin between these temperatures and the annealing temperature of copper is so small that there is great likelihood of weakening the wire.

Equipment. — For erecting the wires several special items of equipment are required, these being as follows:—

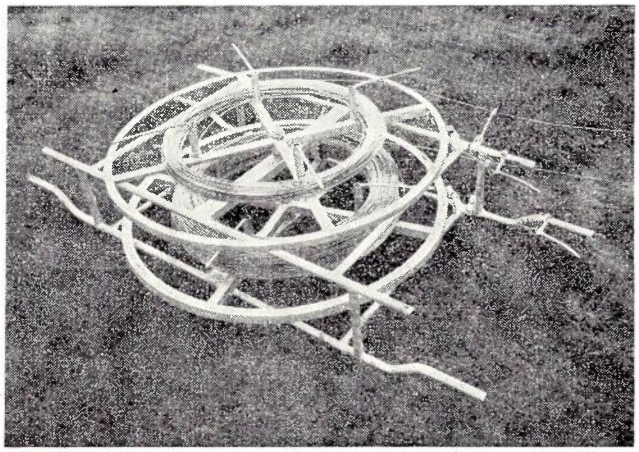


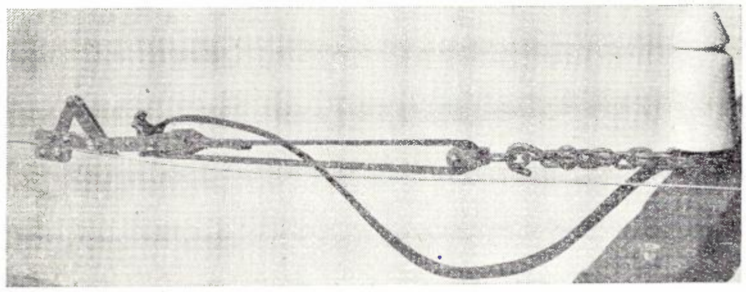
Fig. 38.—Wire Barrow—Tubular Construction.

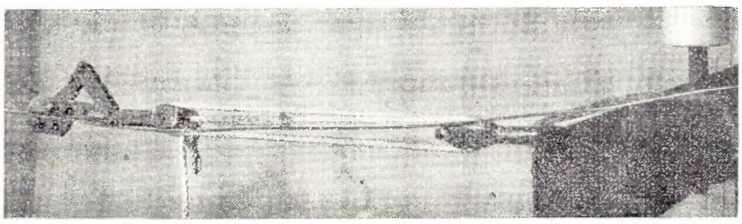
Wire Barrows.—These are used to hold the coil of wire and permit the wire to be paid out without twisting or kinking. The type of wire barrow now being supplied is illustrated in Fig. 38. This is really a double barrow of tubular construction. Two drums each supplied with carrying handles assemble together for mounting upon a truck if the wire is to be paid out in this manner or to rest on the ground if the wire is drawn out. A hand-controlled brake is fitted to each drum, the brake handle being attached to the carrying handle.

Wire Grip.—This appliance is used to grip the wire and pull it up to full tension. It is illustrated in Fig. 39A and consists of a grip which will seize the wire without damaging it and a strong leather strap which passes over a roller so as to permit of a mechanical advantage of three (less friction) (actually slightly less than two) being applied to the wire by the operator. A special cam-shaped clasp with ridges readily grips the strap at the point to which it has been pulled, yet can be released without difficulty. Figs. 39B and 39C show alternative forms of equipment for gripping and tensioning wires. The former is an earlier and still popular form of grip, sometimes referred to as "Buffalo Grip" or "come-along." The latter is called a "Snotter" and is made by wrapping about 2 ft. 6 in. of rope around the wire so that the wire fits into the channel formed between two of the strands of the rope. The grip of the rope on the wire is released by seizing the remote end and drawing it towards the pole. The grip obtained on the wire by such a snotter is effective only with new rope, the channel between the strands quickly becoming worn and smooth.

This method is slower than the others, but can be used with advantage where there are long combiners, which would have to be re-

(a) Standard Wire Grip.





(b) Buffalo Grip—"Come Along."

(c) Rope Snotter.

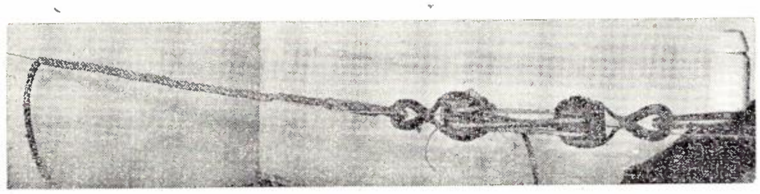


Fig. 39.—Wire Gripping Devices.

moved if wires are to be erected on inside positions or if there are working lines over which working circuits operate on outside positions and the new wires have to be erected on inside positions.

If there are working circuits on lower arms, it is necessary to see that the wires are drawn close to the pole or the combiner so that when the new wires sag they will not foul the lower wires. Whether the wires be drawn against the pole or the combiner will depend upon the extent and direction of the wind and the location of the working wires. Important carrier circuits must be "patched" over on to wires on the other side of the pole or on higher positions, so that there will be as little interference as possible.

Extension Arms. — These are used to provide supports to hold wires out from the proper arms and so prevent them from fouling circuits which might be working over wires on lower arms. Fig. 40 illustrates an extension arm in use. This fitting consists simply of a short piece of 3 in. x 1 in. timber with four slots to hold the wires apart temporarily and with metal clasps to enable the arm to be readily attached to or removed from crossarms. The bolts shown passing through these clasps are not normally required.

Erecting the Wires on the Arms. — Three methods are available, viz.:—

(1) To lay the barrow on the ground back from the starting end and draw the wires out over each crossarm. The leading end of the wire is attached to one end of a length of rope, the free end of which is thrown or passed over the arms and pulled along between poles, so that the wire is drawn over each arm. It is necessary to prevent the wire from being scratched through bearing hard against metal fittings such as steel spindles, poles, transposition bands or combiners, either by guiding the wire away from such fittings or, if this is impracticable, by wrapping the fittings with hessian or other material to prevent the wire bearing on the metal.

(2) To draw the wire out along the ground from the barrow and then lift it on to the crossarm. On rocky or stony ground the wire is liable to be damaged by this means so that discretion must be exercised with regard to the circumstances in which this method is used. If there are working circuits operating over the wires in pin positions below those in which the wires are being erected, it is necessary to lift the wires on the extension arms, draw them to approximately the normal ten-

sion and then transfer them to the desired pin positions.

(3) To carry the barrows either by hand or by cart or truck and "pay" the wire out on the ground. In this way the wire is not drawn

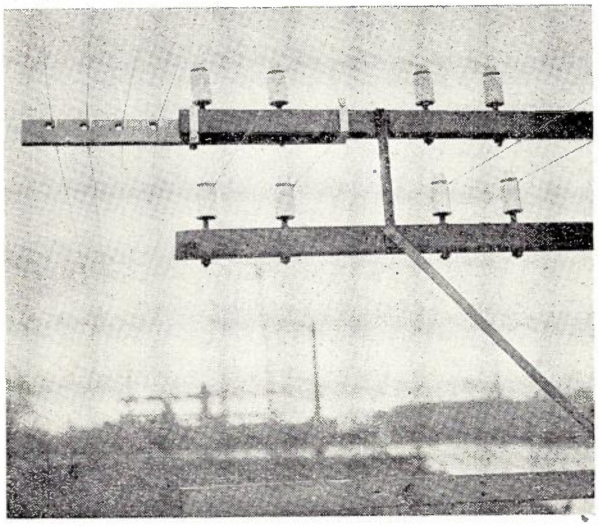


Fig. 40.—Extension Arm in Use.

over the ground, and most of the hazard of scratching the wire is removed. This is the best method where the circumstances permit of its use, but is strenuous if the barrows have to be carried by hand and requires reasonable ground conditions if a cart or truck is to be used. The use of extension arms may be necessary, as described in (2) above.

The method used will depend on the degree to which the following conditions apply:—

(a) The presence of a combiner which would interfere with the possibility of running wires out on the ground, and consequently lifting them on to inside positions on the arms. If the combiner is only of a two-way type it may be more economical to remove the combiner before erecting the wires. If, however, the combiner is attached to three or more arms the work of removing the combiners will usually outweigh any advantages that may be gained in speedier running out of the wires.

(b) The presence of important circuits below the arm on which the new wires are to be erected. In the case of subscribers or minor trunk circuits it may be that the interference can be considered as negligible.

(c) The suitability of the surface of the ground for running out wires on the ground, either for laying them out with a truck or for drawing them along the ground.

Below are set out various combinations of the different conditions and the suggested methods to be used in each combination of conditions:—

Combination of Conditions	Method to be Adopted
A combiner present, removal of which would be uneconomical. Ground conditions suitable for running out wires. Irrespective of important circuits on lower arms.	Wires to be erected on inside positions by threading through the arms. For outside positions run the wires out on the ground and lift up on to arms.*
Either no combiner present or one which could be removed economically. Important circuit present on lower arm. Ground conditions suitable for running out wires.	Run all wires out on the ground and lift on to the extension arms, tension and then transfer into proper positions.*
Either no combiner present or one which could be removed economically. No important circuits on lower arms. Ground conditions suitable for running out wires.	Run all wires out on the ground and lift directly on to the arms.*
Irrespective of presence of combiners. Important circuit on lower arms. Ground conditions unsuitable for running out wires.	Draw wires out over arms.
Irrespective of presence of combiners. No important circuits on lower arms. Ground conditions unsuitable for running out wires.	Draw all wires over arms.

* In most instances where ground conditions are suitable for running out wires, whether the wire will be drawn out or paid out will depend upon the presence of stones or rocks which might scratch the wire as it is drawn along, the nature of the track available near the poles for the passage of cart or truck, and the availability of a suitable vehicle. It is preferable to pay out if practicable, as there is much less chance of damage to it.

Where wires are to be drawn out past sharp angle poles a man should be stationed at each such point to ease the wire around.

Regulating the Wires.—This is the term used to describe the drawing of the wires up to obtain the correct sag. At each regulating or "tensioning" point the wire is first pulled up by hand and a wire grip is then attached to the wire, which is pulled taut by pulling on the leather strap until the correct sag is obtained. The wire grips which are attached to the cross-arm at the "regulating point" continue to hold the wires until the wires are pulled taut from the next regulating point, Fig. 41. Thus two wire grips at least are required for the erection of each wire.

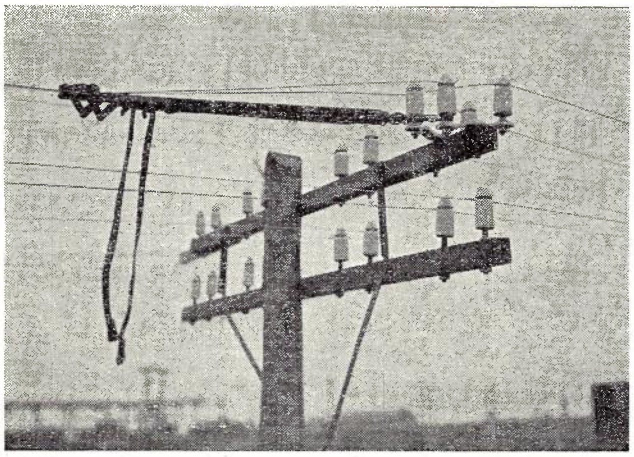


Fig. 41.—Wire Grips hold wires as regulated, until wires are pulled from next tension point.

