The Telecommunication Journal of Australia

Vol. 3, No. 5 | Registered at the General Post Office, Melbourne, for transmission by post as a periodical. | OCTOBER, 1941

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

The

Telecommunication Journal of Australia

Vol. 3, No. 5 *October, 1941*

THE DRUMMOYNE AUTOMATIC EXCHANGE—SYDNEY

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A rearrangement of the trunking design of the "W" group exchanges in the Sydney metropolitan network was effected on 31st May, 1941, when the Drummoyne Exchange area was converted from manual to automatic working and simultaneously the new automatic exchange became the main switching centre for the group. Previously Balmain was the main exchange and this, together with the former branch exchanges at Hunter, Ryde and Epping, was retrunked as a branch of Drummoyne coincident with the cut-over of the latter exchange.

In this article a description of the equipment installed in the Drummoyne Exchange is followed by details of the procedure adopted for the cut-over. The method used was typical of current practice in Sydney and the points discussed are capable of general application to this type of problem.

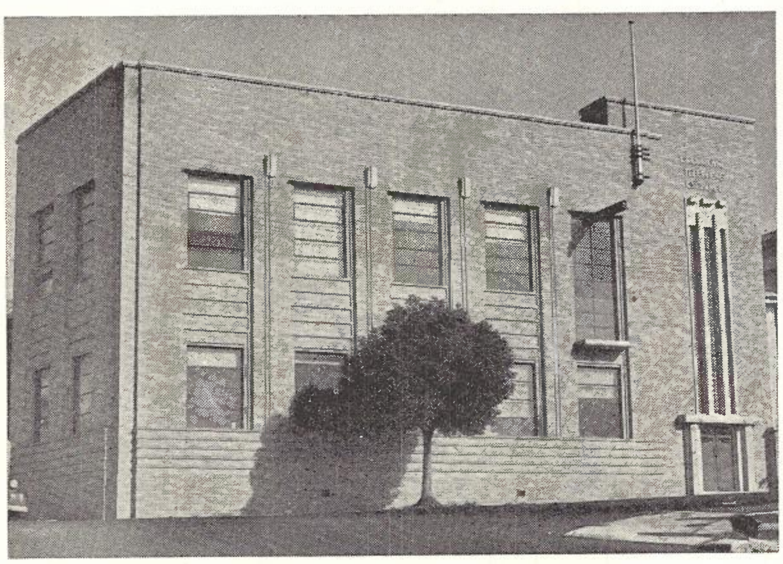


Fig. 1.—Drummoyne Telephone Exchange Building.

The switching equipment was purchased from the Automatic Telephone & Electric Company Ltd., Liverpool, England, and installed under contract by the Automatic Electric Company (A'sia) Pty. Ltd. The power plant, main distributing frame and sub-station apparatus were provided and installed by the Department, which also carried out the final tests and made the necessary arrangements for placing the exchange in service.

The Drummoyne Telephone Exchange building (Fig. 1) has two floors, the construction being such that a third floor may be added when necessary. The cable tunnel is below street level and extends almost the full length of the building, with entrance ducts at either end. A view of portion of the tunnel is shown in Fig. 2, in which the positions of street cables, main joints and cabling to the main distributing frame may be seen. One 200 pair S. and C.C. cable serves each vertical of the M.D.F., which has a capacity of 200 pairs on the fuse and 160 pairs on the arrester side.

Equipment Layout. — Situated on the ground floor, are the main distributing frame and test desk, battery and power rooms, heating and ventilating plant and exchange store. The whole of the first floor space is, therefore, available for switching equipment except for staff rooms located at one end of the building. A general view of the switchroom is shown in Fig. 3. The intermediate distributing frame in the right foreground is directly above the M.D.F., and from left to right are suites of L. and K. relays, primary line finders, final selectors and routiner, third selectors (partly obscured by a cable run to the ground floor) and second selectors. Beyond these are suites of first selectors and auto.-auto. and auto.-manual relay sets. A view of the latter is shown in Fig. 4, looking across the switchroom. On the left of this photograph the wiring sides of the relay set routiner and access rack and the traffic recorder control rack are shown.

The exchange is designed to accommodate a maximum of 2200 subscribers' lines within the 20-year period, the initial installation having a capacity of 2000 lines. As the major function of this exchange in the future will be to provide a junction switching centre, there is little space reserved for additional L. and K. relays, line finder and final selector equipment.

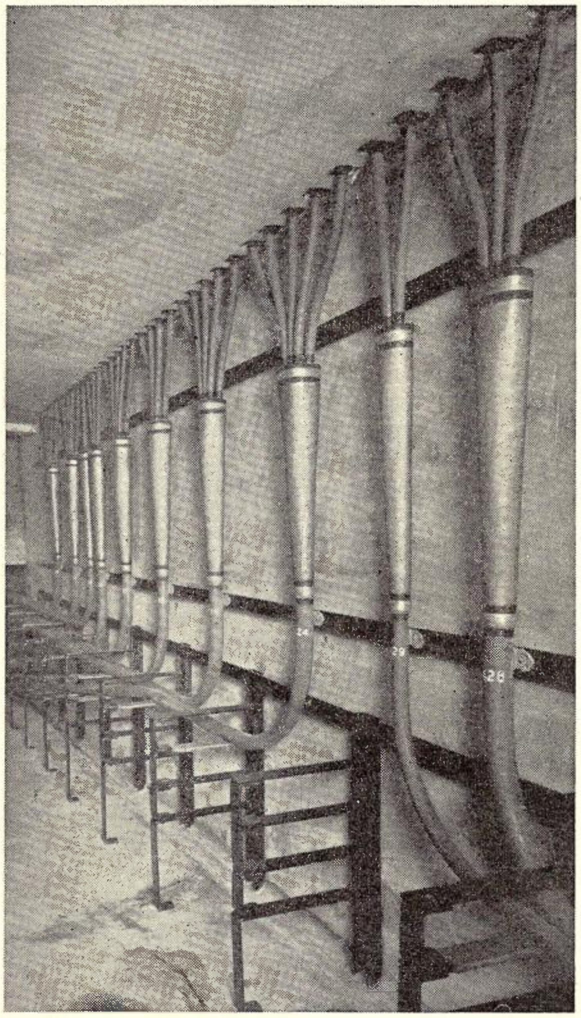


Fig. 2.—The Cable Tunnel.

The effect of the above factors on the layout of apparatus is that first and second group selector racks for incoming junctions have been so spaced that development to the limit of the switchroom capacity will be facilitated. This feature of design also applies to the allocation of space on trunk distributing frames and the M.D.F. and to cable runways and sections.

SWITCHING EQUIPMENT AND TRUNKING

Line Finders.—Standard B.P.O. 2000 type equipment, employing 200 point primary line finders with partial secondary trunking and 200 outlet group and final selectors, is installed. The trunking scheme is shown in Fig. 5. The figures in circles represent the switches and banks in situ.

The primary line finders are arranged with eight direct and 11 indirect finders per group. The secondary line finders are 50 point rotary uniselectors mounted in three groups of 12 switches each.

In this type of exchange it is important that the traffic originated by the subscribers connected to each line-finder group should be approximately equal. This is necessary because in computing the number of line finders required per group the estimated originating traffic is divided into the number of groups installed and switches provided on the basis of average traffic per group. The efficiency of the partial secondary trunking

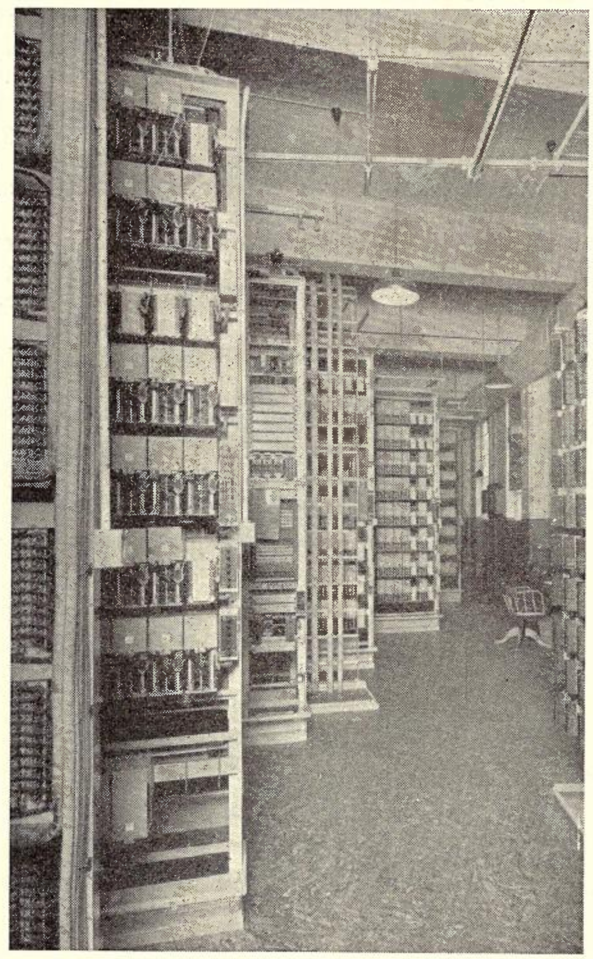


Fig. 3.—The Switchroom.

thus depends upon the equality of traffic loading in the primary groups.

In order to achieve a reasonable degree of uniformity in this regard an analysis is made of the average monthly calling rates of the subscribers. The information is obtained from monthly records of the total calls originated by each. The lines are then classified in accordance with this average thus:—

0– 50 calls per month—Class A
51–100 calls per month—Class B
101–150 calls per month—Class C

and so on. The lines are then allotted an L. and K. relay in each line-finder group in turn, commencing with those in class "A," which are completely distributed before commencing with lines in class "B." In addition, the allocation is arranged in such a manner that the lines having high calling rates are connected to the lower levels of the line-finder banks in order to minimise wear on the switches while hunting.

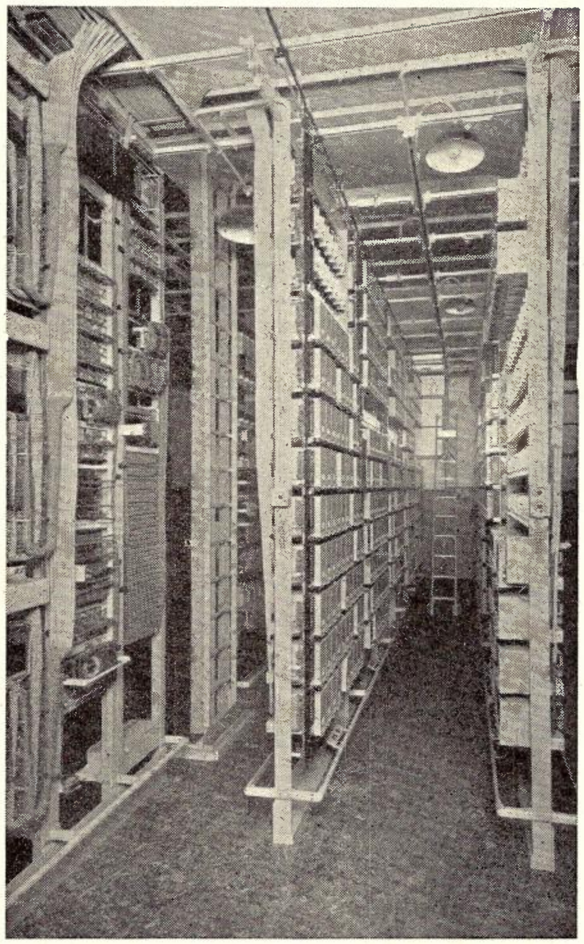


Fig. 4.—Relay Set Equipment.

In practice this method has been found satisfactory as a basis for distribution until a traffic study is made after the exchange is in service, when the actual loading of each group may be determined. In the Drummoyne Exchange a subscribers' I.D.F. is installed, which gives full flexibility of distribution, and the method of analysis described above was employed.

Group Selectors.—All group selectors are of the 10/20 type and the exchange is provided with an automatic routiner. In first and second selector ranks the local and incoming selectors occupy separate racks. The racks for incoming junctions are cabled from the M.D.F., which is used for the dual purpose of protection and distribution of incoming junction groups to selector shelves. Incoming junctions from each exchange are dispersed to all incoming selector racks in order to equalise, as far as possible, the traffic density per shelf. An estimate of this figure as compared with the density per shelf on local selector racks, and since confirmed by measurement, indicated that separate gradings were necessary for the outlets from incoming and local group selector levels. The total trunks in each case were, therefore, divided into two groups in proportion to the traffic to be carried by each grading.

Trunk Distributing Frames. — Selector level outlets are graded on T.D.F.'s, from each of which the trunks are distributed uniformly to selector shelves in the succeeding switch ranks. The provision of feed cables from selector bank terminal assemblies for a particular level is based on the number of groups required in the grading necessary for the estimated trunks at the five-year date. The appropriation of space on the T.D.F.'s to permit extension to the 20-year requirements follows the same method.

Outgoing Junction Relay Sets.—The trunks for outgoing junctions from selector level gradings are cabled from the T.D.F.'s to the relay set racks, as there is no junction I.D.F. provided. These racks are equipped for both automatic and manual exchange junctions, the relay sets for the latter being of a convertible type. The relay set routiner and two associated access racks are shown in the foreground of Fig. 6.

In connection with the trunking design of the exchange, an interesting feature is included in the distribution of traffic to other automatic exchanges. In using 10/20 outlet selectors trunking to relay sets without junction uniselectors which are usual with the 10/10 outlet selectors of earlier exchanges, each junction carries an amount of traffic depending upon its order of selection in the selector level grading, or, in a branch exchange equipped with discriminating selector repeaters, in accordance with its position in the junction hunter bank grading. In an exchange group having a number of 2000 type exchanges installed or proposed, it is therefore necessary to examine the distribution of outgoing junctions to incoming selectors in the distant exchange to ensure that the first incoming selector rack or bay is not overloaded by traffic trunked only from individual choices in graded groups. This point was covered in the

Drummoyne Exchange when allotting junction numbers to the relay sets.