Regulating points should be fairly close, $\frac{1}{4}$ mile to $\frac{3}{8}$ mile being about the desirable limit. On most trunk routes the transposition intervals limit the spacing to eight spans or less. If the wires are to be regulated over an odd number of spans the sag should be set at the centre span, or if the number of spans is even at that span which is adjacent to the central pole, but remote from the regulating point. The wire should be drawn slightly tauter than necessary, and then released until the correct sag is obtained. If there are angle poles intervening between regulating points the wire should be oscillated at a span adjacent to the angle to ease the wire around the angle, and so equalise the tension of the wire on each side of the angle. This should be done both when the wire is pulled taut and also when it is released to obtain correct sag.

The best means of setting the sag is to sight between two markers (or "targets") set at each pole on either side of the span. Each marker is set at a distance below the crossarm equal to the required sag, Fig. 42. If possible, the markers should be set on either side of the wire so that a cross-sight is taken to the lowest point in the wire. The observer sights from one marker to the other and the wire is adjusted until it is directly in line between the two markers. For accurate work the observer should sight through a telescope. This method is used by the Bell System in U.S.A., but, so far as the writer is aware, has not been adopted extensively in Australia. It is considered to have advantages over other methods.

An alternative method is to hold a long rod of adjustable length opposite the point where the wire is lowest. A sight is taken from the top of one arm to the top of the equivalent arm on the other pole and the height of the rod adjusted so that its top is on the line of sight. The rod can then be lowered by a distance equivalent to the required sag. The wires would then be regulated until at its lowest point it just touches the top of the rod.

A third method which is used largely in Australia is known as the "beat method." It depends upon the fact that it takes a wave in the wire longer to travel to one end of a span and return when the sag is large than it takes when the sag is small. The frequency of waves for a given sag can be calculated and allowance made for temperature variation, and this information is made available, either in the form of charts or tables. The wire is plucked by pulling laterally and then releasing sharply, and the time of release noted on the second hand of a watch (preferably a stop-watch). The wave caused by the pluck travels along the wire to the far end and is reflected back and then reflected again and travels back and forth, diminishing in magnitude until it is imperceptible. About 20 such waves may be detected and the time taken for this number to travel back and forth is taken and compared with the data in the chart.

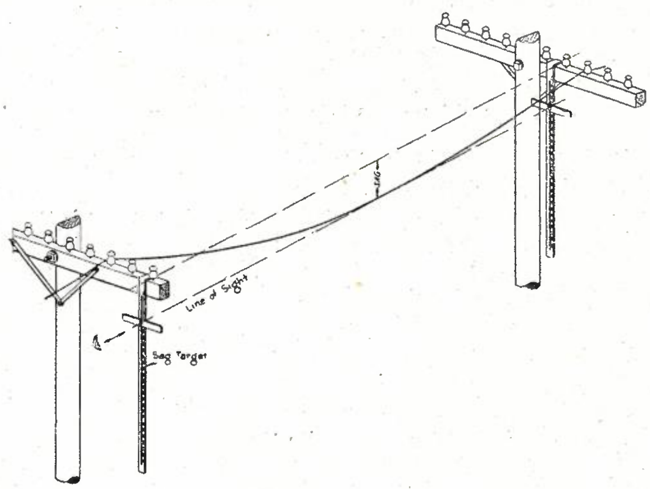


Fig. 42.—Method of setting sag by means of Sag Targets.

The time taken for the wave to travel to the far end and back 20 times is of the order of 16 seconds, depending upon the sag. After 20 cycles the strength of the wave diminishes to such an extent as to be barely perceptible, so that 20 cycles is about the practical limit for such a test. Without a stop-watch it is difficult to determine the time closer than to the nearest second and so the accuracy is of the order of 1/16th or $6\frac{1}{4}\%$, giving variations in sag of the order of $1\frac{1}{2}$ in. This is not sufficiently accurate to meet requirements on modern circuits used for high-frequency carrier operation, where the accuracy desired is of the order of $\frac{1}{2}$ in.

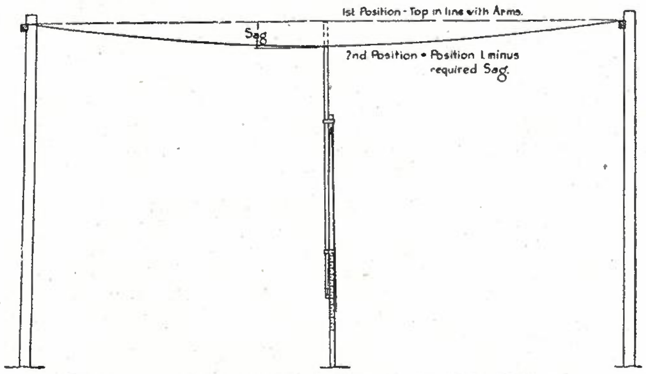


Fig. 43.—Method of measuring sag by means of adjustable rod.

For the above reasons the greatest care is necessary in using the "beat" method and stop-watches are desirable for timing the beats satisfactorily. As the method depends upon the observer's accuracy in counting the beats, reading the watch and checking against the chart, it is not considered as accurate as the direct sighting method with sag target.

APPENDIX 1

Calculation of Stress in Wires with Change of Temperature and Wind Loading

Having determined the stress at maximum temperature, it is necessary to calculate the stress under various severe conditions to ascertain the maximum stress which may be expected.

The (altered) stress f_1 under altered weather conditions may be found from:

$$f_1^2 \left(f_1 - \left(f - \frac{l^2d^2q^2E}{24\ f^2} - a\,t\,E\right)\right) = \frac{l^2d^2q_1^2E}{24} \quad \text{.... (18)}$$

where, in addition to terms already defined:—

a = co-efficient of Linear Expansion ($= 9.22 \times 10^{-6}$ per deg. F.)

t = temperature rise in deg. F. (negative for temperature fall as in this case)

E = modulus of elasticity ($= 18 \times 10^6$)

q_1 = ratio of wind loaded wire to unloaded wire under new conditions.

Putting

$$f - \frac{l^2d^2q^2E}{24\ f^2} = K \quad \text{.... .... (19)}$$

the expression becomes:—

$$f_1^2 (f_1 - (K - atE)) = \frac{l^2d^2q_1^2E}{24} \quad \text{.... .... (20)}$$

By solving for K in (19) and substituting in (20) the value of f_1 is found.

Equations of the type of 20 can be reduced to $f_1^2\ (f_1 - N) = M$ and are then readily solved by means of the slide rule as follows:—

Set the cursor at the figure corresponding to M on the top scale. The slide should then be moved until the figure on the bottom scale opposite figure 1 on the slide minus the figure under the cursor on the top scale of the slide is equal to N. The figure on the bottom scale opposite figure 1 on the slide is then the value of f_1. In using this method care must be taken to see that the correct powers are used by a simple check of the powers of 10 involved. After a little practice this method will be found quite simple, and the correct solution, particularly when carrying out a series of computations for temperature changes, can be found in a few seconds. For further information, see "Mechanical Design of Overhead Transmission Lines," by Painton.

Numerical Example.—A 200 lb. H.D.C. wire has a 21 in. sag in a 66 yd. span at 120° F. in still air, resulting in a stress of 10,787 lb. per sq. in. It is desired to ascertain the stress on this wire at 44° F. with a wind velocity normal to the line of 75 m.p.h.

$$f = 10787 \text{ lb.}$$
$$f^2 = 1.1636 \times 10^8$$
$$l^2 = (66 \times 3)^2 = (198)^2 = 39204$$
$$d = \frac{200}{5280} \times \frac{4}{\pi \times .1119^2} = 3.852$$
$$d^2 = 14.8$$
$$P = .003 \times 75 \times 75 \times \frac{.1119}{12} = 16.875 \times .009325 = .1574$$
$$W = \frac{200}{5280} = .0379$$
$$q_1 = \sqrt{1 + \frac{(15.74)^2}{(3.79)^2}} = \sqrt{1 + 4.152^2} = \sqrt{1 + 17.25}$$
$$q_1^2 = 1 + 17.25 = 18.25$$
$$a = 9.22 \times 10^{-6}$$
$$t = (120 - 44)°\text{F.} = -76°\text{F.}$$
$$E = 18 \times 10^6 \text{ lb. per sq. in.}$$
$$atE = 9.22 \times 10^{-6} \times (-76) \times 18 \times 10^6 = -12613$$
$$\frac{l^2d^2q_1^2E}{24} = \frac{39204 \times 14.8 \times 18.25 \times 18 \times 10^6}{24}$$

$$= 79.43 \times 10^{11}$$

$$\frac{1^2d^2q^2E}{24} = \frac{39204 \times 14.8 \times 18 \times 10^6}{24}$$

$$= 4.35 \times 10^{11}$$

From equation (19):—

$$K = f - \frac{1^2d^2q^2E}{24\ f^2}$$

$$= 10787 - \frac{4.35 \times 10^{11}}{1.1636 \times 10^8}$$

$$= 7049$$

Then equation (20) becomes:—

$$f_1^2\ (f_1 - (7049 + atE)\ ) = 79.43 \times 10^{11}$$

$$f_1^2\ (f_1 - 19652) = 79.43 \times 10^{11}$$

and

$$f_1 = 29{,}050 \text{ lb. per sq. in.}$$
(by slide rule).

APPENDIX 2

Calculation of Sags at Various Temperatures—for Preparation of Stringing Charts

For the preparation of stringing charts it is necessary to calculate the sags in still air at various temperature steps between 20° F. and 120° F. The sag at 120° F. is fundamental; that at 20° F. has to be found. If f_2 be the stress in still air at the various temperature steps equation (20) may be utilised by substituting f_2 for f_1.

As there is no wind loading q_1 becomes unity. The stress f_2 is, therefore, found from the expression:

$$f_2^2 \left\{ f_2 - (K - atE) \right\} = \frac{1^2d^2E}{24} \quad \ldots\ldots\ldots\ldots \quad (21)$$

from Appendix I.:—

$$K = 7049$$

$$atE = -12613$$

$$\frac{1^2d^2E}{24} = 4.35 \times 10^{11}$$

hence

$$f_2^2\ (f_2 - 19652) = 4.35 \times 10^{11}$$

and

$$f_2 = 26{,}000 \text{ lb. per sq. in.}$$
(by slide rule)

At this stress the sag, by equation (17) re-arranged, is found from:—

$$S = \frac{1^2d\ q}{8\ f^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$= \frac{3.9204 \times 3.852 \times 10^4}{8 \times 2.6 \times 10^4} \text{ feet}$$

$$= 0.725 \text{ ft. or } 8.72 \text{ in.}$$

In the preparation of the stringing chart as shown in Fig. 37, a series of calculations would be made to find the sags over various span lengths for a stress of 26,000 lb. per sq. in. The whole process of finding f_2 and then the consequent sags over various span lengths would be repeated for every 10° F. step between 20° F. and 120° F.

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CORRECTION TO PART IV.

Arising from a variation to the "Example of Layout" during the preparation of Part IV. for Journal No. 6, Volume 3, the following corrections are necessary:—

1. Top line, left hand column of page 361: the figure "450" should read "720."

2. Figure 26: an R section should be inserted to the left of the S point between D_2 and D_3. The following details will apply: Length 1m. Span basis 32. Span length 165 ft.