Final Selectors. — Straight line groups are equipped with 17 and P.B.X. groups with 18 final selectors and one test final selector each. A final selector routiner is included in the installation.

Automatic Traffic Recorder. — The exchange equipment includes facilities for automatic traffic recording. Briefly, the operation of this unit is as follows:—

The private wires of all switch groups are connected to the banks of access uniselectors, the wipers of which are wired to the wipers of control uniselectors. The banks of the control uniselectors are connected by plugs and cords to the traffic registers which are allotted to the various switch groups. The access uniselectors are caused to rotate in sequence and, in passing over engaged trunks, the registers are operated in turn via the control switch wipers and banks.. The total number of trunks engaged in each group is thus recorded at 30-second intervals. The appropriate registers are automatically connected by the stepping of the control switch. Meter readings, which are noted by the operator after each cycle, form the basis of a subsequent traffic study.

Referring to Fig. 7, a view of the access racks is shown. The terminal strips on the left side of each rack are cabled to the exchange apparatus and those on the right are wired to the banks of the access uniselectors. A total of 32 access switches is provided, giving a maximum capacity of 4704 connecting points. Groups are allotted to the access uniselector switch bank and connected by jumper wires on these racks.

The traffic recorder control rack may be seen in Fig. 6 beyond the relay set routiner control rack. The registers are conveniently placed above the writing slope and below is the connecting field, where, by means of plugs, cords and links, the meters are associated with their allotted positions on the control switch banks. The control switches and access uniselector connecting keys are located above the registers. These are 3-way keys associating three pairs of access uniselectors with one particular control switch as required. By their use a saving in the number of control switches is made. The alternative use of access switches with the one control switch is possible because, in recording traffic, it is not essential to measure all groups in the exchange simultaneously.

In deciding the allocation of access switches to control switches, and of exchange equipment to access uniselectors, groups are selected for

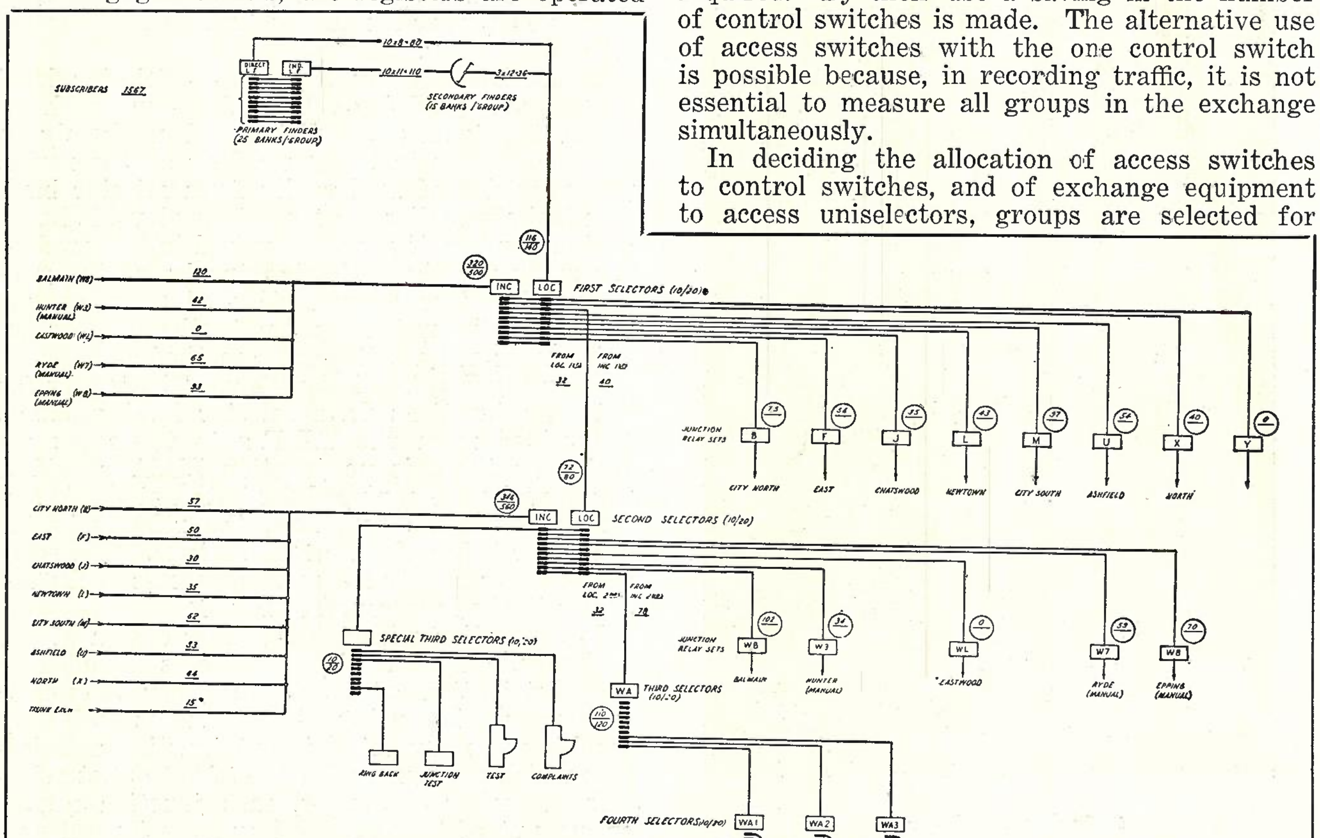


Fig. 5.—Trunking Scheme.

Final Selectors		WA 1000 In situ	WA 1000 2 yr.	WA 1000 5 yr.	WA 2000 In situ	WA 2000 2 yr.	WA 2000 5 yr.
Switches	Reg.	4x17	4x17	4x17	4x17	4x17	4x17
	P.B.X.	1x18	1x20	1x24	1x18	1x20	1x24
	Test	5x 1	5x 1	5x 1	5x 1	5x 1	5x 1
Banks	Reg.	4x25	4x25	4x25	4x25	4x25	4x25
	P.B.X.	1x25	1x25	1x25	1x25	1x25	1x25

simultaneous recording so that as far as possible the results obtained will be self-checking. An article on this subject was published in the July, 1939, issue of this Journal.

POWER PLANT

A general view of the power room is shown in Fig. 8. The commercial supply panels are on the left of the power board, followed by the ex-

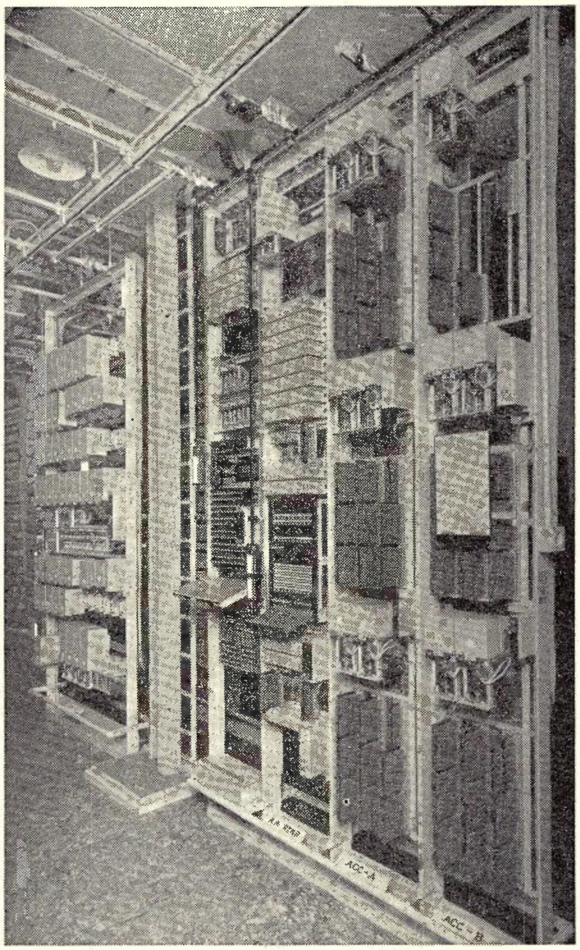


Fig. 6.—Relay Set Routiner Traffic Recorder Control Rack and Miscellaneous R.S.R.

change discharge, two motor generators, voltage regulator and ringing machine panels in that order.

The motor generator sets are of 200 and 100 amperes output respectively, the larger machine being automatically regulated when operating under floating conditions. The motor starters are mounted on iron pipes set in the concrete piers. The supports are used to carry wiring from the starters into the floor trench, which gives access to the power board. In order to prevent the edges of the concrete piers from chipping, monel metal edgings are fitted and the upper surfaces finished with rubber to match the floor covering. The motor generators and ringing machines are mounted on sponge rubber to minimise noise due to vibration. Fixed to one wall of the power room, is an iron rack designed to carry the spare armature for each machine. Covering the rack and fitted to the wall, is a wooden writing desk for battery records, with drawers for the smaller machine parts. This enables the armatures to be readily available as well as affording protection.

Connection is made from the power board to the batteries by copper busbars and discharge leads to the equipment floor are run in braided power cable concealed in an asbestos cement duct.

Two 25-cell batteries, each of 600 ampere-hours' capacity, are installed. The exchange busy hour load is approximately 150 amperes.

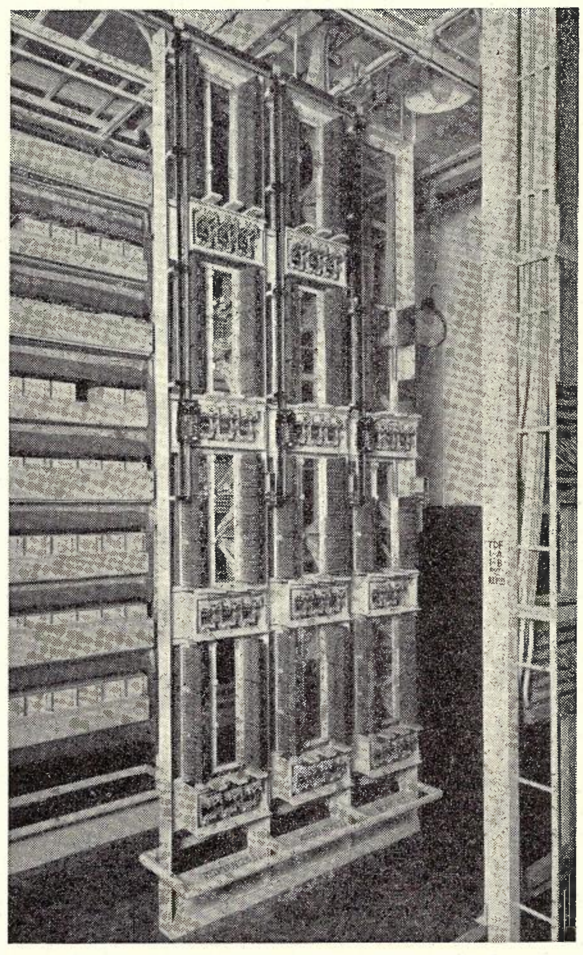


Fig. 7.—Traffic Recorder Access Racks.

HEATING AND VENTILATING EQUIPMENT

The building is equipped with a plant to provide for heating and ventilating. Air is drawn through filters into the exchange by a fan having a capacity of 7180 cubic feet per minute. A duct is installed which enables portion of the air to be recirculated. This amount is adjustable to a maximum of 75% of the fan capacity. Six air registers of 860 C.F.M. each are fitted to ducts in the switchroom and five of 404 C.F.M. each in the M.D.F. room. Before reaching the exchange ducts the air passes through a hot-water heater which is automatically controlled by an oil-fired burner. A schematic diagram of the heating unit, including the pipe connections between boiler and heater via the circulating pump, is shown in Fig. 9.

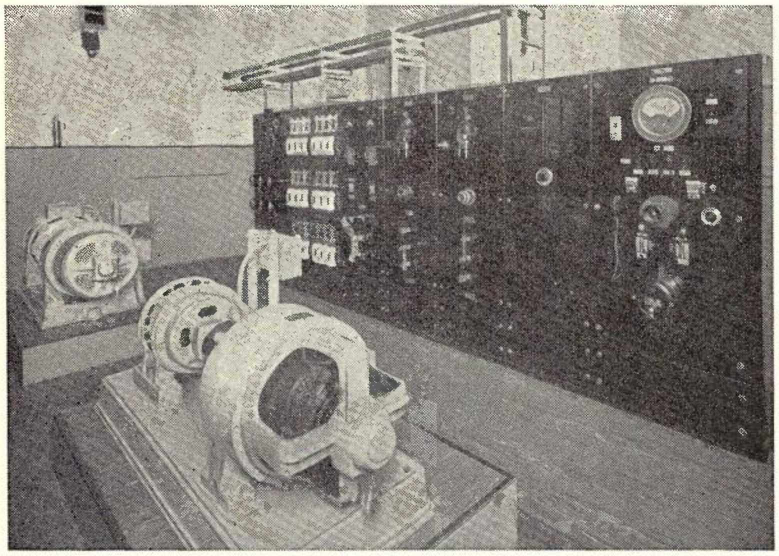


Fig. 8.—The Power Room.

The oil burner for heating the boiler is brought into use manually when the temperature of the exchange warrants its use. Except for the control of the main switch the burner operates automatically under the control of thermally operated switches in the boiler and stack marked A and B respectively in Fig. 9. These switches are adjusted to the desired operating points to allow for adequate heating of the building.

The elements of the burner are shown in Fig. 10.

On operating the main switch the motor starts, causing the oil pump to supply oil from the tank via the oil filter to the by-pass valve. This valve regulates the quantity of oil delivered to the metering pump and returns excess oil to the reservoir. The oil is then pumped into the atomiser, mixed with air and forced through the pipe to the nozzle. Vanes fixed to the nozzle swirl the atomised oil in a given direction before it leaves the pipe. At the same time air under pressure from the fan is passed through the draught pipe, where vanes swirl the air in the opposite direction to that of the atomised oil. This causes a thorough mixing of air and atomised oil. The ignition transformer supplies a pressure of 10,000 volts to the spark gap at the nozzle, where the atomised oil is ignited. After 20 seconds the ignition circuit is opened by the stack switch and combustion of the oil continues. The temperature control switch protects the system against excessive rise in boiler temperature and the stack switch against flame or ignition failure.

TEST DESK

A 2-position test desk provides facilities necessary for the maintenance of sub-station apparatus. The desks are standard except for the addition of a volume testing circuit to enable the transmission equivalent from subscribers' telephones to be measured. This is arranged by providing the area mechanic with a standard noise generator which is used to produce the sound used in testing. Mounted on the test desk is a voltmeter with suitable line termination, calibrated in decibels to a reference level of 1 milliwatt.

A feature of the test desk is the filing system for cable records and subscribers' master cards as shown in Fig. 11. This was incorporated by extending the cable turning section to carry filing trays and drawers. The test desk key shelf was also extended to form a convenient table surface which is protected from wear by hard rubber. The cable cards are filed in Roneodex metal trays, each card being fastened to a brass rod. In the photograph one of the trays has been withdrawn from the cabinet and the cards opened. In effect, the records are in book form with facilities for removing any particular card if desired.

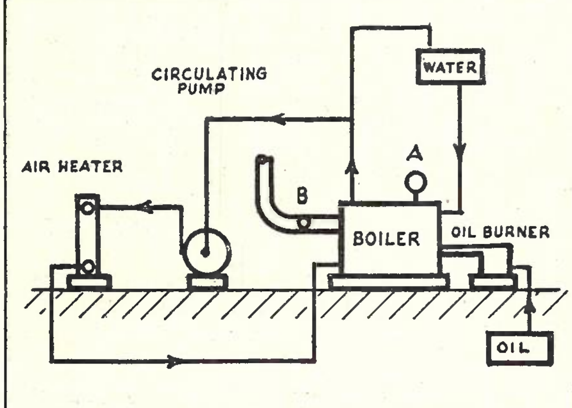


FIG. 9. ELEMENTS OF HEATING PLANT.

Drawers are fitted for the subscribers' master cards, the arrangement of which may also be seen in Fig. 11.

CONVERSION FROM MAGNETO TO AUTOMATIC WORKING

The problems associated with the conversion to automatic working of the Drummoyne Exchange included the provision of 1300 junctions to seven main and four branch exchanges and the simultaneous retrunking of the former main exchange at Balmain as a branch of Drummoyne.

The complete conversion may be considered in three stages as detailed hereunder:—

Stage 1.—Installation and Construction Work, including the following:—

(1) The installation of automatic equipment in the new exchange and the erection of automatic sub-station apparatus.

(2) The diversion of subscribers' cables to the new exchange M.D.F.

(3) The provision of junction cables for main and branch exchanges.

(4) Equipment installation and retrunking in the Balmain exchange.

(5) Installation of additional junction equipment necessary in all other main and branch exchanges concerned.

(6) The allocation of cable pairs for junction circuits.

(7) The testing of all equipment, both substation and exchange.

(8) The preparation of an organisation schedule for the cut-over.

Stage 2.—The Cut-over.

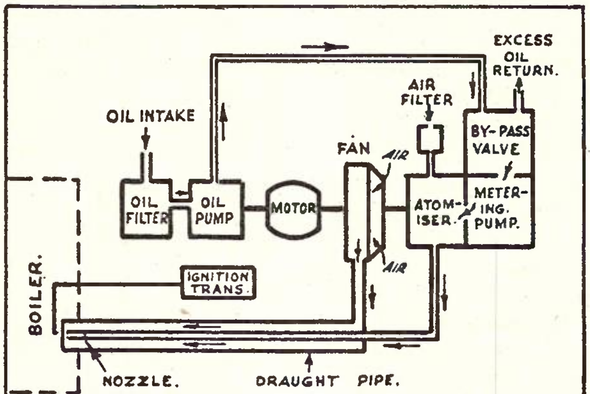


FIG. 10. DIAGRAM OF AUTOMATIC OIL-FIRED BURNER.

This was effected in the following sequence:—

(1) The connection of outgoing junctions to the Drummoyne automatic exchange.

(2) The transfer of subscribers' lines from the magneto to the automatic exchange.

(3) The connection of junctions incoming from main and branch exchanges.

Stage 3.—Operations Subsequent to the Cutover including the following:—

(1) The testing of exchange equipment, subscribers' lines and junctions.

(2) Traffic patrol and redirection of subscribers using incorrect numbers.

(3) External fault organisation.

(4) Cutting away external cables and temporary cross connections in M.D.F.'s.

(5) The recovery of magneto sub-station apparatus.

In the following paragraphs items from the above which are more directly related to the procedure adopted for the cut-over are briefly discussed.

Junction Cables to Main Exchanges. — The alteration in location of the main exchange made practicable the opening of direct cable routes from Drummoyne to several other main exchanges. New cables were laid to Chatswood, City North and City South which were used for portion of the junctions to these exchanges and for circuits to East, North Sydney, Ashfield and Newtown pending the completion of cables to Ashfield and East Exchanges. The remaining circuits were provided in existing cables via Balmain Exchange. North Sydney junctions were also connected via Chatswood Exchange. The various routes used for the junctions may be seen by reference to Fig. 12. This drawing details the complete junction cut-over arrangements for each exchange. The operations and their timing are shown by symbols and sufficient of the trunking rearrangements in Balmain are included to give an appreciation of the work involved in this exchange. Further reference will be made to these points in later paragraphs.

The allocation of cable pairs for each group of junctions was based on factors such as:—

(1) The total number of pairs required.

(2) The cable pairs already in use as working junctions.

(3) The alternative routing of junctions in case of emergency.

(4) The transmission equivalent.

(5) The requirements of the plan for subsequent cable rearrangements.

Branch Exchange Junctions. — As shown in Fig. 12, junction cables from the branch exchanges at Hunter, Ryde and Epping to Balmain were connected through the Drummoyne automatic exchange M.D.F., as were the Balmain-Chatswood junctions after the completion of the direct cable from Drummoyne to Chatswood.

All junction circuits through the Drummoyne M.D.F. which were to be intercepted for connection to equipment in Drummoyne were wired to a panel fitted with break type jacks. At the cut-over these circuits were opened by the insertion of switch plugs. The cable pairs used for manual exchange junctions to and from Balmain were re-allotted for Drummoyne-Balmain junctions at the cut-over. The use of the jack-field was found to facilitate testing and cut-over operations on these circuits.

Balmain Exchange Retrunking. — Under the original conditions Balmain subscribers were trunked via Keith type primary and secondary line-switch units to first selectors. A repeater trunk board was installed and at the cut-over, trunks from the secondary line-switches were cut away from the first selectors in the I.D.F. and diverted to Drummoyne via repeaters.

The WB second selector level in Drummoyne was graded to provide the junctions outgoing to Balmain. These were terminated on the original second selectors which became third selectors after the conversion, while the former third selector rank reverted to fourth selectors trunking to final selectors. By this means as much as possible of the original trunking was retained.

Cable pairs carrying junctions from the manual branch exchanges to Balmain were reallotted for connection as Drummoyne-Balmain junctions at the cut-over and additional arrester strips were installed temporarily on the Balmain M.D.F. to facilitate the rejumpering of these circuits. The appropriate diagram in Fig. 12 shows the rearrangement in schematic form. The symbols used against the various connecting points in the circuit indicate those to be closed prior to and at the cut-over, the circuit points to be opened at cut-over and the jumpers subsequently to be cut away in the M.D.F.'s.

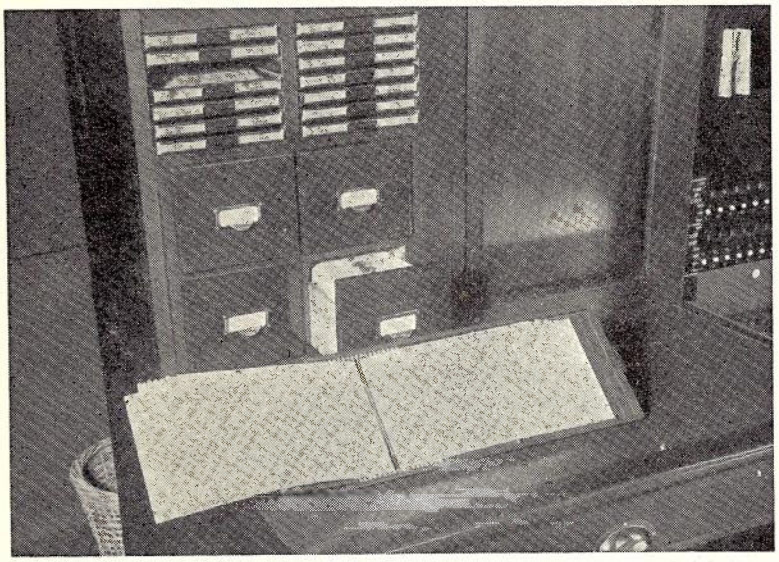


Fig. 11.—Filing System for Cable Records and Subscribers' Master Cards.

Organisation of the Cut-over. — The general procedure adopted for placing the new exchange in service was to connect outgoing junctions to the automatic exchange by operations on the M.D.F.'s in Balmain and Drummoyne; secondly, to disconnect subscribers' lines from the Drummoyne manual exchange and connect to the automatic exchange; and finally, to connect junctions incoming from main and branch exchanges. Simultaneously Balmain Exchange was retrunked as a branch of Drummoyne as described above.

A control switchboard with direct magneto lines to the exchanges involved, was installed in the automatic exchange to ensure proper coordination of the work.

Officers-in-charge of the manual exchanges at Drummoyne, Hunter, Ryde and Epping were notified five minutes before the scheduled time of cut-over so that telephonists could advise calling subscribers of the impending conversion to automatic working.

The organisation included the distribution of sub-station staff at suitable points in the area for convenient despatch on faults, the immediate testing of all urgent services and junctions, the ringing of subscribers from the final selectors, the challenging of the W4 Drummoyne manual exchange level after cut-over and the supervision of the automatic equipment in Drummoyne.

A complete schedule of all duties to be carried out in the twelve exchanges involved was prepared. This included details of the staff allocated to each portion of the work, an area map showing the external fault organisation, a junction diagram of all cables affected by the junction cut-over, together with the junction groups connected in each, and a schematic diagram of the junction cut-over arrangements as reproduced in Fig. 12.

Details of the Cut-over Procedure.—It is not possible to include in this article the complete arrangements as scheduled. However, the following staff duties listed for the Drummoyne manual and automatic exchanges indicate the methods of carrying out the principal operations:

Duty A.—Control Switchboard.

The officer in charge of the control switchboard will initiate operations for the cut-over in the following sequence:—

12.30 p.m.: Newtown Exchange. Fuses in junction circuits to be re-routed at cut-over will be inserted in the M.D.F. in accordance with Newtown Instructions Duty A. Completion to be reported to Drummoyne by telephone to W.2449.

North Sydney Exchange. Circuits through special arresters for North Sydney-Balmain junctions which will be re-routed via Chatswood at cut-over, will be closed in accordance with North Sydney Instructions, Duty A. Report completion to W.2449.

12.50 p.m.: Inform Hunter, Ryde and Epping manual exchanges that junctions will be taken out of service at 12.55 p.m. (Manual Exchange Instructions, Duty A), and Drummoyne Manual Exchange that junctions will be disconnected at 12.55 p.m. and subscribers at 12.58 p.m., as detailed in Drummoyne Instructions, Duty C (a).

12.55 p.m.: Balmain Exchange. Main and Branch Exchange junction circuits will be opened at arresters, jumpers cut in I.D.F. and Drummoyne repeater and arrester circuits closed in accordance with Balmain Instructions, Duties A, B, C, D and E. Completion to be reported on direct line.

Drummoyne Automatic Exchange. Intercept junctions at special panel and cut away 26 jumpers marked in red in accordance with Drummoyne Instructions, Duty B.

12.58 p.m.: Drummoyne Manual Exchange. Disconnect lines at M.D.F. as per Drummoyne Instructions, Duty C.

Drummoyne Automatic Exchange. Cut in outgoing junction circuits at M.D.F. as in Duty D.

1 p.m.: Drummoyne Automatic Exchange. Cut in subscribers to automatic exchange and incoming junction circuits at M.D.F. as in Duty E. Duties detailed under F to P inclusive will then be carried out.

(b) The subscribers' and junction lines will be disconnected from the manual exchange by removing the heat coils from the M.D.F. (The arrester carbons will be replaced by wooden blocks during the week prior to the cut-over.) Jumper wire will be used to remove the heat coils, a length of wire being inserted behind them in each strip and secured at the top.