INFORMATION SECTION

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

POWER SUPPLY TO C.B. P.B.X.'s

In the past, the most common method of supplying power to P.B.X.'s has been to feed the exchange battery out via spare cable pairs to the P.B.X. busbars, a large capacity condenser being placed across the latter to prevent cross talk between cord circuits. There are several disadvantages of this method, viz.:

(1) The voltage falls as the number of simultaneous connections increases, thus degrading the service from a transmission and operating point of view.

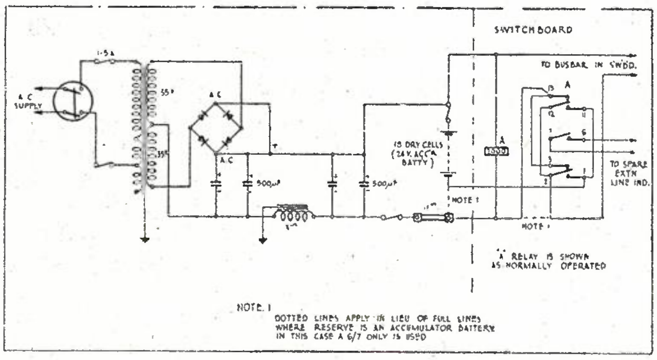


Fig. 1.

(2) In the event of the cable from the exchange to the P.B.X. becoming faulty from any cause, local intercommunication is cut off, this being of particular inconvenience when the P.B.X. extensions are spread over a large area, such as in the case of big business establishments, hospitals, etc.

(3) Electrolysis troubles are increased by the concentration of more current on the cable sheath.

(4) Pairs are sometimes taken up which are urgently required for subscribers' services.

It is, therefore, of advantage to use a source of supply which is independent of power leads and with the advent of metal rectifiers the use of power leads is decreasing.

In South Australia the circuit as illustrated in Fig. 1 is used. The apparatus consists of a small A.C. rectifier converting the commercial supply to D.C. of about 30 volts with a good smoothing circuit. The unit need not be elaborate. Should a power failure occur, an automatic changeover to a reserve dry-cell battery takes place. This system is used where the power supply is reliable. In the cases where the mains' supply is not so assured the rectifier is floated continuously across an accumulator battery which has a greater reserve capacity than the dry cells. The rectifier illustrated is designed to supply power for the average 100-line installation.

For larger city buildings where several P.B.X.'s are in use, the system has been introduced in Melbourne of installing a small power plant consisting of a $1\frac{1}{2}$ amp. Westat rectifier floated continuously across a 48-volt motor-car type battery; this unit is installed in the vicinity of the main distributing frame, which serves the building.

E.J.B.

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. 2363.—MECHANIC, GRADE 2, TELEPHONE INSTALLATION AND MAINTENANCE

W. C. KEMP

Q. 1.—List and describe briefly the functions performed by one of the following:—

(a) Final Selector, Straight line.
(b) Final Selector—Repeater, straight line.
(c) First Selector, Siemens No. 16 System.

A.—The functions of a final selector repeater are:—

(a) To provide access to a group of 90 P.A.B.X. extensions, including information lines to the manual switchboard and 10 exchange lines.

(b) To apply holding and busying earth to the private wire to hold the uniselector or line finder, and prevent the switch being seized by another hunting uniselector.

(c) To connect dial tone to the calling extension.

(d) On extension to extension calls to—

(i) Step the switch shaft and wipers vertically and then horizontally on receipt of impulse trains from the calling extension dial.

(ii) Test the called line to determine whether it is engaged or free. If the called line is engaged, busy tone is returned to the calling extension.

(iii) Apply busy conditions to the called line, to guard against intrusion.

(iv) Apply ringing current to the called line and ringing tone to the calling line.

(v) Cut off the ringing current, connect the extensions and provide battery for transmission when the called party answers.

(vi) Release the switch on the completion of the call and guard against seizure during the release period.

(vii) Operate supervisory alarms at the end of a delay period if either extension fails to release.

(e) On extension to exchange calls to—

(i) Step the switch shaft and wipers vertically to the 0 level under the control of impulses from the calling extension dial.

(ii) In the case of an extension which is barred exchange access, the switch steps automatically to the 11th contact and busy tone is returned to the calling extension. This also applies on any 0 level call if all outlets are engaged.

(iii) An extension permitted exchange access, the switch steps automatically until a free outlet is reached and loops the exchange line.
(iv) Repeat impulses from the calling extension dial to switches in the distant exchange.
(v) Provide transmission battery for the calling extension.
(vi) Release itself as for extension calls.

Q. 2.—Explain why the armature of a telephone relay does not release immediately the current in the operating winding is disconnected. Describe the different arrangements which may be used to produce a greater release lag in relays.

What are the effects of varying the following:—
(a) Spring Tension.
(b) Armature Air Gap.
(c) Residual Air Gap.

A.—The release of a relay armature depends upon the speed of decay of the magnetic flux in the air gap between the armature and core, the weight of the moving system and the tension of the contact springs.

The electromagnetic circuit of a relay is highly inductive, therefore, by Lenz's Law, when the current is suddenly started, stopped or varied in value, the resultant magnetic effect is to prolong the existing magnetic state. Owing to this magnetic effect when the current flow through a relay winding is suddenly stopped, the armature cannot immediately release until the original magnetic flux and the secondary induced flux has decayed sufficiently to allow the spring tension to take control and restore it to normal.

Some methods of producing release lag in the relays are:—
(i) The fitting of copper sleeves or slugs to the core. Eddy currents produced with flux changes set up a secondary flux which is of such a polarity as to prolong the effect of the original flux and delay the armature release. Sleeves affect both operating and release times, but a slug placed on the heel end of the core mainly prolongs the release lag.
(ii) The short circuit of the whole or part of the relay winding by means of an external contact has the same effect as a slug under certain conditions.
(iii) The connection of a non-inductive resistance in parallel with the relay winding.
(iv) A metal rectifier so connected that on operation of the relay the potential applied to the rectifier is in the high resistance direction. On release the induced current flows in the conducting direction.
(v) If the winding is shunted by a condenser, when the circuit is made, the condenser is charged to the normal potential difference across the relay winding. When the circuit is broken the condenser discharges through the relay winding, thus tending to maintain the operating circuit and the relay releases more slowly.

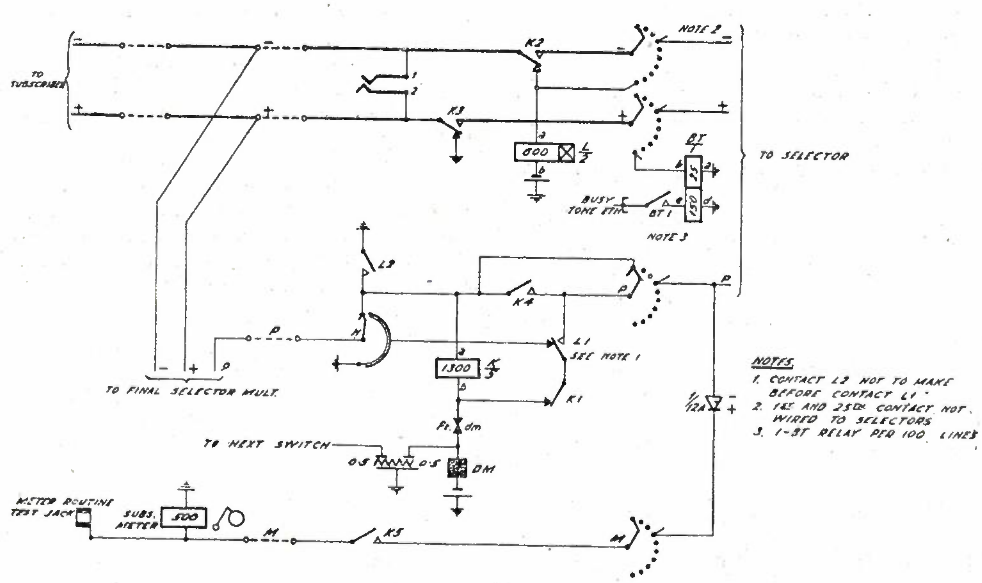
(a) Heavy spring tensions increase the operate lag and decrease the release lag.

(b) Operating time can be controlled by armature air-gap travel. Short travel decreases the operating time, but long travel has the opposite effect.

(c) Release time can be determined by the residual air gap, a fine residual adjustment increases the release lag, but a large residual decreases it.

Q. 3.—Describe fully the operation of a subscriber's rotary uniselector (rotary lineswitch)—homing or non-homing—when a subscriber originates a call.

A.—The circuit of the City West homing type uniselector is shown in Fig. 1. When a subscriber lifts the handset, relay L operates via contacts K2 and K3. The DM circuit is from negative battery via DM, dm, K1, L1 operated, P wiper and home contact to earth at L2. This earth also busies the private normal wire to mark the final selector multiple engaged. This earth is later supplied from the "H" segment when the wipers step off-normal. The H wiper is a bridging type to provide a make before break feature when stepped from the home contact to the "H" segment. The DM by interaction with dm springs steps the wipers to the first contact. If this trunk is free there will not be an earth on the P contact and K relay will operate from earth at L2, K 1300, dm, DM to negative battery. (DM will not operate in series with K 1300.) K1 opens the homing drive circuit. K2, K3 and K4 switch the negative, positive and private wires through to the



Q. 3, Fig. 1.

first selector. The meter circuit is prepared via K5. The selector returns a holding earth on the private wire which holds K operated after L restores and thus transfers control of the connection to the switch ahead. Should an open circuit exist on the selected trunk or in the associated selector no holding earth will be returned and "K," after operating and releasing L, will restore. K1 will complete the homing circuit and the wipers will be stepped over the faulty trunk.

L relay will immediately re-operate due to the loop and the normal hunting circuit will come into operation again. If a tested trunk is busy, K relay will be short-circuited due to the earth at both L2 and the P contact on either side of it, and will not operate. The DM circuit is now made from earth at the busy P contact, L1 operated, K1, dm, DM to negative battery. P wiper is a bridging type to maintain the short circuit on K relay whilst passing busy contacts.

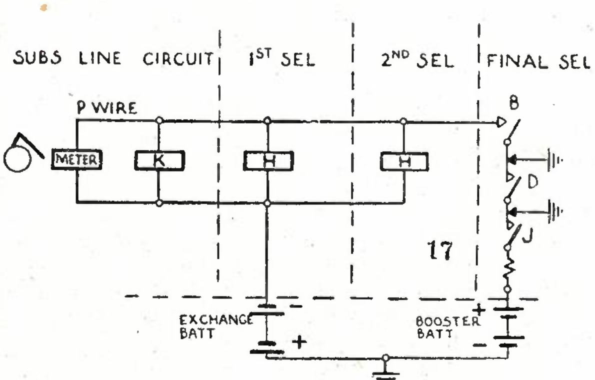
If all trunks are engaged, the wipers are stepped to the last contact and K will cut through, as no earth is found on this private contact. Circuit is made from earth, 25 ohm of "BT" relay, positive wiper, K3, loop, K2, negative wiper, relay L to negative battery. "L" remains operated and "BT" operates and connects Busy Tone to the 150 ohm winding. This tone is induced into the 25 ohm winding and extended to the subscriber.

Relay L is slow releasing because L2 must keep the private grounded until earth is returned from the first selector. L1 contact must operate before L2 to ensure that the test circuit to the private wiper is made and a short circuit established around K relay before L2 connects earth to one side of K relay, otherwise it would operate prematurely.

Q. 4.—Explain fully how a call is registered against a subscriber in any automatic exchange with which you are familiar.

What circuit arrangements prevent re-registration of the call?

A.—Fig. 1 shows the elements involved in effecting registration of a local call in an exchange employing booster battery metering. Prior to registration the call has been successfully extended from the subscriber's uniselector, through 1st and 2nd group selectors to the final selector. The P wire at this stage is earthed through contact B1, and current flows through the



Q. 4, Fig. 1.

meter, K relay and group selector H relays. The meter is designed and adjusted to require a current of 33 mA to operate it, but it does not receive this current when an EMF of only 50 volts is applied. The final selector will have tested and switched to the required line, so that the final selector H relay is operated. Consequently relay J is energised by H1. J1 prepares a circuit to hold this relay via F1 at a later stage. J2 prepares for the application of 50 volts booster battery to the private wire.

Ringing current is fed to the called subscriber's line and when this subscriber lifts the receiver the F relay operates and at F2 and F3 extends the loop to relay D, while F1 disconnects the circuit over which the J relay was operated, and reconnects this relay via contact J1. Relay D operates over the called subscriber's loop and D1 disconnects J, which does not release for at least 250 milliseconds. During this time 50-volt booster battery is applied to the private wire via the 50 ohm non-inductive resistance in series with the 50-volt main exchange battery, a total EMF of 100 volts, and raises the current through the meter to the operating value of 33 mA. When J finally releases and cuts off the booster supply the meter will be held by the current of 17 mA which normally flows through it. Rectifier MR maintains a holding earth on the private wire, but does not shunt the booster battery as it is in the non-conducting direction in relation to this battery.

Two precautions operate in the circuit to prevent re-registration of a call. Firstly, J is prevented from re-operating during the same call once it has restored to normal because its circuit cannot be re-established as F1 remains operated and J1 is now open. A second pulse cannot, therefore, be given over the private wire and in addition the meter, once operated, is retained until the call is finalized, thus preventing a second operation due to any unstandard conditions.

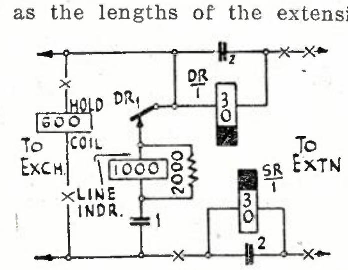
Q. 5.—Give schematic diagrams showing the basic circuit conditions of a common battery P.B.X. switchboard, cordless type, when an extension line is connected to—

(a) The main exchange.

(b) Another extension.

(Key contacts should not be shown.) Explain the action of the reactance coil, and the 10 μF condenser, associated with the power leads, when two extension circuits are in communication.

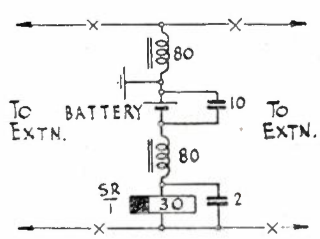
A.—The diagrams required are shown in Fig. 1 (a) and (b). On an extension to extension call the current for the transmitters is fed from the battery busbars of the P.B.X. to the A and B lines via the 80 + 80 ohm reactance coil. This arrangement is different from the normal bridged impedance method of transmission used in main exchanges, in that a common 80/80 ohm reactance coil is used for both the calling and called subscribers. The circuit used at the P.B.X. has the advantage of greater simplicity and less cost, but varies in efficiency as the lengths of the extension lines con-



Q. 5, Fig. 1 (a).—Exchange to Extension.

nected together differ, being most efficient where calling and called extension lines are almost equal in resistance. This condition applies in most P.B.X. installations and this arrangement proves satisfactory. Local battery working would be necessary in the exceptional case of a high resistance extension. The reactance coil is designed to offer a very high impedance to the currents of speech frequency so that whilst direct current is fed through the reactance to the transmitters from the battery source the speech currents are forced to traverse the extension lines only and the shunting effect of the reactance on them is negligible. The reactance is split into two sections in order to balance the impedance of each line to earth.

The power supply to cordless P.B.X.'s is for economic reasons either a primary battery situated at the subscriber's premises or a power lead from the exchange. A primary battery has appreciable internal resistance and similarly there is resistance in a power lead from the exchange. Any variation in the current taken by the P.B.X. would, except for the effect of 10 μF condenser, result in variations in the P.D. at the busbars. In a similar manner any speech currents



Q. 5, Fig. 1 (b).—Extension to Extension.

which pass via the reactance and battery would cause corresponding variations in the P.D. at the busbars. Variations in the P.D. of the P.B.X. power supply would result in clicks and overhearing between conversations, and a 10 μF condenser is fitted as a "reservoir" or low impedance shunt for high frequency variations. Rapid changes in the P.D. across the condenser cause heavy charge and discharge currents to flow and these currents produce a potential drop in the battery supply which counteracts the original change in potential.

The resulting P.D. applied to the transmission bridges is for all practical purposes constant, i.e., the condenser produces a condition similar to that which would exist if a battery of negligible internal resistance were used for the power supply.

Q. 6.—What protective arrangements are provided in a subscriber's telephone line at—

(a) the Subscriber's premises;

(b) the Exchange.

State the functions of each component and the conditions under which it would operate.

A.—Protection is designed to guard against electrical hazards such as lightning and accidental contact with electric supply lines. Protectors are fitted at the subscriber's premises, unless the distribution is entirely underground, and at the Exchange M.D.F.

The sub-station protector H.C. & F. 2/2:—Fuses protect plant against heavy currents such as may occur through accidental contact between external conductors and electric power lines. Each line is separately fused. The standard fuse for exchange and substation use is Fuse T/1.5 and it should operate between 2.25 and 3 amperes, and has a carrying capacity of 1.5 amperes and should not exceed 0.25 ohms in resistance. Protection is afforded by the resultant disconnection of the circuit.

Heat coils are fitted to protect the apparatus from damage by overheating due to a current of relatively small magnitude flowing over a long period, which would not operate a fuse. When the heat coil operates it opens the line. The heat coil (A, green) operates on 0.5 ampere in less than 1 minute and its resistance is from 4.5 to 5.5 ohms. It is connected to the instrument side of the protector.

The lightning arrester consists of two pairs of carbons, protector No. 14, one pair between each side of the line and earth. Each pair comprises two carbon blocks slotted on their outer surfaces. The inner surfaces of the blocks are bevelled to prevent leakage across the edges and are given a coat of pink varnish to seal any disintegrated carbon dust. To insulate the blocks from one another these inner surfaces are given a covering film of insulating varnish 0.0015 inches thickness. This provides a separation of 0.003 inches when assembled between the mounting springs. The breakdown voltage is 500 to 750 volts when a low impedance path is provided between the line and earth.

An efficient earth must be provided for protectors and should be as close as possible to the protector. The earth wire should be as straight as possible, sharp bends and angles being avoided.

Exchange protection:—Standard fuse T/1.5, as described above, is provided in fuse mounting of 20 or 25 pairs, which are fitted on cable side of M.D.F.

Heat coils "BB" black earthing type mounted in strips of 20 pairs. For detailed description, see Vol. 3, page 370. They are mounted on the equipment side of the M.D.F. in conjunction with 80 carbons, No. 14, to form Protector H.C. and Test 40B.

Q. 7.—What are the important points to be observed in maintaining a lead acid accumulator battery as used in an exchange? What are the chief causes of reduced capacity? Give indications of each condition.

A.—The following precautions should be observed to maintain a secondary battery in good working order:—

1. After the initial charge the specific gravity of the electrolyte should be checked to ensure it is of the correct value, i.e., from 1.210 to 1.215. The specific gravity range is 30 to 35 points from 1.180. If too strong this tends to produce sulphation during discharge and if too weak the capacity of the battery will be reduced.

2. A certain amount of water is lost due to evaporation and gassing leading to over-concentration of the acid. The electrolyte should, therefore, be topped up when necessary, at least every two weeks, with water of suitable purity, and the level should be kept half an inch above the upper edge of the plates.

3. A careful check should be kept on the specific gravity of each cell. If one cell is found to have a much lower specific gravity than the rest it will indicate a fault in that particular cell.

4. The battery should not be overcharged for extended periods at too high a rate, as the gassing which results is liable to loosen the active material out of the plate grids. This material may even lodge between adjacent plates.

5. If the battery is over-discharged, or infrequently or insufficiently charged, sulphation may occur. This reduces the capacity of the battery. Under no circum-

stances should a cell be discharged below 1.75 volts or it may be seriously damaged. The normal voltage range is from 1.85 to 2.2 volts.

6. The battery should not be charged or discharged at too high a rate. This tends to cause buckling of the plates and also tends to loosen the active material from the plates.

7. After the battery has been in use for a considerable time any active material which has fallen to the bottom of the cell should be removed, as this is liable to cause short circuits and also reduces the specific gravity of the electrolyte.

The chief causes of reduced capacity and the indications are:—

(a) The loss of active material from the plates during their life. This is greatly accelerated by charging at excessive rates. It is indicated by the amount of sludge falling to the bottom of the cell and reduced capacity.

(b) The spongy outgrowths from the negative plates called treeing can cause short circuits between positive and negative plates. This condition can be detected by the rise in temperature which occurs in the electrolyte of a cell where a short circuit exists.

(c) Buckled plates are due to unequal stresses set up in the plate by uneven work. Visual inspection will reveal these.

(d) Sulphated plates are indicated by a loss of capacity and premature gassing on charge and show up by appearance of hard white patches on the plates.

Q. 8.—Explain the construction and function of the Resistor Barrettor No. 1 (Ballast Resistor) as used in an automatic to automatic repeater (Relay Set Auto.-Auto.) or final selector.

What alteration has been made to the design of the associated relay and why?

A.—The construction of a ballast resistor consists of two iron wire resistance elements sealed in a glass bulb similar to a radio valve. Four exterior soldering tags, to which connections are made, and an anchoring screw, are provided in the moulded base.

Iron has a large increase of resistance with temperature as well as a high resistivity. When current flows through the iron wire filaments the heat developed is proportional to the square of the current. This results in large changes in resistance for relatively small changes in current values. For example, when 85 mA flows R = 130 ohms; when 100 mA flows R = 350 ohms. Chemical damage to the filaments, due to heating, is prevented by exhausting all oxygen from the glass bulb. The required characteristics are obtained and controlled by filling the glass bulb with helium or hydrogen gas, either of which conducts heat well, but does not react chemically with iron.

The function of the ballast resistor is to effect economies in line plant since a higher line resistance can be allowed for the same transmission efficiency. The sending efficiency of a C.B. telephone depends on the value of current supplied to the transmitter. On long lines, this value can be increased by the reduction of relay resistance in the transmission feeding bridge. As these relays are part of the common equipment, ballast resistors are required to equalise the current fed to all lines, so that on short lines the transmitters will not receive too much current. The increase in resistance of the ballast resistor rapidly restricts to a proper value any excessive current which tends to flow. The resistance of the feed relay coils are reduced from 200 to 50 ohms. This reduces the ampere-turns which would lessen the impedance of the relay to voice currents. Nickel iron sleeves are fitted over the relay cores before winding to counteract this effect. These sleeves, being of special magnetic material, greatly increase the impedance of the relay to voice frequency currents. The nickel iron has high resistivity, the sleeves form laminations around the core and are split from end to end. These factors combine to reduce losses due to formation of eddy currents.