At 12.58 p.m., when instructed to proceed, the heat coils will be forced out by pulling on these

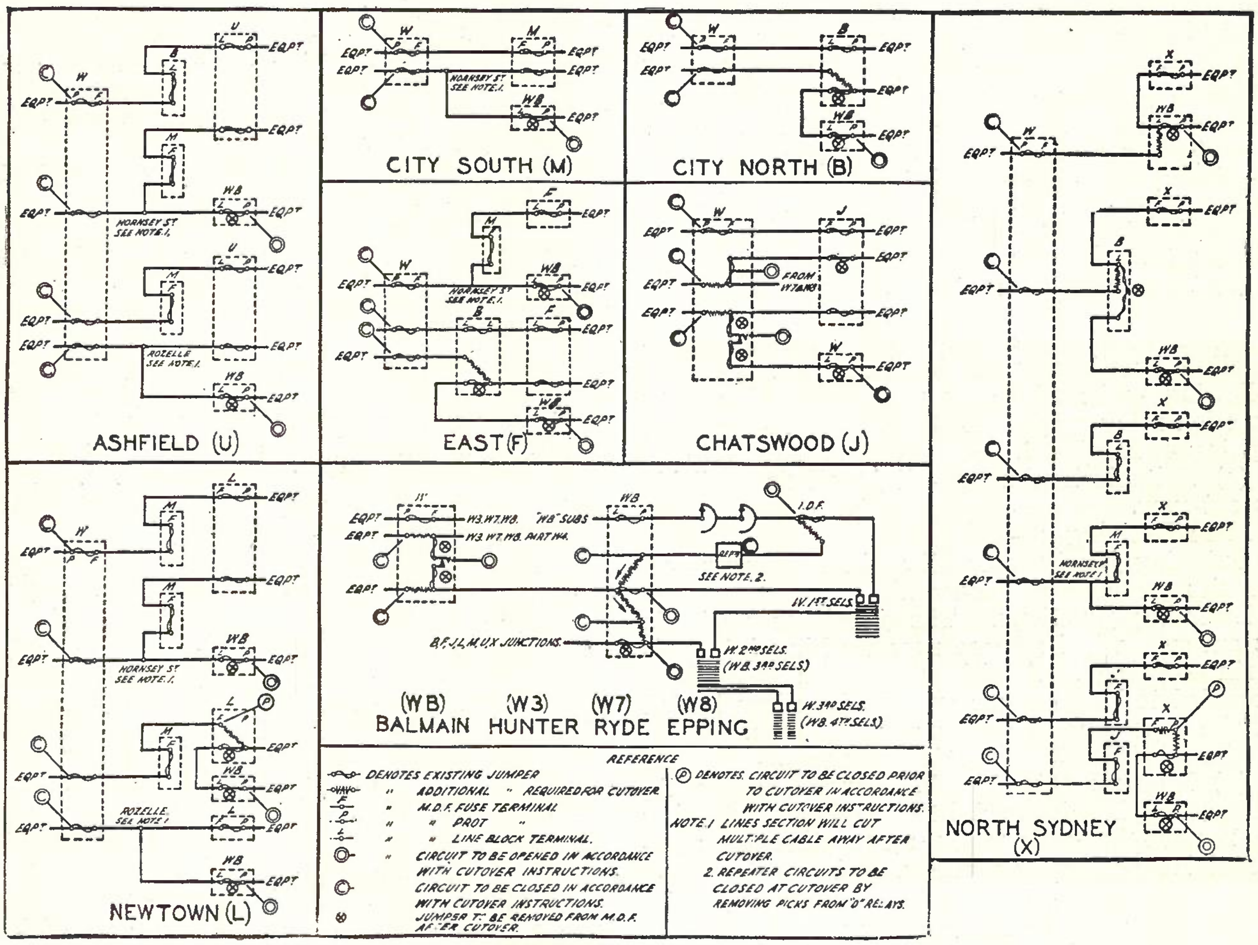


Fig. 12.

Duty B.—Intercept Junction Circuits.

(a) All manual exhange junctions connected through the special panel will be disconnected by inserting a switch plug in each jack to open the break springs and thereby free cable pairs for Balmain junctions.

(b) 26 jumpers coloured red which carry manual exchange junctions from Ryde and Epping to Chatswood will be cut away to prepare for connection to Drummoyne.

Duty C.—Cutting out at Manual Exchange M.D.F.

(a) The officer-in-charge of this duty will be notified at 12.50 p.m. that junctions will be disconnected at 12.55 p.m. and subscribers at 12.58 p.m. He will pass on this information to the Traffic Officer in charge of the manual exchange.

wires from the lower end, one vertical at a time. Each man will then inspect the verticals allotted to him to ensure that all lines are clear.

To avoid possible faults due to the wooden blocks and/or heat coil springs being displaced during the operation of removing the heat coils all the fuses in the M.D.F. will then be withdrawn.

Duty D.—Cutting in Outgoing Junction Circuits.

Outgoing junctions will be connected to the new exchange by closing the circuits at the heat coils of the new M.D.F. This will be done by removing the sash cords from the protector strips. Each protector will then be inspected to ensure that heat coils and/or carbons have not been displaced during the operation.

Duty E.—Cutting in Subscribers' and Incoming Junctions.

When instructed to proceed, these circuits will be connected to the automatic exchange and the protectors inspected as detailed in Duty D.

The order of closing the circuits will be:—

Subscribers' lines.

Incoming junctions.

Duty F.—Challenge Circuits, W4 level.

Twenty trunks from the W4 level have been equipped with relay sets to permit the challenging of incoming calls from subscribers incorrectly calling the Drummoyne manual exchange after cut-over. Subscribers will be referred to the May, 1941, issue of the Telephone Directory or requested to Dial B073 (Information).

Duty G.—Connect Additional Junctions.

The cut-over will take place with the following junction facilities:—

Branch Exchanges—

(a) Incoming from manual exchanges Ryde, Hunter and Epping—all junctions available.

(b) Outgoing junctions to manual exchanges—existing junctions available at cut-over with the following to be added by transferring incoming junction relay sets from Drummoyne:—Ryde 19, Epping 4, Hunter 6.

(c) Balmain Exchange—all junctions available at cut-over.

Main Exchanges—

Outgoing junctions to all main exchanges—all circuits available at cut-over.

Incoming junctions. The junctions available at cut-over will be those now working into Balmain exchange. Additional circuits have been provided to Drummoyne and the junctions busied at the repeaters in each main exchange.

The staff detailed to this Duty will—

(a) Instruct City North, East, City South, Chatswood, Newtown, Ashfield and North Sydney to remove busy flags from repeaters on additional Drummoyne junctions, and

(b) Despatch incoming junction repeaters by motor truck from Drummoyne manual exchange to Hunter (6), Ryde (19), and Epping (4). The repeaters are marked with the shelf position in which they will be installed in these exchanges.

Duty H. — Cutting-away connections to break jack panel.

On completion of Duty E the cables terminating on the break jack panel will be cut away from the fuse side of the new M.D.F. at the fuse strip terminals to obviate possible interference with the automatic exchange junctions.

Duty I.—Test of Urgent Services.

A list of all urgent services has been prepared and these will be tested as soon as possible after cut-over.

All faults affecting service will be immediately referred to:—

(1) Internal faults. The officer in charge of Duty N.

(2) External faults. The officer in charge of Duty O.

Duty J.—Subscribers' Services.

To prove subscribers' services and check numbers, each line will be called from the final selectors.

Duty K.—Complaints.

Operators will be detailed to both positions of the Complaints Desk, and faults reported to them will be referred to the officer in charge of Duty I.

Duty L.—Traffic Patrol.

The men on this patrol will pay particular attention to permanent loops on first selectors and to "no progress" calls which may be detected on the 1st and 2nd levels of the second selectors due to subscribers calling Balmain numbers without the correct prefix letters WB.

Permanent loops will be passed over a direct line to the M.D.F. for temporary disconnection and immediately referred to the officer in charge of Duty I for testing.

Where possible, subscribers will be informed of the correct operation of the automatic telephone and the need for avoiding the use of the magneto telephone pending its recovery.

Duty M.—Junction Test.

Immediately after the cut-over, a test will be made of all outgoing junctions by dialling the junction test number from each repeater.

In testing junctions to the manual exchanges, each circuit will be checked for correct designation of junction number and the satisfactory operation of cord circuit supervisory lamps under conditions of calling, registration and clearing. A telephone will be installed near the incoming auto. positions in each manual exchange for this purpose.

The additional junctions to be provided as detailed in Duty G (b) will be tested before being placed in service.

Duty N.—Internal Faults.

All internal faults affecting service will be referred to the officer in charge of this duty, who will detail men to clear them as circumstances demand.

Duty O.—External Faults.

All external faults affecting service will be referred to the officer in charge of this duty, who will control the despatch of sub-station staff.

External faults requiring the attention of the Lines Staff will be referred to Line Inspector on duty.

Duty P.—Battery and Power Plant.

(1) In order to be prepared for any abnormal exchange load the 200A generator will be used to float the battery on discharge. The machine will be placed in operation 15 minutes before the time of cut-over.

(2) The power and ring supply to the manual exchange will be disconnected immediately the lines are cut away at the M.D.F.

Duty Q.—Emergencies.

The men scheduled for this duty will stand by in the new Exchange M.D.F. room. They will be used to reinforce other duties as required and for emergencies."

In conclusion, it will be appreciated that, in carrying out a work of this type, when the date of the cut-over is advertised some time beforehand, that the successful completion depends largely upon close attention to detail on the part of the staff. Whether in the matter of mechanical adjustments or circuit detail, sub-station equipment or cable work, each section must be fully co-ordinated and thoroughly tested. A description of the cut-over would be incomplete without mentioning this aspect and acknowledgment is, therefore, made of the work performed by the Contractors and Departmental Staffs, which resulted in the conversion being effected successfully.

DIRECT SWITCHING BETWEEN AUTOMATIC BRANCH EXCHANGES

D. J. Mahoney

The advantages of direct switching between branch exchanges in the same group and the necessary alterations to existing equipment to introduce the facility are discussed in this article. The term branch exchange is used in this article but it may also be called a satellite exchange.

Early Trunking Methods.—In early automatic branch exchanges, the originating traffic was trunked from the line switch units to repeaters to which junctions to the main exchange were tied. This meant that a call from one local subscriber to another occupied a line switch (and probably a secondary line switch), a repeater, a junction to the main exchange, a first selector, second selector, junction uniselector and repeater in the main exchange, a junction back to the branch exchange, a third, fourth and final selector in the branch exchange. The inefficiency of this method was apparent and led to the introduction of switching selector repeaters, or discriminating selector repeaters which is the new term for this type of switch.

Switching Selector Repeaters.—With the introduction of switching selector repeaters, calls from one local subscriber to another were switched direct and the junction to the main exchange was released after the second digit. When such a call is set up the equipment occupied is a line switch, switching selector repeater, third, fourth and final selector. All this equipment is in the branch exchange. There are no junctions in use, and the equipment previously required in the main exchange is now thrown spare. The ultimate aim is to free as much common equipment as possible in main and branch exchanges so that this equipment can be used for other calls.

Reasons for the introduction of direct junctions.—It has been realized that further economies with the use of switching selector repeaters can be effected, if calls originating at a branch exchange and destined for a subscriber in a nearby branch exchange in the same group are switched direct in a similar manner to local switching. Fig. 1 shows a geographical layout of the "F" group in the Sydney Metropolitan Network. This is the largest automatic exchange group in the Commonwealth, having 30,474 lines connected at present. The existing and proposed exchanges in this group and the number of lines connected at present are shown in Table 1.

TABLE 1

Exchange	Call Letter	Number of Lines Connected	
East	FA (and FL at present)	6140	
Ocean Street	FB	—	Not yet established.
Kensington	FF	—	Not yet established.
Maroubra and La Perouse	FJ	1885	La Perouse not yet established.
Coogee	FL	—	Not yet established.
Edgecliff	FM	6032	
Vaucluse and Watson's Bay	FU	4559	Watson's Bay not yet established.
Waverley	FW	5562	
Randwick	FX	6296	
Bondi	FY	—	Not yet established.
	Total lines connected	30,474	

The direct distance between any two branch exchanges is far less than the route via the main exchange. This is a case for an economic comparison of the costs of providing junction cables between the branch exchanges against the junction cables from each branch to the main exchange and equipment in the main exchange. In this case it has been found economical to provide direct junctions, and as an example, the following equipment will be saved

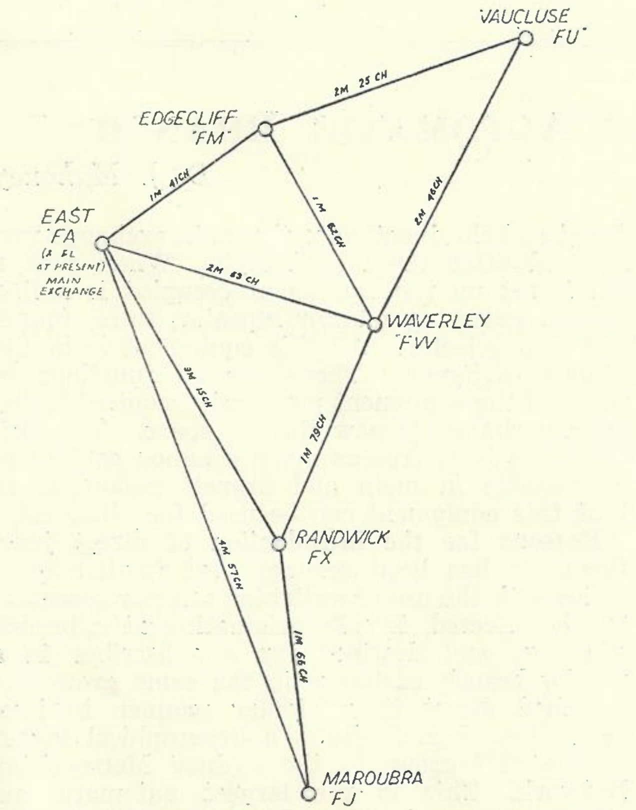


Fig. 1.—"F" Group Junction Arrangement.

in the main exchange when the inter-branch traffic is diverted by the introduction of the full scheme:—

152 incoming first selectors.
200 local 2nd selectors.
380 junction uniselectors.
128 auto-auto repeaters.

Figs. 2 and 3 show typical trunking schemes for a branch exchange in the "F" group before and after inter-branch junctions are provided.

EQUIPMENT PROBLEMS IN THE INTRODUCTION OF DIRECT JUNCTIONS

(a) **The alteration to switching selector repeater circuits.**—The switching selector repeaters introduced originally in the Commonwealth, repeat impulses over the junction to the main exchange on all calls except after the discriminating digit on local calls. Local calls are switched direct to local 3rd selectors. The negative, positive and private trunks are extended to the switch ahead and the repeating element is then open circuited. Figs. 4 and 5 show the circuit conditions on a call to the main exchange and a call to the local exchange respectively on this type of switch.