Generally ballast resistors are applied to both calling and called subscribers' lines on junction calls, but only to called subscribers on local calls. The exception to this rule is where the transmission bridge is included in D.S.R.'s in satellite exchanges.

EXAMINATION NO. 2295—ENGINEER—TELEPHONE EQUIPMENT

J. A. KLINE, B.Sc.

Q. 6.—(a) Discuss the reasons for using counter E.M.F. cells for automatic exchanges: Why were end-cells introduced instead of counter E.M.F. cells? State the voltages used in an automatic exchange and the extent to which the voltage is controlled in each of the two regulating systems.

(b) Explain in detail the ringing and tone equipment installed for use with a modern telephone exchange of the 2000 type.

(c) With the aid of a full schematic sketch explain the operation of the "ring fail" alarm and change over circuit in a 2000 type automatic exchange.

A.—(a) In early installations C.E.M.F. cells were used to regulate the battery voltage within the limits for satisfactory working of the exchange equipment. In the normal arrangement there are 25 cells in the main battery and 5 C.E.M.F. cells so connected that these can be switched in or out of circuit one at a time as required. Cells can be discharged down to 1.85 volts but usually a higher voltage than this is taken in practice to indicate when discharge should cease.

When the battery is fully charged and then connected to the exchange load, the battery voltage would be above the allowable limit. It is therefore broken down by switching in circuit the necessary number of C.E.M.F. cells to bring the voltage below the upper limit of the safe working of the exchange equipment. During discharge the voltage of the main battery will fall and the C.E.M.F. cells are progressively switched out of circuit. The C.E.M.F. cells, therefore, give a reasonable method of controlling the exchange voltage within narrower limits than the normal battery voltage. This is the method used with the charge/discharge, duplicate battery system. Special arrangements are made in some installations to provide a battery floating system. In such case the charge circuit is connected to the main battery and the C.E.M.F. cells are connected in the discharge circuit.

The full floating system has many advantages. End-cells were introduced mainly for the purpose of giving a simple system for the required control of the terminal voltage when the full floating system is adopted.

The main battery has 23 cells and there are 3 end-cells connected for switching in one group in series with the main battery. The end-cell arrangement gives the following advantages:—

(1) Allows the introduction of a practically full float system.
(2) In emergencies the batteries can be further discharged as there are 26 cells available compared with 25 with the C.E.M.F. system.
(3) Smaller cells can be used because of the floating system, and the switching arrangements are simpler.

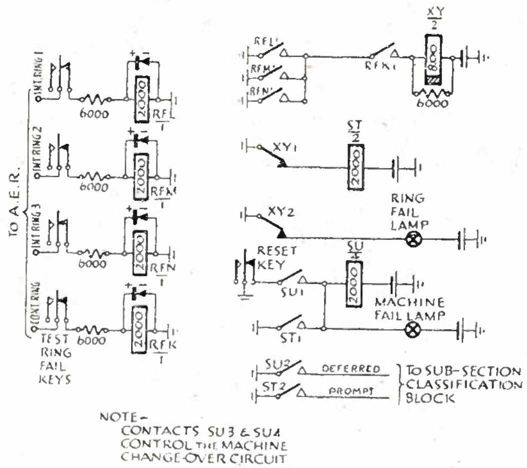


Fig. 1.

(4) The floating system is more efficient in power consumption.

The voltage range of modern equipment in automatic exchanges is 46 to 52.

The C.E.M.F. system can give control in steps of 2 volts and provides for discharge down to 1.85 volts per cell when the bus-bar voltage would be 46.25 volts. The terminal voltage can, therefore, be kept close to the optimum value for operating the exchange equipment, except towards the end of the discharge.

The end-cell arrangement with the charge circuit across the 26 cells and the exchange tapped across 23 cells may range from 46 to approximately 52 volts depending on the state of charge of the cells. When they are discharging without the floating circuit, the 23 cells could be allowed to discharge from 2.25 volts to 2 volts per cell giving a bus bar voltage of 51.75 to 46 volts and then the three end-cells would be switched in to raise the voltage to 52. The discharge could then proceed till all cells reached 1.85 volts and the bus bar voltage dropped to about 48 volts. The end-cell arrangement with switching of three cells in a group takes full advantage of the working range of the equipment and does not provide for as fine a control of the bus bar voltage as does the C.E.M.F. system.

(b) Two ringing and tone machines are provided. One is a motor generator set operated from the commercial power supply, the other is operated from the exchange battery. For outputs up to 2 amps this second machine is usually a dynamotor but for outputs above this value it is usual to have a motor generator set. A choke is included in the motor circuit. Either set can be connected to the exchange load. The mains operated unit is normally used but an automatic change-over is provided so that if the ringing fails, the battery operated machine is started up and the exchange circuit is switched from the mains operated unit to the battery driven machine. Associated with each ringing machine is an inductor tone generator and cam operated spring interrupters which give the required interruptions to the various tones generated.

(c) The ring fail alarm circuit is shown in Fig. 1. The ringing circuit is continuously tested by tapping circuits taken from each ringing bus bar to relays RFK, RFL, RFM and RFN. If a failure occurs the appropriate testing relay releases thus allowing relay XY to restore and operate relay ST. The alarm lamp is lit and relay SU is operated. A contact of relay SU closes a starting circuit for the battery driven machine and a contact of ST changes over the ringing and tone leads from the mains operated machine to the battery driven machine.

EXAMINATION NO. 2295.—ENGINEER—TRANSMISSION—BROADCASTING

H. W. HYETT

Q. 4.—Explain the functions of the Electrodes in a Pentode Electron tube.

Give briefly the uses for which each of the following types of Electron tubes are most suitable:—

(a) Triode;
(b) Tetrode; and
(c) Pentode.

A.—The Five elements from which the pentode electronic tube derives its name are:—Cathode, Control Grid, Screen Grid, Suppressor Grid, and Anode.

In an indirectly heated tube, the heater and cathode are separate units, but the former, as its name implies, is necessary only for the purpose of maintaining the cathode at a temperature sufficient for the emission of the electrons. The elements of the tube are contained in a glass or metal envelope from which all air has been exhausted.

The Cathode.—The purpose of the Cathode in a pentode tube, as in all other electron tubes, is to emit electrons or negative particles of electricity, and this emission occurs under the influence of heat. Were there no difference of potential between the cathode and other elements in the tube, the electrons emitted by the cathode would remain in the vicinity of the latter in the form of a cloud. This cloud of electrons surrounding the cathode is referred to as the "space charge."

The Anode.—If the anode is now made positive with respect to the cathode, the electrons emitted, being of negative potential, will travel to the anode. This electronic flow is termed the "anode" or "space" current. The number of electrons which flow to the anode is a function of the temperature of the cathode, and the difference in potential between the cathode and the anode.

The Control Grid.—The control grid is located between the cathode and the anode, and if its potential is made negative with respect to the cathode, the flow of electrons to the plate will be restricted. The more negative this grid is made with respect to the cathode, the less will be the electronic flow, until a point is reached at which the flow ceases entirely. If an alternating potential, which varies between the limits of zero and the value at which the electronic flow ceases, is applied between the grid and the cathode, the electronic flow will be varied in accordance with the variations in the applied potential. If this grid were allowed to become positive with respect to the cathode, the electron stream would be directed to it and it would behave as an anode, thus current would flow in the external circuit between the grid and the cathode.

The Screen Grid.—In a 3 element vacuum tube, the control grid and anode behave as plates of a condenser, and a considerable electrostatic field exists between these elements.

At radio frequencies, this inter-electrode capacity provides a low impedance path for feed-back currents, and causes instability, or even oscillation of the amplifying stage. By the insertion of another element of open mesh formation between the control grid and the anode, this capacity is considerably reduced in a manner similar to the reduction which takes place when two condensers are connected in series, and tubes having this fourth electrode are, therefore, very stable in operation.

This additional electrode must be positive with respect to the cathode, otherwise it would restrict the flow of electrons to the anode, yet it must be at the same potential as the cathode in so far as alternating currents are concerned. This condition is achieved by connecting the screen grid to a DC potential somewhat less than that applied to the anode, and by by-passing the alternating currents to the cathode by means of a condenser of value which offers a low impedance to the R.F. currents.

The reduction in inter-electrode capacity by the insertion of the screen grid greatly increases the amplifying efficiency of the tubes, as a large inter-electrode capacity causes a large "space charge," which in turn has the effect of keeping the amplifying efficiency of the tube at a low value. Incidentally, the A.C. anode impedance of the tube is also greatly increased by the introduction of the screen grid.

The Suppressor Grid.—When electrons are reaching the anode in large numbers, the latter becomes heated due to the bombardment and emits electrons which repel those arriving from the cathode. This emission from the anode is referred to as "secondary" emission.

In addition to this phenomenon at certain portions of the A.C. cycle the potential on the screen grid will exceed that on the anode, and those electrons emitted from the anode, together with a large proportion of those flowing from the cathode, will be diverted to the screen grid. This effect can be prevented by limiting the amplitude of the A.C. signal so as to prevent the instantaneous potential of the anode becoming less than that of the screen grid.

By the introduction of a 5th electrode of open mesh formation in close proximity to the anode, and the connection of this element to the cathode so as to maintain it at the same potential as the cathode, the effects of "secondary" emission can be eliminated, as the electrons emitted from the anode are repelled back thereto by this additional electrode, and are thus prevented from reaching the screen grid. This modification greatly increases the power capability of the tube, as more electrons flow to the plate due to the elimination of the effect of "secondary" emission.

The uses for which the following types of electron tubes are most suitable are as follow:—

Triode.—i. Audio Frequency Voltage Amplifier.
ii. Audio Frequency Power Amplifier.
iii. Radio Frequency Power Amplifier in Transmitters. In this condition it is necessary to neutralize the amplifier stage in order to ensure stability.
iv. Grid Leak and Anode Bend type Detectors.

Tetrode.—i. Radio Frequency Voltage Amplifier.
ii. Anode Bend Detector.

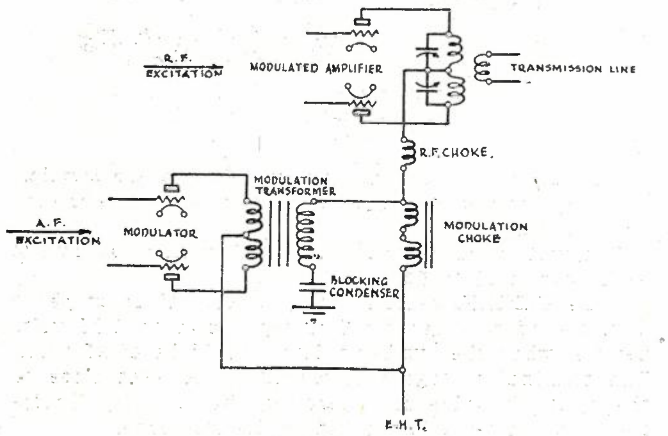
Pentode.—i. Audio Frequency Voltage Amplifier.
ii. Audio Frequency Power Amplifier.
iii. Radio Frequency Voltage Amplifier (no neutralization necessary).
iv. Radio Frequency Power Amplifier (no neutralization necessary).
v. Anode Bend Detector.

Q. 5.—Describe a method of modulation to be used in a Medium Frequency Radio Broadcasting Transmitter, and state its advantages and disadvantages.

Illustrate your reply with a schematic circuit diagram.

A.—The method of modulation finding favour at the present time, suitable for Medium Frequency Radio Broadcasting Transmitters, is the system best described as "High-level Class AB1 Anode Modulation." This method is applicable to amplitude modulation only.

If applied to the final stage of the Transmitter so that advantage can be taken of the increased operating efficiency of the former as a Class "C" amplifier, im-



Q. 5, Fig. 1.

proved over-all efficiency for the Transmitting plant is obtained. This is particularly desirable in Transmitters having output powers of 10 kW or greater, as the saving in commercial power is appreciable.

A schematic diagram of the system is shown in Fig. 1.

The principle of operation is basically similar to the Heising method, the anode voltage on the Modulated Amplifier being varied by the audio frequency signal from the Modulator between the limits of zero and twice the steady D.C. potential on that stage for full modulation. Sufficient audio frequency voltage to cause this variation is obtained by using a pair of tubes in push-pull Class AB1 as the Modulator. This necessitates a coupling transformer to match the plate impedance of this push-pull stage to the Modulated Amplifier load. In a Transmitter having an unmodulated carrier power output of 10 kW, this transformer must be capable of operating at a power level of 7.5 kW of audio frequency, and is, therefore, of very large dimensions. The frequency response of this transformer must be of a very high order, so that the overall frequency response of the transmitter will be within the limits of the specification.

The D.C. plate current of the Modulated Amplifier will be about 1.5 amps in a 10 kW Transmitter, and normally this current would pass through the secondary of the modulation transformer. The difficulties of manufacturing a high quality audio frequency transformer capable of withstanding such a large magnetising current in one of its windings are very great, and it is much simpler in practice to choke feed the Modulator Amplifier as shown in the diagram. The inductance of this choke will depend on the impedance of the load reflected from the Modulated Amplifier to the Modulator. The higher this impedance, the greater must the inductance be; therefore, values of the order of 100 to 120 henries are necessary. The blocking condenser for preventing the Modulated Amplifier plate current from flowing through the secondary winding of the modulation transformer is connected on the ground side of the transformer, as this maintains the primary and secondary windings of the transformer at the same D.C. potential, and thus simplifies the insulation problems.

The tubes in the Modulator are arranged in a Class AB1 connection, so as to obtain as high an efficiency as possible. In this arrangement, the tubes are biassed to a point much closer to plate current cut-off than is usual in normal Class A amplification. The amplitude of the audio frequency signal is then adjusted so that the maximum peaks do not swing the grids beyond the point of zero potential, thus grid current does not flow during any part of the cycle in this class of amplification, and the steady value of the D.C. plate current with no signal is much lower than would be the case in normal Class A amplification.

The Modulated Amplifier operates at the same efficiency as a similar stage in the original Heising method of modulation, i.e., 60 to 65%. Due to the improved over-all transmitting efficiency obtained, the saving in commercial power is appreciable, especially in transmitters having an unmodulated carrier power greater than 10 kW.

It is essential that the extra high tension supply for the anodes of the Modulator should have extremely good regulation, owing to the varying load imposed by the type of Modulator used. This requirement necessitates the use of hot cathode mercury vapour rectifier tubes, as the high vacuum type would not give the required regulation.

The advantages of this method of modulation are as follow:—

i. Improved over-all Transmitter Efficiency.
ii. Improved Transmitter stability and lower harmonic distortion due to the absence of linear Amplifier stages after modulation.
iii. Simplicity of adjustment, as there is only the one tuned circuit after modulation takes place.
iv. The R.F. Amplifier stages prior to the Modulated Amplifier, with the exception of the buffer stages, may operate under Class "C" conditions, thus giving increased efficiency in each stage.
v. The maximum E.H.T. voltage required is about 25% lower than that required for linear Amplifier stages for the same power output.
vi. In the case of water-cooled tubes, a smaller cooling system is required, as the heat to be dissipated is less for the same power output, owing to the improved efficiency of the Amplifier stages.

The disadvantages are:—

i. A large and expensive modulation transformer and modulation choke are required.
ii. The audio frequency portion of the Transmitter is increased in size, as a high audio frequency gain [about 68.75 db for a 10 kW Transmitter capable of operating from an input level of 0 VU (1 mW)] is necessary.
iii. As the tubes in the Modulator stage and the Driver stage thereto must be capable of a large audio frequency power output, it will not be possible to obtain suitable types having indirectly heated cathodes. In order to maintain the noise due to A.C. ripple at a suitably low value, it is, therefore, necessary either to use D.C. on the filaments of the Modulator tubes, or alternatively, if A.C. is used, sufficient inverse feed-back must be applied to reduce the noise to a satisfactory value.

The advantages considerably outweigh the disadvantages, especially as the power of the Transmitter increases, and with plant capable of 50 or 100 kW, design features alone would prevent a low level modulation system being used.

Q. 6.—For the reception of short-wave broadcast programmes, describe a Diversity receiving system. Give i. the type of receiving antenna;
ii. the manner in which the antennae would be fed to the receiver equipment; and
iii. the type of receiver equipment.

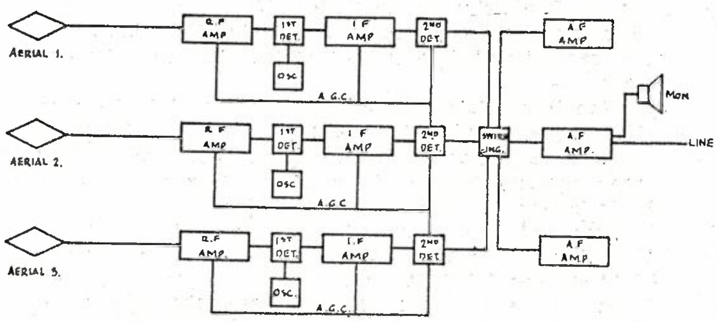
A.—Diversity reception is the principle whereby advantage is taken of the fact that fading does not occur simultaneously on—

i. Parallel channels of different frequencies;
ii. Antennae of different polarisation on one frequency; and
iii. On spaced antennae of one polarisation and on one frequency.

The system described below makes use of the spaced antennae method, which is the most effective in practice.

Briefly, the system consists of a method of making simultaneous use of two or more receiving aerials spaced about 1,000 ft. apart, so that advantage is taken of the fact that the maxima and minima in the signal strength due to fading do not occur simultaneously at locations a few hundred yards apart.

Each aerial is connected to a radio frequency Amplifier of the super-hetrodyne type, and the de-modulated signals from each of these Amplifiers are combined and fed into the audio frequency Amplifier. Means are provided in the switching equipment prior to the audio frequency Amplifier for correctly phasing the audio frequency signals, as it would be possible to have signals from any two of the radio frequency channels reversed in phase.



Q. 6, Fig. 1.

As one of the requirements of any radio receiving system is that it shall discriminate against atmospheric noise as much as possible, it is necessary to provide means of preventing the gain of any one of the receivers being increased by the A.G.C. (Automatic Gain Control) when the signal in that receiver falls to a lower level than that in the other receivers, otherwise the level of the noise in the system would be increased. This condition is achieved by inter-connecting the A.G.C. circuits of all receivers, so that the gain of the whole group is controlled by the receiver in which signal is at the highest level.

i. **Type of Antennae:** The individual aerials may be of any suitable types depending on the requirements. Best results are, of course, obtained by using directional aerials, but this arrangement necessitates a group being provided for each direction of reception. The most satisfactory of the directional types is the horizontal rhombic, its advantages being:—

(a) It is highly directional both in the vertical and horizontal planes.
(b) A frequency range of 3 to 1 can be obtained on one aerial.
(c) A low wave angle and high gain can be obtained using relatively low masts.
(d) By using a suitable terminating resistance at one end, it can be made unidirectional, and the direction of reception can be reversed by transferring the termination to the opposite end of the array.
(e) Due to the highly directional properties in both the vertical and horizontal planes, the signal to noise ratio is greater than with any other type of aerial.
(f) The cost of the aerial is low and it can be constructed using standard line practice.

The rhombic aerial, as the name implies, is diamond shaped, and is suspended in the horizontal plane by masts located at each of the four corners. The length of the sides, the ratio of the major and minor axes, and the height of the wire above the ground, are all functions of the operating frequency, and the angles of reception in both the vertical and horizontal planes.

ii. **Connection between Aerials and Receivers:** As the aerials are spaced approximately 1,000 ft. apart, some form of transmission line from the aerials to the receivers will be necessary. Two types of transmission line are generally available:—

(a) Coaxial Transmission Line.
(b) Open-wire Transmission Line.

For use with a Rhombic aerial the 600 ohm open-wire transmission line is best suited, for the following reasons:—

(1) The Rhombic aerial can be constructed to have an impedance of 600 ohms and this will enable direct connection to the 600 ohm transmission line without the necessity for any form of coupling transformer.
(2) It is less costly than a coaxial line.
(3) Standard line construction can be used.
(4) It has a low attenuation equivalent, approximately 0.14 db per 1,000 ft. at 1 mC.
(5) It can be connected direct to the 600 ohm input terminals on the receivers.

iii. **Receiving Equipment:** The receiver assembly for diversity reception consists essentially of one receiver for each aerial being used, each receiver having its own radio frequency amplifier, beat frequency oscillator, intermediate frequency amplifier and diode rectifier. The audio frequency outputs from the diodes are combined and amplified in a common audio frequency amplifier. It should be noted that merely to combine the audio outputs of the receivers is not sufficient, because at the instant when the signal reaching any particular receiver is very weak due to fading, the automatic gain control of that receiver will increase the gain so that the output will consist mainly of noise, and this noise will appear in the combined output. It is, therefore, necessary for the A.G.C. circuits of the receivers to be interconnected in such a way that the gain of all the receivers is controlled by the receiver in which the signal is greatest.

The following is a brief resumé of the desirable features of each individual receiver used in the complete assembly:—

(1) Maximum possible tuning stability.
(2) Absolute sensitivity so that an input of one microvolt modulated to a depth of 30%, with a 400 c.p.s. tone will give an output of 6 mW into a 600 ohm line with a signal to noise ratio of 1 : 1 or better.
(3) Variable Selectivity Control.
(4) Audio frequency response 50 to 6,000 c.p.s. within ± 2 db.
(5) Provision of a high quality tuning dial to allow accurate calibration in terms of frequency.

The whole assembly is connected in such a manner that full monitoring, switching, and phasing facilities are available so that the outputs can be properly phased, and each or all receivers connected to any 600 ohm line as required.

A block schematic circuit of a typical 3-channel diversity receiver installation is shown in Fig. 1.

An audio frequency amplifier is provided for each R.F. channel, so that the receivers may be used as individual units if required.

Some of the higher priced receiving systems make use of a double frequency change before the signal is demodulated, the first I.F. amplifier operating at a frequency of 300 kC, say, and the second at 50 kC.

The first intermediate frequency is sufficiently high to permit of the required R.F. image ratio of 10,000 : 1 being obtained, whilst the second is of such a value as will enable a sufficiently sharp cut-off to be obtained at the extremities of the pass band.