If switching to branch exchanges is required,

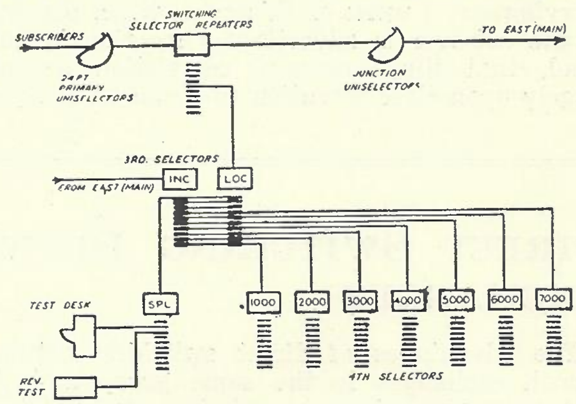


Fig. 2.—Trunking Scheme—Edgecliff Branch Exchange before the introduction of Direct Junctions between Branch Exchanges.

it is essential to retain the repeating element in the circuit. The circuits of the latest switching selector repeaters supplied provide for repeating on all levels and no alteration is necessary to

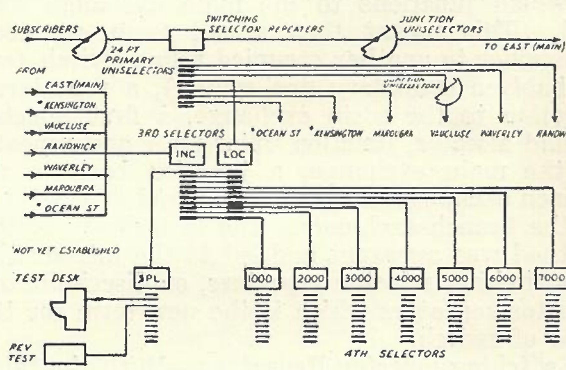


Fig. 3.—Trunking Scheme—Edgecliff Branch Exchange after the provision of Direct Junctions between Branch Exchanges.

these switches; however, the earlier types must be altered to repeat on all levels. The alterations necessary are shown in Fig. 6 and may be summarized as follows:—

(1) The repeating element is retained in circuit on all calls.

(2) The contacts of relay "H" are arranged to normally complete the connection to the main exchange, but on local or branch exchange calls to disconnect the loop to the main exchange and connect the wipers in lieu.

(3) The wiring of the RT wiper is modified to connect a ground to the P contact of the bank to guard against intrusion on a local or branch exchange call.

(4) An additional set of contacts is fitted to the "H" relay to break the "hold" trunk and open the circuit to the "B" relay in the junction

uniselector associated with the switching selector repeater.

(b) **Strapping of P1 contacts on switching selector repeater banks.**—The disconnection of the junction to the main exchange and the connection of the wipers of the switching selector repeater in lieu is necessary on a call to a branch exchange. This is effected by the operation of the "H" relay (see Fig. 6) which is controlled by the condition encountered by the C wiper on the 1st contact of the level reached by dialling the second digit. It is, therefore, necessary to provide the

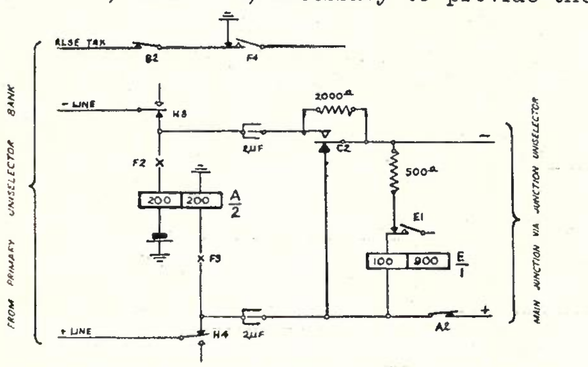


Fig. 4.—Impulsing Condition during Calls to Main Exchange.

correct condition on the branch exchange levels to allow the "H" relay to operate.

Typical level strapping schemes before and after the provision of direct junctions, are shown in Fig. 7. The top contact is the P1 and is associated with wiper C. The P1 contacts on each level of all S.S.R. banks in branch exchanges are wired to 10 x 2 terminal blocks to facilitate the strapping. These blocks are mounted at the rear of the S.S.R. shelves and are wired in a short form to the P1 contacts of the S.S.R.

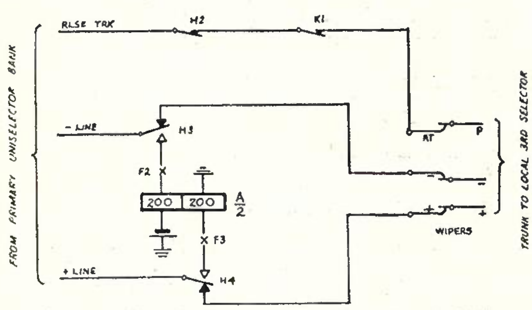


Fig. 5.—Circuit Condition during Local Call.

banks. One block provides for two banks. This arrangement meets all future development and obviates any further wiring of banks when new exchanges are added to the group. The frequent handling of banks causes many wiring faults and should be avoided wherever possible.

(c) **Disconnection of booster battery from final selectors.**—It can be seen from Fig. 6 that when the "H" relay operates (that is on a local or branch exchange call) a ground is connected to the RT or private wiper. If metering is carried out from the final selector, the meter pulse would be earthed at H2 contact (on local calls). Metering is therefore effected for all calls from the

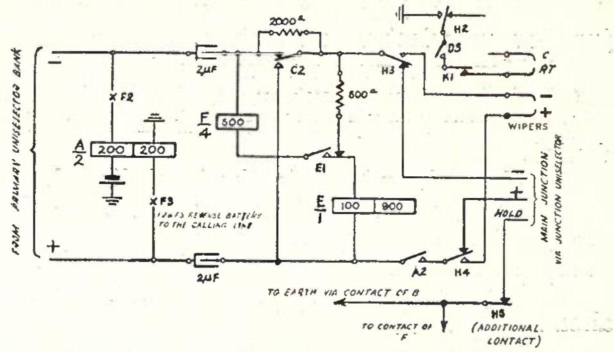


Fig. 6.—Alterations to Switching Selector Repeater Circuit.

switching selector repeater and the booster battery is disconnected from the final selectors and earth connected in lieu.

CIRCUIT EXPLANATION OF SWITCHING SELECTOR REPEATERS ADAPTED TO REPEAT ON ALL LEVELS. SWITCHING ON SECOND DIGIT. SEE FIG. 8.

Functions

(a) **Calls to other switching groups.**

(1) Hold the switch behind operated and guard itself against intrusion. Cause the outgoing junction uniselector to function.

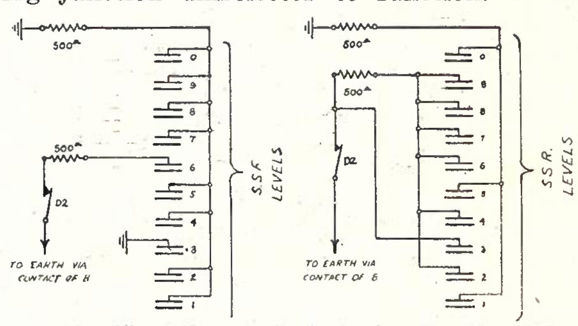


Fig. 7.—Strapping of "P1" Contacts for Trunking Schemes shown in Figs. 2 and 3.

(A) Strapping of "P1" Contacts before inter-Branch Switching is established. Trunking Scheme Fig. 2 refers.

(B) Strapping of "P1" Contacts when full inter-Branch Switching is established. Trunking Scheme Fig. 3 refers.

(2) Move the wipers to the level dialled. Give the calling party the busy tone when all junctions to the main exchange are busy.

(3) Automatically cut-in on the level dialled.

(4) Repeat impulses to the switches ahead.

(5) When the called subscriber answers, cause the calling party's meter to operate and reverse battery back to the calling line.

(6) Supply transmission battery to the calling line.

(7) Release when the calling party hangs up. Allow the switch behind to release and make itself free.

Allow the switches ahead to release.

Give an alarm if it fails to release.

(b) **Calls to a local subscriber in the same exchange.**

(1) Hold the switch behind operated and guard itself against intrusion. Cause the outgoing junction uniselector to function.

(2) Move the wipers to the level dialled.

(3) Automatically cut in on the level dialled.

(4) Automatically release from the level dialled.

(5) Move the wipers to the level dialled.

(6) Automatically cut in on the level dialled.

(7) Automatically hunt for a free trunk and seize the first free trunk encountered.

(8) Repeat impulses to the local switches ahead.

(9) Free the junction to the main exchange.

(10) When the called subscriber answers, cause the calling party's meter to operate, and reverse battery back to the calling line.

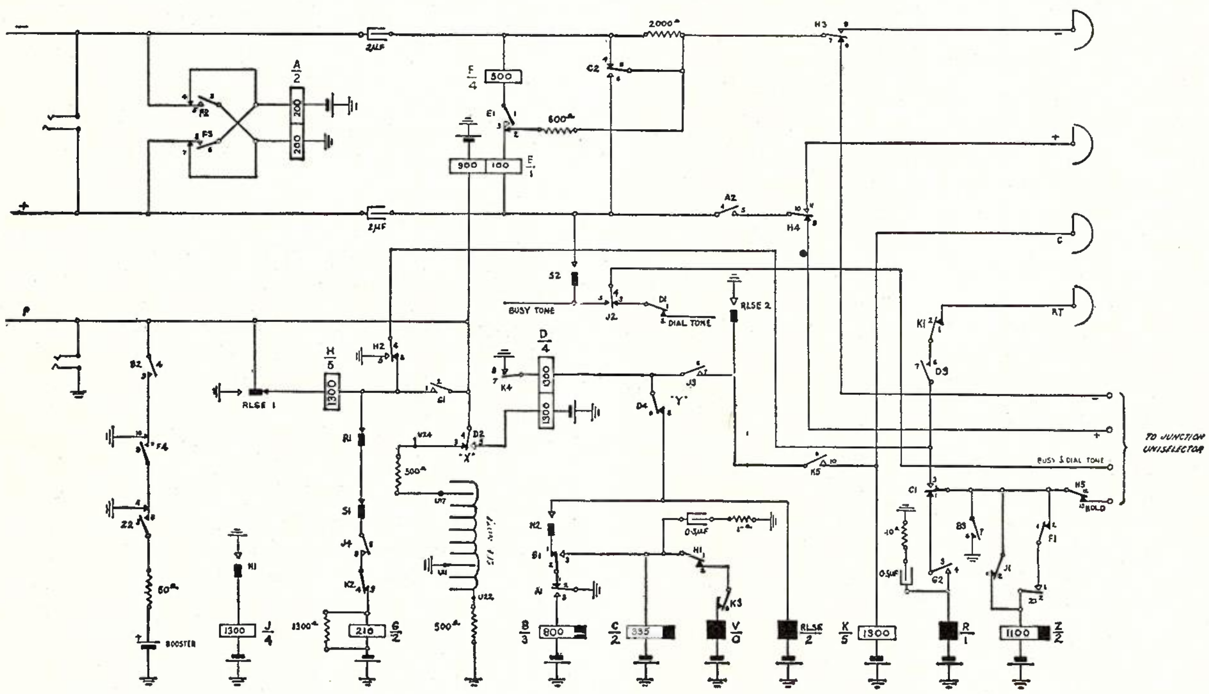
(11) Supply transmission battery to the calling subscriber.

(12) If all trunks on the local level are engaged remove the wipers from the bank and give the calling party the busy tone.

(13) Release when the calling subscriber hangs up. Allow the switch behind to release and make itself free. Give an alarm if it fails to release.

(c) **Calls to branch exchange in the same group.**

The functions are the same as for a call to a local subscriber except that for function (8) the impulses are repeated over a junction to the branch exchange required instead of to the local switches.



Note 1:—P1 Strapping.
U17 to Level corresponding to 2nd but not first digit of local Nos.
U22 to Levels corresponding to neither 1st nor 2nd digit of local Nos.
U24 to Level corresponding to both 1st and 2nd digit of local No.
U11 to Level corresponding to first digit of local No.
Note 2:—Contact "X" to make before contact "Y" breaks on relay "D."
Note 3:—Mechancally operated contacts = N /2 and S /2.

Fig. 8.—Switching Selector Repeater adapted to repeat on all levels.

Operation

(a) **Calls to other switching groups.**

1. **Seizure.**—When the switch is seized A relay operates over the calling subscriber's loop and closes the loop to the outgoing junction uniselector through the 100 ohms winding of E and 500 ohms N.I., and closes the circuit to B relay. B relay operates, grounds the release trunk, closes the circuit to Z relay which operates and locks, closes the circuit to the 900 ohms winding of E and grounds the "HOLD" lead to hold the junction uniselector operated. E relay does not operate because the magnetic fields associated with its windings oppose each other.

The 600 ohms loop on the trunk operates the line relay of the junction uniselector causing it to search for an idle trunk. If there is a free junction to the main exchange the junction uniselector extends the 600 ohms loop over the junction to the incoming selector at the main exchange. The incoming selector connects dial tone on the junction. If there is not a free junction to the Main Exchange the associated junction uniselector connects dial tone to the trunk via the "Busy and Dial Tone" lead, to indicate to the calling subscriber that a local call may be made.

2. **Moving Wipers to the level dialled.**—The "A" relay responds to the impulses from the dial; when "A" releases on the first impulse, the vertical magnet and "C" relay operate in parallel. C2 short circuits the 100 ohms winding of E and 500 ohms N.1. to improve impulsing conditions and C1 prepares the rotary cut-in circuit. The vertical magnet raises the shaft to the level dialled. B and C. remain operated during impulsing. The N springs operate on the first vertical step and close the circuit to J relay which operates and opens the operate circuit of Z relay. J2 connects busy tone to the "Busy and D.T. lead" and J4 closes the circuit to G relay which operates and locks via the R1 contacts.

If all junctions to the main exchange are busy, the junction uniselector connects the Busy and D.T. lead to the trunk, and J relay having operated connects busy tone to the trunk giving the calling party the signal.

3. **Automatic cut-in on the dialled level.**—On the completion of the last impulse of the train, C relay restores and replaces the 600 ohms holding loop. C1 completes the circuit of the rotary magnet which operates and rotates the shaft on the first contact of the level dialled. R1 contacts open and allow G relay to restore and open the circuit of the rotary magnet. The P1 contacts of levels other than the level corresponding to the first digit of the local numbers are connected to earth through 500 ohms. This earth is extended through the C wiper to relay K which operates and opens the vertical magnet and G relay circuits so that these circuits will be open on subsequent trains of impulses. The release magnet does not operate.