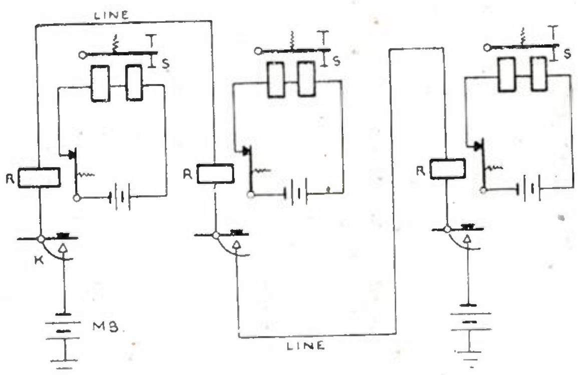
EXAMINATION NO. 2295.—ENGINEER TELEGRAPH EQUIPMENT

S. T. WEBSTER

Q. 1.—Describe the following Telegraph systems:—
(i) Simplex, manual;
(ii) Duplex, manual;
(iii) Murray Multiplex.
Illustrate your answers by simple schematic diagrams.

A.—(i) **The Simplex Manual Telegraph System** provides a means of communication between any number of stations over a single line, transmission at any one time being from one station only. In Fig. 1 the circuit of a closed circuit Morse simplex set is shown. The signals are transmitted manually in the form of pulses of current of varying length transmitted by the operation of the morse key K. As each key not in use is closed at its circuit closer, the line circuit is completed from the main battery MB through all line relays R in series to earth at the distant end when the key at the sending station is closed. With the opening of the key, the line current is interrupted, and each relay armature is released. Hence, the transmitted signals are followed by each line relay, which in turn controls its associated sounder S.

(ii) The duplex manual system permits of the transmission of messages between two stations in both directions simultaneously. The circuit of a differential duplex system is shown in Fig. 2. In this circuit the line relays are of the differential polarised type. Duplex working is made possible by the use of an artificial line network AL, the variable components of which are adjusted to such values that the artificial line simulates approximately the characteristics of the line. The sending battery is applied to the split of the differential relay and as the resistance of the artificial line is



Q. 1, Fig. 1.

approximately equal to that of the line, with earth applied to the split at the distant end, equal currents pass through each winding in such direction that the total magnetic effect in the relay is nil. Double current transmission is adopted and the polarised relay at the distant end is entirely under the control of the home polechanger PC, whilst the home line relay is under the control of the distant polechanger. In manual working, each relay tongue controls its associated sounder S and signals are transmitted by the manual operation of the key as in the simplex morse circuit.

(iii) The Murray multiplex provides a means by which intelligence can be transmitted over a number of channels in each direction over one physical line or telegraph carrier link. The line time is devoted to each channel successively by the distributor, which includes a phonic motor and plateau consisting of three solid rings and three segmented rings, one of each type forming a pair. Each pair of rings is swept by a pair of brushes joined electrically together, but insulated from frame. The distributor phonic motor, the spindle of which carries the pairs of brushes spaced 120° apart, is driven by a vibrator which consists of a weighted reed which is kept vibrating at a uniform rate in the same manner as a trembler bell.

The Murray multiplex system makes use of the 5-unit code, each character being of the same length and being transmitted by five signal units arranged as various combinations of positive and negative elements.

The circuit of a Murray multiplex terminal is shown in simple schematic form in Fig. 3.

The segmented rings, R—Receiving, S—Sending, and L—Local, each contain—

(No. of arms or channels × 5) + 2 segments.

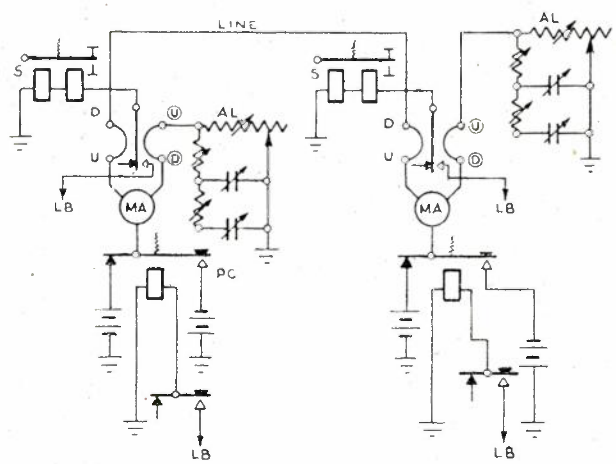
On each arm the following equipment is provided:—

Sending. (a) Perforator which perforates a paper tape with message holes corresponding to the marking (negative polarity) elements of the character to be transmitted. For each character a feed hole is also perforated.

(b) Transmitter—through which the perforated tape is passed and which transmits the signal elements, marking and spacing corresponding respectively to a hole or a blank on the tape.

Receiving. Morkrum Printer in which are 5 impulse magnets. The code of the received signal is stored in these magnets, those operated corresponding to the marking elements, while the remainder represent the spacing elements. The printer translates the received elements into printed characters.

The connections between the printer and transmitter of one arm and their associated segments are shown in Fig. 3. The transmission and reception of signals can best be briefly described by considering the local run conditions. Under these conditions, the sending conductor is connected through a resistance LR to the receiving relay. It will be seen from the sketch that

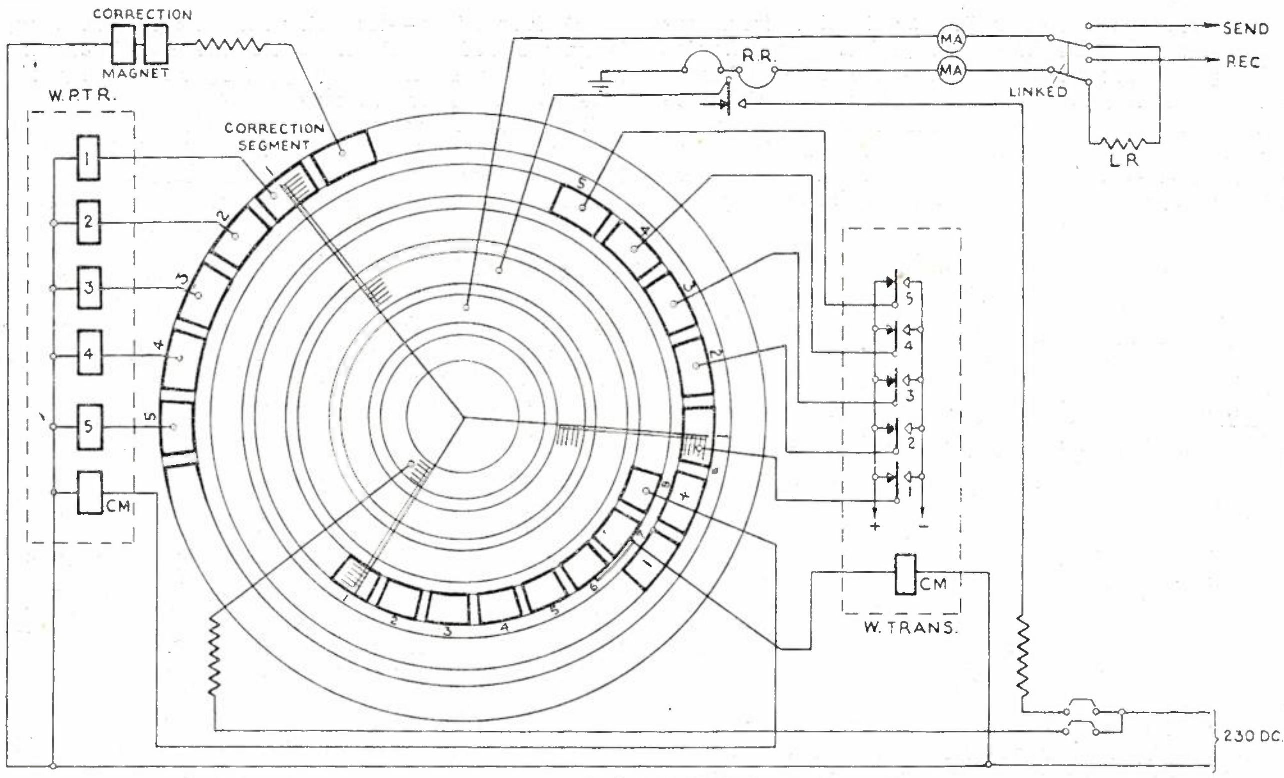


Q. 1, Fig. 2.

at any instant the receiving relay RR will be held to spacing or marking according to the polarity of the potential applied to the transmitting segment, which is being passed over by the send brush. When the relay is held to marking the printer impulse magnet connected to the receive segment being swept by the receive brush will be operated. Hence the signal set up in the transmitter will be reproduced in the impulse magnet bank of the printer. As W1, 2 and 3, etc., printer segments are passed over by the receiving brush while the sending brush is passing over W1, 2 and 3 transmitter segments, the code set up in the transmitter will be reproduced on the printer.

Similarly, transmission between distant stations will be possible if the send and receive brushes at the opposite ends of the line maintain this same relationship, i.e., if the brushes are in synchronism.

Synchronism is maintained in the following manner: —One station is corrected by the other (correcting) station. At the correcting station two segments of the send ring are permanently connected to marking and spacing polarity respectively. The corrected station phonic motor runs slightly faster than that at the correcting station. The result is that the brushes at the corrected station gain slowly on those of the correcting station until the receive brush is passing over the correcting segment when the relay is moved to marking by the correcting signal from the distant end. When this happens, the correction magnet is operated. The operation of the correcting magnet effects correction which



Q. 1, Fig. 3.

has the effect of retarding the brushes 1½° relative to the phonic motor. The receive brush, moving faster than the distant send brush, gains slightly each revolution until correction again takes place. By this means the brushes at the two terminals are maintained in synchronism with each other, and transmission over a number of channels in each direction is possible.

Q. 2.—State the advantage and disadvantage of single and double current working as applied to telegraph signalling.

Which system would you advocate for the following circuit:—

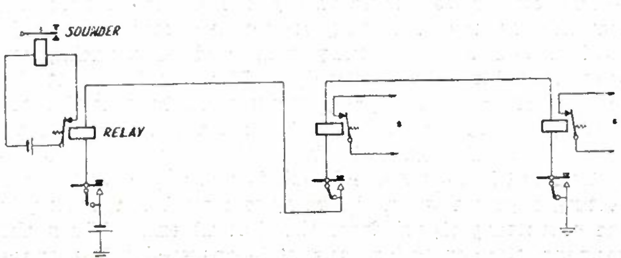
(i) An open wire land line 200 miles in length;

(ii) A submarine cable of the same length.

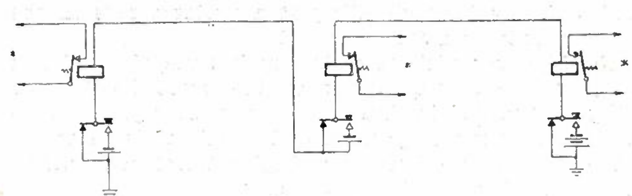
Assume values as you may desire for calculations necessary to support your recommendation.

A.—When considering the advantages and disadvantages of single and double current working, it might first be stated that there are two methods of single current telegraph transmission. In both these methods, current flows in the line during the marking period, whilst no current flows for the spacing interval. Fig. 1 shows the methods of transmission employed. In (a) the line is opened at the sending point during the spacing period, whilst in (b) the circuit is closed without the inclusion of a line battery at this time.