4. **Repeating impulses.**—The A relay responds to the impulses of each succeeding digit from the dial and when in its normal position opens the loop circuit to the main exchange and closes the circuit to C. C operates and short circuits the 600 ohms holding loop across the junction to improve impulsing conditions.

5. **Called subscriber answers.**—When the called subscriber answers, the battery on the junction is reversed, this reverses the magnetic field in the 100 ohms winding of E relay. E relay now operates and connects F relay in series with the 100 ohms winding of E across the trunk and removes the 500 ohms N.1 resistance.

F relay operates and reverses the battery on the calling line for supervision if required and Public Telephone operation. F4 connects the booster battery circuit and F1 opens the circuit of Z relay. Due to its slow release action, Z relay remains operated for approximately 200 milliseconds during which time the booster battery pulse is connected to the private to operate the calling subscriber's meter. When Z restores, the booster battery is replaced by earth.

6. **Transmission.**—The A relay supplies current to the transmitter of the calling line during conversation.

7. **Releasing.**—When the receiver is replaced on the calling telephone A relay releases, opens the loop on the junction to allow the switches in the distant exchange to release and opens the circuit to B relay. B restores and removes the ground from the release trunk to allow the switch behind to release and make itself free, opens the circuit to the 900 ohms winding of E, removes the ground from the "HOLD" trunk to allow the junction uniselector to release and closes the circuit to the release magnet. The release magnet operates and restores the shaft to normal and opens the N springs. The N springs open the circuit to J relay and the release magnet. The release magnet springs replace ground on the P wire to guard the switch during release.

The battery to the release magnet is connected through a supervisory relay so that an alarm will be given if the shaft fails to restore and open the off normal springs.

(b) **Calls to a local subscriber in the same exchange.**

(1) **Seizure.**—When the switch is seized it performs the functions explained under heading (1) in section (a).

(2) **Moving the wipers to the dialled level (1st digit of local number).**—The operation is as explained under heading (2) in section (a).

(3) **Automatic cut-in on the level dialled.**—The operation is as explained under heading (3) in section (a). The P1 contact of the level corresponding to the first digit of the local numbers is connected to earth. This earth is extended through the C wiper and operates relay K. K5 extends the earth to the release magnet which operates and also shunts the operate winding of D relay to prevent D from operating till the shaft restores to normal.

(4) **Automatic release from the level.**—The release magnet operates and closes the locking circuit to K relay to hold K relay operated till the shaft restores to normal, also closes the locking circuit to its own winding to ensure a clear release of the shaft to normal. The N springs open when the shaft restores and open the circuit of J. J restores and J3 removes the shunt from the operate winding of D relay. D operates in series with the release magnet from ground at K4 and locks. J3 also opens the locking circuit of the release magnet. D2 opens the ground from the 500 ohms resistance which is strapped to the P1 contact of the level corresponding to the second digit of the local numbers. This will allow the switch to select a free outlet on the local level if a local number is dialled. D4 opens the circuit to its operating winding and D1 opens the dial tone. When the locking circuit of the release magnet is opened at J3 the release magnet restores and allows K relay to restore.

(5) **Moving wipers to the dialled level (2nd digit of local number).**—The operation is per-

formed as explained under heading (2) in section (a).

(6) **Automatic cut-in on dialled level.**—The operation is performed as explained under heading (3) in section (a).

(7) **Automatic hunting for a free trunk.**—If the first trunk on the dialled level is busy, G relay on restoring (when its circuit is opened at R1 contacts) is again operated (when R1 contacts close again) by the earth on the RT wiper. G relay locks and operates the rotary magnet which rotates the shaft causing the wipers to be moved to the next contact and opens the circuit of G. G restores and opens the circuit to the rotary magnet. The foregoing operations continue until a free trunk is found or the wipers step to the 11th contact. During hunting the H relay is short circuited by ground on RT wiper.

(10) **Called subscriber answers.**—This function is explained under heading (5) of Section (a).

(11) **Transmission.**—This function is explained under heading (6) of Section (a).

(12) **Release of the wipers from the bank when all trunks are busy.**—If all the trunks on the local level are busy, the shaft operates the S springs on the 11th rotary step. S1 opens the circuit to G to prevent H relay operating. S2 connects busy tone on the + trunk to give the dialling party the busy tone.

(13) **Release.**—This operation is explained under heading (7) in section A.

(c) **Calls to other branch exchanges in the same group.**

The switch functions in the same manner as for a call to a local subscriber. The P1 contacts of the levels corresponding to the branch exchanges on which switching is required are con-

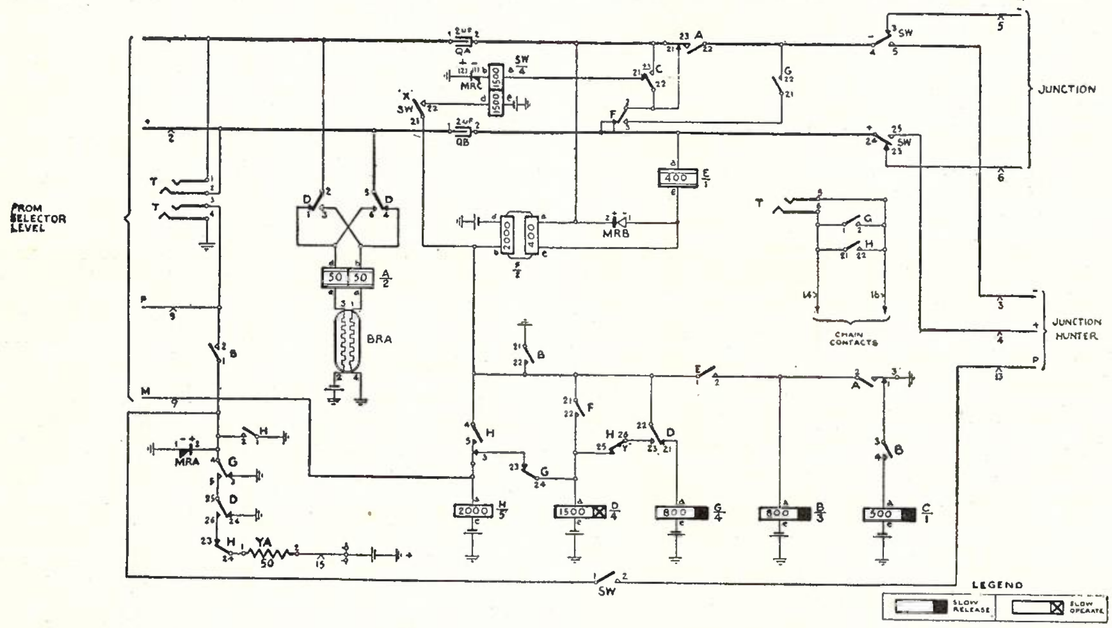


Fig. 9.—Auto.-Auto. Relay Set—Repeater, Switching.

When a free outlet is encountered, the wipers come to rest and the short circuit on H relay is removed by the absence of ground on the RT wiper. When the rotary magnet fully restores, R1 close and complete the circuit of H relay in series with G. G relay will not operate in series with H. H relay operates and changes over the holding loop from the junction to the wipers which are extended through the bank to the local switch ahead.

(8) **Repeat impulses to the switches ahead.**—This function is performed as explained under heading (4) in section (a), but the impulses are repeated to the local switches ahead.

(9) **Free the junction to the Main Exchange.**—When H relay operates the junction is opened at H3 and H4 and the "HOLD" trunk to the junction uniselector is opened at H5. The junction is now free to be selected for other calls.

nected to D2 through which ground is extended. When the D relay operates on the first digit of a call to a branch exchange, the ground is removed from the P1 contact. K relay therefore will not operate when the wipers are cut in on the level corresponding to the second digit of a local number. K2 completes the circuit of G relay and the switch searches for a free outlet as described under section (b) paragraph (7), and repeats all further impulses over the junction selected to the branch exchange required.

SWITCHING SELECTOR REPEATERS, SWITCHING ON THIRD DIGIT.

Certain numbering schemes require that the local exchange is determined by the third digit of the train. This usually occurs in small satellite exchanges and if the use of switching selector repeaters is found to be economical, the circuit should be arranged so that switching on the local level occurs on the third digit of the train if a local number is dialled.

This function has been provided by arranging for the discriminating relay (D relay Fig. 8) to operate after the second digit of the local numbers.

Direct Switching Repeaters

A further development in direct switching is the recent introduction of the switching repeater. This equipment is used to switch calls from an automatic main exchange to an automatic branch exchange in a different group but situated comparatively close to the main exchange in which the call originates.

The circuit is similar to the auto to auto repeater, but in addition is provided with an extra relay SW and rectifier MRC (see Fig. 9). One winding of the relay is connected through a rectifier to earth and to the positive line of the junction. During impulsing the contacts of C relay remove the SW relay from the circuit to prevent impulse distortion, but the relay is again connected at the end of each impulse train. At the completion of the second train of impulses when the incoming second selector at the distant main exchange is stepped to the level corresponding to the branch exchange required, a positive pulse is connected to the positive line of the junction and operates the SW relay which locks. SW relay operated, opens the junction to the main exchange and transfers the loop to a junction hunter which searches for a free direct junction to the branch exchange for which the call is intended.

It is essential that the incoming second selectors be grouped together and a negative grounded battery connected to the positive trunk of the bank multiple on the level corresponding to the branch exchange on which direct switching is required at the originating exchange.

Features in the Supply of Power to Automatic Exchanges

L. D. Cross

The importance of maintaining a continuous service is realized by all associated with the electrical communication services, but to none, is this aspect of more importance than to those engaged in the telephone service. In an automatic telephone exchange, many sets of apparatus and alternate trunking channels or circuits are available for the setting up of calls, so that a fault on any individual circuit or item of switching equipment usually has little effect on the service and is relatively unimportant, but as the proper functioning of all equipment depends upon the supply of electrical energy from a common source, the necessity of having a thoroughly reliable power plant is apparent. The reliability of generators, rectifiers and the Commercial Electricity Supply systems, which are the primary source of power for an exchange, falls short of the requirements of the telephone service from the continuity of service aspect, therefore, to ensure continuity of service, secondary batteries are provided to operate the exchange for a space of time dependent on the capacity of the batteries and the current drain. In general, a battery capacity capable of carrying the exchange for 24 hours provides ample safeguard against interruption of the service. There remains only the exceptional emergency of an abnormal failure to guard against, which can be met only by the use of some Prime Mover type of reserve, and for this purpose, portable charging sets (consisting of an Internal Combustion Engine and Generator) can be held at convenient centres for use at the small and moderate sized exchanges and Stationary Engine Alternators provided at the larger and more important centres, in particular, those at which 24 V., 50 V. and 130 volts are necessary for automatic exchange and long line equipment.

The development of power control circuits has been governed mainly by the method of operating the secondary batteries. In the original schemes, the charge-discharge method of operation was used, but with advances in the design of generators and rectifiers and the use of smoothing filters in the charging circuits between the machines and the secondary batteries, an output sufficiently free from audio-frequency disturbance can be obtained to permit the use of the floating method of working, with the consequent economic advantages this system confers, viz.:—

(1) Only half the total battery capacity is required;

(2) A longer cell life is obtained by reducing the wear on the plates caused by gassing and the mechanical stresses resulting from the expansion and contraction of the active material during the charge-discharge cycle; and

(3) The increased efficiency obtained by supplying the energy from the machines direct to the exchange busbars.

Floating systems have been standard practice for many years, and a survey of the plants in use will reveal that this practice is well established, although continuous floating is practised at only a few of the larger exchanges. The adoption of the floating system of operation, focussed the attention of engineers and research workers on the desirability of improving the machines and rectifying plant and simplifying the methods of operation.

The choice of the type of plant that is provided to supply the Direct Current is decided on economic considerations, and generally rectifiers are used where the commercial supply is A.C. and outputs of less than 50 amps. are necessary and motor generators in all other cases except the case of minor installations with a total daily current load of under 100 amp. hours located in areas having a D.C. commercial supply, in which case the usual practice is to install 2 batteries operated on the charge-discharge system, the batteries being charged direct via a limiting resistance from the commercial supply leads.

Where rectifiers are installed, these will be either of the self-regulating type such as the Siemens Transrector (Reference 1) and the Westat Constant Potential rectifier (Reference 2), or of the manually adjusted types (References 3 and 4) used in conjunction with an automatic high and low voltage control relay set to cut the rectifier in and out of circuit as may be necessary to hold the battery voltage, and consequently the busbar voltage, between the minimum and maximum values required for the proper functioning of the automatic exchange equipment.

For the continuous floating of secondary batteries, a constant direct current supply is desirable, as with a supply of this nature the drop in battery voltage when current is taken out of the battery is sufficient to make the charging rate increase in proper proportion to restore the loss and thereby maintain the battery in a fully charged condition. Where motor generators are used, shunt wound generators are provided for battery charging in favour of series or compound machines, as these types of machines are not safe, for in the event of the failure of the commercial supply coupled with the non-operation of the circuit breaker, the generator operates as a motor, and as a result of the reversed current in the series winding, causes the machine to rotate at dangerous speeds. Shunt wound generators have drooping voltage characteristics, and when used for battery charging, some form of voltage control is essential. This is provided by the inclusion of a variable resistor in the field circuit by means of which the field excitation is regulated and the voltage controlled. Regulation originally was manually performed by means of hand operated regulators or rheostats, but in recent years automatic regulators operated by the voltage across the exchange busbars have been developed and, where installed, are giving satisfactory service.

Automatic Voltage Regulators.—There are two general types of these regulators in use in Australian exchanges, one containing a resistor in the form of a Carbon Pile (Fig. 1A), the resistance of which is varied by varying the compression on the pile, whilst in the other type (Fig. 1B), the resistor element consists of a number of series resistances connected to a conveniently arranged series of stud terminals, so that they can be short circuited or otherwise by the moving system and the overall resistance thereby varied as required.