It will be appreciated that both these methods of working permit the inclusion of many stations in the one line, but whereas the circuit (b) requires the provision of a battery at each station, in circuit (a) only a single battery is required, and this can, of course, be installed at the most convenient and suitable point or points. Comparing these two methods of working, it has been established that, under Australian conditions, the method of working shown in (a) is to be preferred to circuit (b) because, although in the former there is a waste of energy due to the flow of current while the circuit is idle, this waste is more than counterbalanced by the cost of installing and maintaining separate batteries at each office as required in circuit (b).



Q. 2, Fig. 1 (a).



Q. 2, Fig. 1 (b).

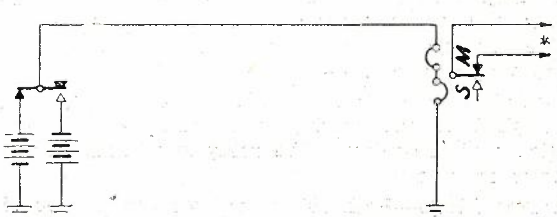
With double current working, as shown in its simplest form in Fig. 2, positive and negative potentials are applied during the spacing and marking intervals respectively, to operate a polarised receiving instrument at the distant terminal.

In Fig. 3, in which single current working is shown, the charge upon the line during the marking interval is represented by the shaded figure. At the completion of the marking signal, earth is applied to the sending end and the line is discharged to earth at both ends of the circuit, prolonging the signal at the distant terminal.

The application of a battery of opposite potential at the sending end instead of the earth hastens the discharge of the line, reducing the prolongation of the received signal or, in other words, reducing the distortion in reception, thereby permitting an increase on the speed of working.

It can be shown that the form of the arrival curve for current received over a submarine cable is identical, whether the sending end potential is changed (a) from earth to negative potential V or (b) from positive potential ½ V. to negative potential ½ V. It will be seen, therefore, that to secure a given speed of working on the cable, it would be necessary to apply twice the voltage under signalling conditions (a) as compared with those stated in (b).

Condition (b), which of course corresponds to double current working, would therefore be chosen if the speed of working of the circuit was limited by the line characteristics and not by the sending and receiving apparatus. That the line characteristics are the limiting factor in the case of a 200-mile submarine cable can be shown by the application of the K R law. This law states that the speed of working of a circuit is inversely proportional to the product of the capacity and resistance of the circuit and can be expressed:



Q. 2, Fig. 2.

$$\text{words per minute} = \frac{A}{k\ r\ l^2}$$

where A = a constant depending on the sending and receiving equipment.

k = capacity per mile in farads.

r = resistance per mile in ohms.

l = length in miles.

It has been stated that for simplex Wheatstone operation with relay reception, a constant of 12 can be taken as an average value. Hence, for a submarine cable with a capacity of 0.3 μF per mile and a resistance of 8 ohms per mile 200 miles in length, the theoretical speed of working in words per minute may be taken as:

$$\text{speed of working} = \frac{12}{8 \times 3 \times 10^{-7} \times (200)^2}$$

$$= \frac{12 \times 10^7}{8 \times 3 \times 4 \times 10^4}$$

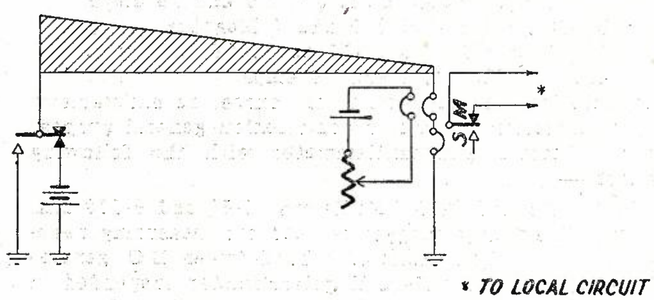
$$= 125 \text{ words per minute.}$$

This would correspond to a duplex speed of working of approximately two-thirds this figure, i.e., about 84 w.p.m.

This speed of working is well below the limit of operation of a Wheatstone transmitter, and consequently double current signalling would be adopted. Although other refinements such as cable code transmission and recorded reception may be used to increase working speeds, double current operation would be adopted in the first instance, as this would result in a gain in speed as compared with single current working with practically no increased cost of provision.

Other advantages of double current working are as follow:—

(a) The receiving relay is operated in the neutral position, which is its most sensitive state. In the single current case the relay must, of course, be biassed either electrically, magnetically or mechanically.



Q. 2, Fig. 3.

(b) The reversal of current reverses the magnetisation of the relay cores, which tends to reduce the effects of residual magnetism.

(c) The double current working is not as critical as single current working to variations of received current. With single current operation, the relay is given a fixed bias; hence, if the received current is reduced by leakage, bias distortion is introduced. With double current working, however, both positive and negative currents would be affected equally by leakage and consequently the output from the relay tongue would remain unbiassed.

Summarised, due to the increased speed of working which could be obtained by double current operation, this method of working would be adopted for the submarine cable.

In the case of the open wire land line, if the main requirement was to handle a maximum of traffic between the two terminals, the same method of working would be recommended. If, on the other hand, the land line were required to connect a number of stations on a route on which the total traffic could be handled manually, closed circuit simplex morse operation would be preferred.

Q. 3.—Describe the testing instruments and equipment required for a modern large telegraph office—

(a) To locate internal faults or verify condition of internal equipment;

(b) To test and locate faults in outside line plant.

A.—The testing instruments and equipment required for a modern large telegraph office are as follow:—

(a) To locate internal faults or verify condition of internal equipment—

(i) a general purpose voltmeter, milliammeter, ohmeter, etc., such as an "Avometer";

(ii) detectors No. 4;

(iii) a bridge megger;

(iv) a buzzer test set;

(v) a teleprinter test set (Telegraph tester);

(vi) a Murray multiplex test set;
(vii) a Wheatstone test set (where Wheatstone equipment is used);
(viii) reversal generator;
(ix) relay test set.

(b) To test and locate faults in outside line plant—
(i) Wheatstone Bridge;
(ii) Voltmeter and milliammeter;
(iii) Distortion Measuring set.

Purpose and Description of Instruments and Equipment.

(a) (i) The Avometer or similar instrument is a combination voltmeter, ammeter, milliammeter, and ohmeter with the following full-scale readings:—

D.C. Volts: 1, 10, 100, 400 and 1000 V.
D.C. Amps: 0.002, 0.01, 0.1, 1.0 and 10 amps.
Ohms: 10,000, 100,000 and 1 Megohm.
A.C. Volts: 10, 100, 400 and 1000 V.
Amps: 0.01, 0.1, 1 and 10 amps.

Separate instruments would, of course, be satisfactory.

(ii) Detector No. 4 is a combination general purpose D.C. voltmeter and milliammeter with the following ranges:—

Volts: 0-5 and 0-50. Milliamps: 0-50 and 0-500 mA.

(iii) The bridge megger is used for measuring resistance values. It consists of a hand-driven D.C. generator and moving double coil galvanometer suspended in a magnetic field furnished by bar magnets. One coil is connected across the generator, whilst the other is connected in series with the resistance being measured. When current flows through the current coil it tends to turn the movement in a direction opposite to that produced by the E.M.F. coil, consequently the final position of the coils and pointer depends on the value of the current. When in this condition, the meter is used for measuring resistances of high value such as insulation resistance, etc.

By operating a switch to the "Bridge" position, the bridge megger, in conjunction with an external resistance box, is used as a Wheatstone Bridge, with the current coil connected across ratio arms to serve as galvanometer. In this condition, the meter is used for measuring the lower resistance values.

(iv) A buzzer test set consists of a buzzer with battery connected to test leads and is used for testing continuity of conductors and testing the accuracy of new wiring.

(v) The Telegraph Tester for teleprinter testing consists of a plateau of segmented and solid rings over which brushes rotate to transmit from seven equal segments per revolution at a transmission speed of 50 bauds. From this plateau, recurring teleprinter signals of any combination set up on a key panel may be transmitted to a teleprinter receiver. A control is provided to vary the position of the commencement of the start signal with respect to the signal impulses. By this means the receiving margins of the teleprinter receiver may be tested.

To test the transmitting mechanism of a teleprinter, the output of the unit is connected to control a receiving relay. A neon lamp mounted on the brush spindle behind a rotating slotted disc flashes on each change over of the relay contacts. These flashes may be compared with a circle divided into 140 equal parts, each part thus representing 1 millisecond or 5% distortion. Any distortion of the transmitting mechanism may be measured by this means.

(vi) The Murray multiplex test set provides a means of testing Morkrum Printers, Murray transmitters and the tape produced on Murray Perforators. A suitable arrangement would be the provision of a vibrator, distributor, distribution box, plateau and brush arms connected as a Murray multiplex set in a local run condition. One arm only would be equipped with transmitter and printer jacks and the piece of equipment to be tested would be subjected to trials with other components which were known to be in good condition. On this set, units would be given extended trials after overhaul before placing in use.

(vii) The Wheatstone test set would consist of a Wheatstone transmitter and receiver connected as in a local run condition and tests would be conducted as in (vi).

(viii) A reversal generator is installed in a C.T.O. to generate square wave reversals for tests over long-distance physical channels and telegraph carrier channels. It consists of a rotating commutator with positive and negative potentials connected to alternate segments. The segments pass beneath a stationary brush which is connected to the line being tested.

(ix) The relay test set provides a ready means of checking polarised relays for operation and adjustment before placing them in service. Alternating current of small magnitude is passed through the line windings to operate the relay tongue. The following tests are applied and the results observed on a centre zero meter in the tongue circuit:—

Neutrality.—Equal positive and negative potentials are applied to the spacing and marking contacts respectively of the relay. The relay is neutral when the meter is on zero.

Transit Time.—Both relay contacts are connected to the same battery supply, i.e., an E.M.F. of equal magnitude and polarity. When the relay tongue is held on either contact the same value and direction of current is observed on the meter in the relay tongue circuit. When the relay is vibrating due to the passage of the A.C. through the line windings, the reduction in the current measured on the meter represents the transit time of the relay, i.e., the time spent whilst the relay tongue is travelling between contacts, and consequently has no E.M.F. applied to it.

(b) (i) The Wheatstone Bridge provided is basically of the same form as the original Wheatstone Bridge with a sensitive meter connected across the extremes of the ratio arms. It is used for making conductor resistance, Varley and Murray loop earth location tests, etc., and keys are usually provided to set up the circuit conditions for the various tests performed.

(ii) Voltmeters and milliammeters are provided for general tests of circuit conditions. A voltmeter of high resistance, say, 1000 ohms per volt, is used to obtain a quick indication of the insulation resistance of a line by connecting via the voltmeter a known potential to the line open circuited at the distant end. From the reading, the insulation resistance can be quickly determined if the resistance of the meter is known.

(iii) The Telegraph tester referred to in (a) (v) provides a useful means of measuring distortion introduced in a circuit or relay set, etc., by transmitting various combinations of signal elements from the plateau to line and applying the received signal to the receiving or stroboscope relay to operate the neon lamp.

The various instruments provided for purely mechanical tests of equipment and the equipment provided for primary and secondary cells have not been included.

(To be continued.)

A GENERAL SURVEY OF THE TELEPHONE CABLE CORROSION PROBLEM

C. J. Griffiths, M.E.E.

The following bibliography is associated with Mr. Griffiths' article published in Vol. 3, No. 6, page 349. The references are only intended to provide sources of more detailed information on corrosion problems and methods referred to generally in the paper rather than to be a comprehensive bibliography on corrosion and cable damage:—

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