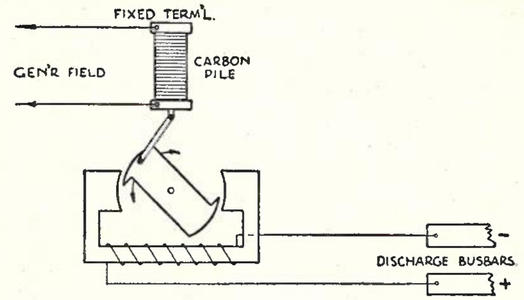


Fig. 1A.—Carbon pile type, automatic voltage regulator.

In both types of regulator, the moving system, through which the resistance element is varied, is connected to the armature of the magnetic system, the stationary portion of which includes the potential or exciting coil. This coil is connected direct across the exchange discharge busbars, so that any change in battery voltage as a result of load variation will cause a variation in the current in this coil and a corresponding alteration in the strength of the magnetic field in which the armature is situated. This will result in the immediate response of the armature and consequent variation in the resistance of the regulating element.

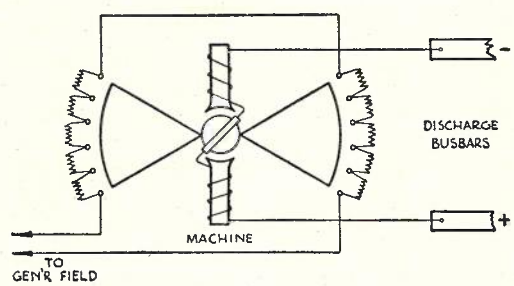


Fig. 1B.—Moving Coil type, automatic voltage regulator.

As the regulating element is connected in the field circuit of the generator in the manner shown in Fig. 2, any alteration in the regulator resistance varies the field strength of the machine and causes the generator output to change to meet the load requirements, with the result that a constant voltage is maintained across the battery and the exchange busbars. At the Carlton Exchange, where an automatic regulator of the Carbon Pile type is in constant service, it has been found that under all conditions of load the voltage remains constant within 0.5 volt and this is typical of the performance of other similar installations.

Reference to Fig. 2 shows that the automatic voltage regulator is connected in series with the hand operated regulator through a changeover switch so that either regulator may be used as required. When the automatic regulator is in use, a portion of the resistance of the hand regulator is left in circuit to safeguard the generator against the cutting out of the automatic regulator.

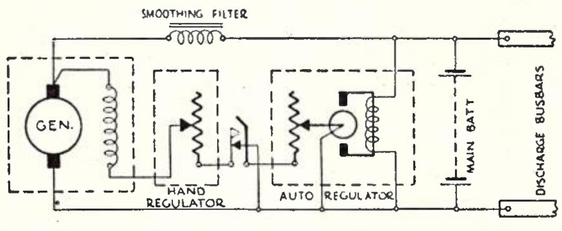


Fig. 2.—Method of connecting automatic voltage regulator.

Diverter Pole Generator.—Although shunt field generators with automatic regulators have proved satisfactory, the desirability of obtaining a generator that in itself would maintain a constant voltage and yet not "run away" on a reversal of current was realized, and a compound machine, known as the Diverter Pole Generator having these characteristics has now been produced, with outputs of up to 200 amps, and is being introduced into some exchanges.

The voltage characteristic of this new generator compared with that of a shunt wound generator with and without a regulator is shown in Fig. 3. It will be seen that the diverter pole

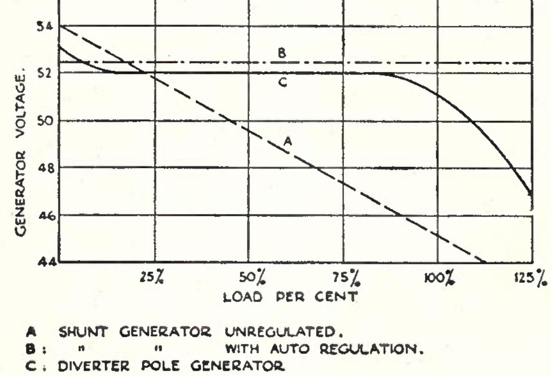


Fig. 3.—Voltage Characteristics of shunt wound generator, with and without a regulator and of a diverter pole generator.

machine maintains its voltage constant up to nearly full load, after which the voltage commences to fall. The decrease in voltage above full load prevents the motor carrying heavy overloads and helps to equalize the load between generators when two or more machine are run in parallel, and in this respect should be an improvement on the automatically regulated shunt machine, which tends to maintain a constant voltage regardless of the load.

As illustrated in the sketches comprising Fig. 4, this machine has a series field winding wound on separate poles called diverter poles situated centrally between the main poles carrying the shunt field windings, instead of on the same poles, as is the case with the regular form of compound machine.

Joining each diverter pole to the adjacent main pole in the direction of rotation of the armature, is a magnetic bridge. Under no-load conditions there is no current in the series winding and part of the magnetic flux from the main pole is diverted via the bridge and diverter pole and does not cross the main gap. This reduces the voltage generated in the armature windings. To limit the amount of flux diversion, the sectional area of the bridge is reduced by holes in it, so that it becomes saturated at the desired flux density.

When current flows in the series winding it produces a flux to oppose the diversion of the main pole flux and more is forced through the armature, increasing the generated voltage until at full load the whole of the main pole flux is forced into the armature. Since the diverter poles cannot increase the main-pole flux, the machine operates similarly to a shunt machine and the voltage drops as the load is increased.

If the power to the motor fails and the circuit breaker does not operate, the generator will run as a motor off the battery: and the series diverter pole winding will tend to reduce the flux in the air gap and increase the motor speed, but because of low saturation point of the bridge between the main and diverter pole, little reduction of the main flux is possible and the speed will not increase beyond safe values.

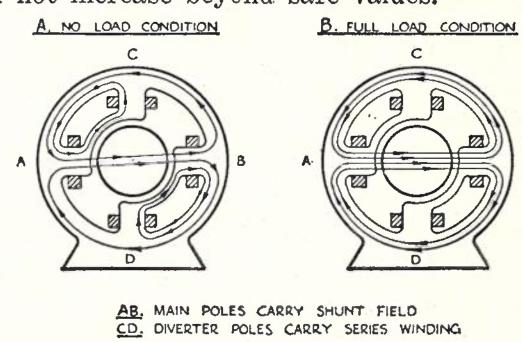


Fig. 4.—Diverter pole generator showing flux distribution.

Audio-Frequency Disturbance.—Laboratory and field measurements have proved that the maximum noise that can be tolerated at the exchange busbars is produced by an A.C. with an E.M.F. of 2 millivolts, R.M.S. value at a frequency of 800 cycles. This value is now internationally recognized. As the noise potential produced at the busbars is proportional to the impedance of the battery circuit, the impedance of this circuit should be kept at a low value. This can be achieved by arranging the installation so that the common charge and discharge circuit, including the battery, form a loop, the both leads of which are of equal length, be kept close together and be as short as possible.

Measurements made on various installations at a frequency of 1000 cycles per second reveal that the impedance of a battery loop is largely inductive. Minimum and maximum values of 10 and 23 microhenries were obtained, and an average value of 20 microhenries can be considered the maximum value of the inductance of

The arrangement of the smoothing filters is important, and they must be situated to avoid inductive interference from extraneous sources and to ensure that when condensers are included, the leads thereto are short, so as to keep the impedance at a minimum.

Power Systems.—The systems for supplying power in use in automatic exchanges can be divided into 2 main classes—

(a) Single Battery system.
(b) Duplicate Battery system.

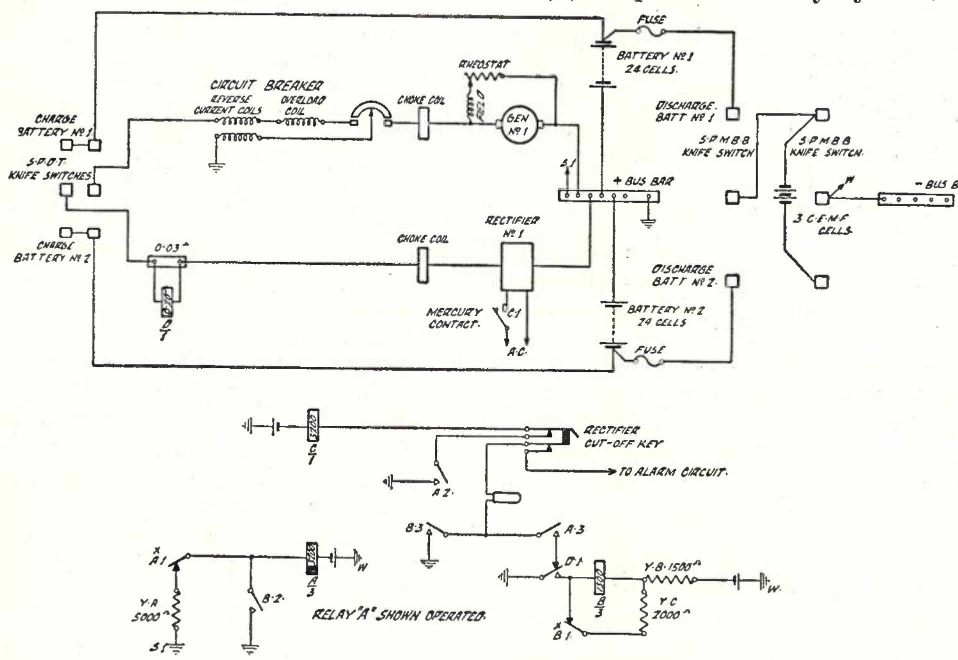


Fig. 5.—Power Circuit—Single Battery System—Relay Control.

modern installations. At 800 cycles per second the reactance of a 20 microhenry inductor is 0.1 ohm, and this value may be accepted as the impedance of a standard battery installation at the accepted average audio-frequency of 800 cycles per second.

The layout of the plant in the battery room, by virtue of the mutual inductance between the duplicate battery circuits and the practice of having a common charge-discharge lead connecting the positive busbar to the positive terminal of the battery, contributes considerably to the amount of noise produced.

To ensure that the permissible limit of audio-frequency E.M.F. at the exchange busbars is not exceeded, it is the practice to specify that all D.C. generating plant shall, if it does not of itself meet these requirements, be provided with a smoothing filter to ensure that these requirements are satisfied. The maximum audio-frequency potential difference measured with a psophometer across a non-reactive resistor in the load circuit shall not exceed the equivalent of 2 millivolts r.m.s. across 0.1 ohm when the output is varied from 1/4 to full load.

The single battery system is provided at branch exchanges with an ultimate capacity of up to 3000 exchange lines, whilst two batteries are installed at the larger exchanges. In both systems a total battery capacity sufficient to provide a full day's reserve is provided.

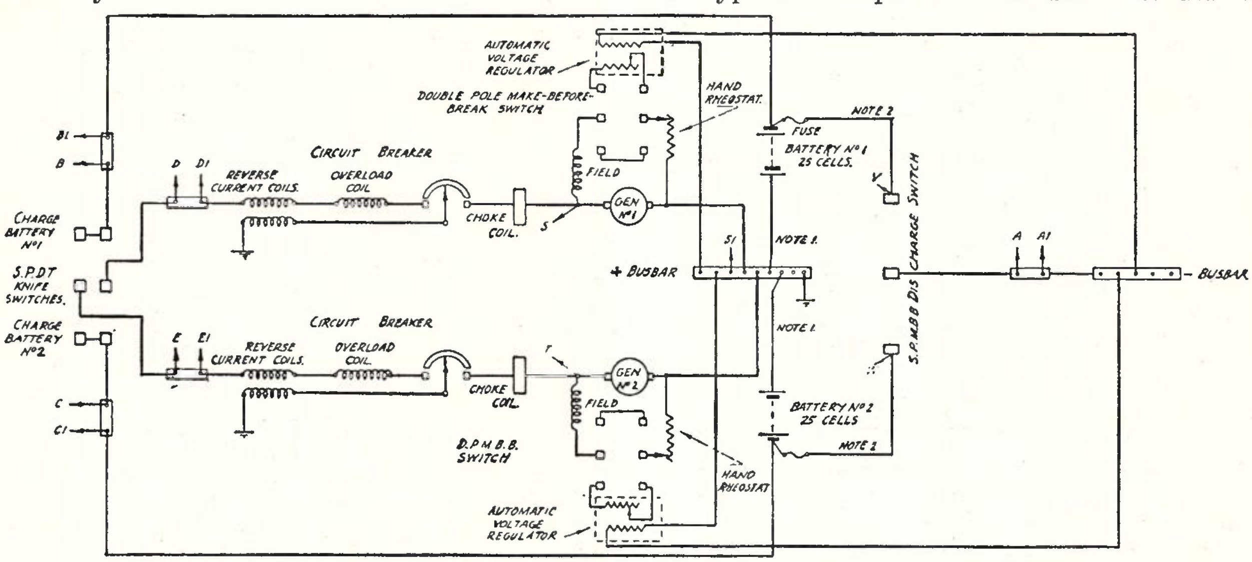
The single battery system, a schematic circuit of which is shown in Fig. 5, functions with a battery of 24 cells and 3 C.E.M.F. cells which are switched as a group and are provided so that the main battery can be given a full charge, when necessary, without increasing the busbar voltage beyond the upper limit of 52 volts.

Normally, the rectifier is connected to the load with the battery floating, and if not of the self-regulating or constant potential type, is automatically controlled by means of an associated relay set. To maintain a reserve for emergency purposes, the battery is operated between 48 and 52 volts, and the output of the rectifier is adjusted to supply the normal day load. The battery will therefore float at approximately 50 volts and frequent stopping and starting of the rectifier will be avoided. The conditions shown in Fig. 5 show the battery on discharge with the charge cut off. The contact of relay C is the mercury tube type. On the battery voltage falling to 48 volts, relay A releases and operates C, which connects the A.C. supply at C1, causing the rectifier to function and current to flow to the battery through relay D. Relay D opens the alarm circuit and completes the circuit of relay B, which however does not operate until the battery voltage reaches 52 volts. When B operates it operates relay A, releasing relay C, cutting off the A.C. supply and terminating the charge. Relay A also open circuits; relay B opening the alarm circuit. Relay A is held via contact A1 and resistance YA.5000. The alarm circuit is provided to indicate when the A.C. supply fails, the rectifier ceases to function or the control set functions incorrectly.

only to a capacity to carry the 10-year load, 10 years being the average life of the plates.

The schematic circuit is shown in Fig. 6, whilst a photograph of a typical power board is shown on page 258. Some of the features are as follows:—

Two or more rectifiers or motor generators are installed, the outputs of the various units provided being such as to permit of the operation of one or more machines at maximum efficiency to supply the exchange load, and of a total output capable of meeting the ultimate peak load and permit charge-discharge working in the event of a power failure, that is, they shall be capable of fully charging the both batteries in 8 hours. Where a rectifier is installed as one of the power supply units, unless it is of the constant potential type it is operated the same as for the



NOTES.—1. Separate lead for each battery. 2. Separate discharge lead. 3. Designations A-A1, S, etc., are leads to the voltmeter and differential ammeter switches, which are not shown.

Fig. 6.—Power Circuit—Duplicate Battery System—Automatic Regulator Control.

In addition to the various current limiting resistances, relays A and B are fitted with micrometer adjustments and X contacts to provide definite operation immediately the relay armatures start to move.

The motor generator is provided for emergency purposes in that after a commercial power failure it is necessary to fully charge the battery as expeditiously as possible. The second battery may be required when the exchange reaches its ultimate capacity.

In the past, for the larger exchanges the standard practice was to provide two 23/26 cell batteries of equal capacity, the last 3 cells in each battery being end cells—see Vol. 1, page 99. With the advent of automatic voltage regulation, the standard practice now is to provide two 25 cell batteries without end or counter cells.

In new installations, battery boxes for the ultimate 20-year plates are provided but plated single battery case with an associated voltage control relay set. The largest and the smallest motor generator set (unless of the Diverter Pole type) is provided with an automatic voltage regulator. When it is necessary to use the machines in parallel, one machine will be controlled by the automatic regulator and the other machines set with the hand regulator and allowed to trail.

The automatic voltage regulator is adjusted to control the field current and thereby the output of the motor generator so as to maintain the busbar voltage between the limits of 50.5 and 51.75 volts, just under the maximum operating value for the automatic equipment, viz., 52 volts. The scheme is designed for operation with a battery continuously floating across the D.C. supply, but in some of the existing installations suitable D.C. generating or rectifying units to enable economical operation at the periods of light load are not available, and it is necessary to operate for these periods on a discharge basis.

Even when continuous floating is the practice, it will be noticed that there is a slight gradual fall in specific gravity and loss of charge due to the voltage per cell being less than 2.15 volts, the minimum voltage at which cells can be kept in good condition. To repair this loss and avoid a serious reduction in the reserve available, each battery is used as the floating battery alternately for periods of a week at a time. When a battery is taken off load, it is given an overcharge to ensure that the maximum capacity is available in case of emergency.

Another feature, not shown in Fig. 6, is the provision, when necessary, of a switch to permit both batteries to be connected in parallel to the discharge busbars in case of power failure. This arrangement halves the load on each battery. The batteries will be discharging at a lower rate than would be the case if they were switched on load in succession, therefore a greater number of ampere hours will be available before the voltage drops to the minimum of 46 volts which is required for the satisfactory operation of the automatic exchange equipment.

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SLOW RELEASE RELAYS AND DELAYED ACTION DEVICES

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

In previous issues of this Journal many works of considerable magnitude have been described. Typical examples are the articles on City West Exchange and the New Melbourne Trunk Exchange. Works of these types are built up of a series of elements—relays of various types, resistances, lamps, switches, cables, etc., all coordinated so that each element serves its allotted function. When the work is completed and power is connected, the parts work in an ordered manner and the equipment performs its allotted task in meeting the telephone requirements of a city.

Whilst articles on new exchanges such as City West are of very considerable interest, on occasion, it is of advantage to review some of the elements used. In this article, some aspects of "Slow Release Relays" and "Delayed Action Devices" will be reviewed.

Slow Release Relays

The purpose of a copper slug: When the circuit of any relay is opened, the magnetic field produced by the current in the coil, dies away rapidly, but, in doing so, it causes eddy currents to flow in the core, yoke and armature; all of which, are conducting materials. These eddy currents produce a magnetic field which is in the same direction as the main field and the armature is thus held for a short period after the circuit of the coil has been opened. The release lag of a relay may be increased by several methods. Possibly the earliest method adopted to increase the release lag was to fit a copper slug on the heel end. (Fig. 1a.) The slug is an annular ring of copper and is equivalent to a short circuited winding having one turn of very low resistance.

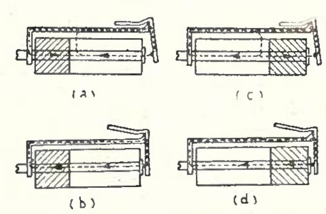

Fig. 1.—Effect of a copper slug fitted on the armature or heel end of a relay.

When the circuit of the coil winding is closed, the lines of force of the rising magnetic field induce a current in the slug, the magnetic field of which will oppose the field due to the current in the coil. The effect is to delay the building up of magnetic flux in that part of the core enclosed by the slug, whilst portion of the coil flux leaks across the gap between the core and the yoke and completes the magnetic circuit through the arma-

Lecture delivered before the Postal Electrical Society of Victoria on 9th September, 1940.

ture and the air gap to operate the relay. The effect on operating lag is negligible because the opposing flux of the slug reduces the inductance of the coil winding and allows more rapid increase in the current in the initial stages and this partially compensates for the added magnetic reluctance.

When the coil circuit is opened, the collapse of the magnetic field induces a current in the coil and in the slug in the same direction. (Fig. 1b.) The resultant magnetic fields are now in agreement and in the same direction as the original field due to the coil. The flux through the armature is now prolonged and the relay is slow to release. Reliable release lags of up to 350 m.s. may be obtained.

Although it is not intended to cover slow operating relays in this article, the effect of fitting a slug to the armature end is examined (Fig. 1c). The electrical and magnetic effects are the same as described previously, except that when the relay circuit is first closed, the opposing flux due to the slug, delays the growth of flux across the armature air gap, that is, the relay is slow operating. The result is that the relay does not operate until the reaction between the two fields has subsided to such an extent as to allow sufficient of the coil flux to traverse the air gap and attract the armature. When the relay circuit is opened (Fig. 1d) the effects are the same as when the slug is fitted at the heel end and the relay is slow to release. Typical operating and releasing lags are 100 m.s. and 250 m.s.

To provide for slow release, on Strowger type relays 11/16", 1", 1¼" and 1½" slugs are used, whilst the lengths of slugs used in 3000 type relays are ½", 1" and 1½".

The principle of the slow release relay, as explained, applies to all methods described hereafter.

The Use of a Copper Sleeve (Fig. 2).—This method is used frequently for relays which have to hold during dialling, that is, the relay has to remain operated for about 100 m.s. to provide a margin for adjustment. An interesting variation is a combination of a sleeve and slug which is used on the ring trip relay on Strowger final selectors. This combination makes a greater range of adjustment possible.

Fig. 2.—Use of copper sleeve and sleeve and slug combined.

Studies have been made of the effect on operate and release times of variation in the size and location of copper slugs and variation in size of sleeves. For the volume of copper usually used, sleeves give much longer operate and release values than either heel end or armature end slugs. Therefore, it is possible to use a smaller volume of copper in the form of a sleeve than that required for copper slugs to secure either slow operation or slow release. This offers the advantage that more winding space is available. Copper sleeves cannot be used to secure quick operation and slow release in combination such as is provided by heel end slugs.

Use of a Short Circuited Coil (Fig. 3).—The disadvantage associated with the use of copper slugs or sleeves is that the amount of winding space available for the coil is reduced. In many instances, when it is desired that a relay shall have fast operation at one period in a sequence of circuit operations and a slow feature at another or vice versa, a short circuited winding is

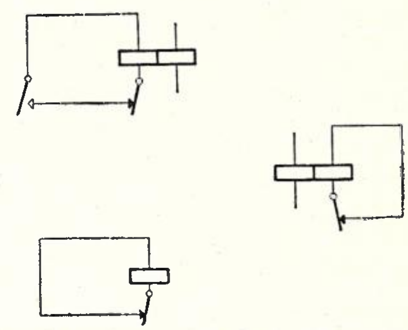

Fig. 3.—Typical arrangements of short circuited windings.

used. In some cases, it is possible to arrange for a relay with a single winding to be short circuited to provide for slow release, but in other circuits it is necessary to use a relay with two windings in that it is not possible to short circuit the operating winding. The winding which is short circuited may be located either at the heel or armature ends for slow release and at the armature end for slow operating. Various combinations of relay contacts can be arranged to bring in the short circuited winding as required.

The Use of a Metal Rectifier.—Although the use of rectifiers was covered fully in Paper No. 30, to present a complete story, reference is made to the connection of a rectifier to provide a slow release feature. The rectifier is connected in parallel with the relay (Fig. 4a). When the relay is operated, very little current flows through the rectifier as it is connected in the high resistance direction. When the relay is disconnected, the inductance of the coil tends to maintain the flow of current. A path for the current is provided through the local circuit of the rectifier; the current then flows in the low resistance direction. The current in the coil does not fall to zero immediately, but dies gradually and the armature is held for a short period. This method is frequently employed for holding a standard type relay operated when ringing current is applied to the circuit.

Shunting by a Resistance (Fig. 4b). — The effect of the resistance is similar to that of a metal rectifier, but the resistance coil is not so effective in that it offers the same resistance to current in both directions. Therefore more current is required to operate the relay. The local circuit for the current after the relay is disconnected has a higher resistance than is the case when a metal rectifier is used, but the armature is held for a short period only.

Shunting by a Condenser (Fig. 4c).—By means of a condenser of a suitable capacity, which may be connected across the relay winding either direct or in series with a resistance as shown in Fig. 4 (c), release lags of up to 1 second can be

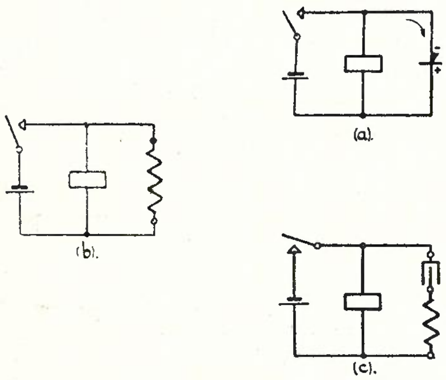

Fig. 4.—The use of (a) a rectifier, (b) a resistance, and (c) a condenser to provide for the slow release of a relay.

obtained. When the circuit is closed, the condenser is charged and when it is opened the condenser discharges through the relay winding.

Effect of Relay Adjustment on Release Lag.—The spring loading on a relay must have a definite effect on the speed of release; for a particular relay, the heavier the spring load, the shorter the release lag. Increasing the spring tension will reduce the release lag, as when the circuit of a relay is opened the magnetic field would not have to fall to such a low value before the spring tension overcomes the magnetic pull and so releases the armature.

Increasing the armature air gap, if no other factor is involved, has no effect on the release time. However, this would normally increase the travel and therefore the spring tension in the operated direction. Therefore the release time would be slightly reduced.

Increasing the residual air gap reduces the release time of a relay. When the residual air gap is increased, the reluctance of the magnetic circuit is also increased. Therefore when the relay is operated, the flux is reduced and when the relay is disconnected the falling flux will hold the relay armature for a shorter period.

It is not desirable to reduce the residual below $1\frac{1}{2}$ mils, as the screw dents the pole face and the air gap may become zero and cause the armature to stick.

For 3000 type relays, the release lags to be expected for relays having five contact units are as follow:—

	Residuals	
	4 mil	12 mil
$\frac{1}{2}''$ slug	100 m.s.	50 m.s.
1″ slug	180 m.s.	90 m.s.
$1\frac{1}{2}''$ slug	260 m.s.	140 m.s.

It has been found that the release lag changes very little when over 300 ampere turns are provided on a relay and for this reason the number of ampere turns on a coil should always exceed 300 so that the lag will not vary with variations in battery voltage.

Delayed Action Devices

In some instances, a delay period is required which is longer than can be obtained by the use of a slow release or a slow operating relay. This can be arranged by the use of one of the following:—

(i) A Thermostat relay.
(ii) A Dashpot relay.
(iii) A valve controlled to operate a relay in a definite time.
(iv) A Uniselector.

The Thermostat Relay, Th (Fig. 5), consists of a small coil of wire wound on a bimetallic spring. The heat generated by the current traversing the coil causes the spring to bend and if it is fixed adjacent to two other springs it can be arranged to make or break contacts. A thermostat relay can be made to operate at periods between 150 milliseconds and 2 minutes, but suffers from a disadvantage that after operation it requires time to cool down, otherwise it will reoperate much faster when the circuit of the heater winding is again completed. In some cases this disadvantage can be partly offset by introducing resistance in the circuit of the heater winding. The effect of the operation of the Th contact on the other relay shown in Fig. 5 is described later.

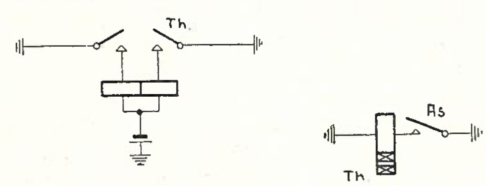

Fig. 5.—The thermostat relay.

The Dashpot Relay (Fig. 6).—This is one of the oldest type of delayed action devices in that these relays were used in the earliest automatic exchanges installed in Australia. It consists of a solenoid, the plunger of which is connected to a piston which is drawn through a cylinder filled with oil. The coil is mounted above the dashpot. The time taken for the piston to travel through the oil can be varied by means of a screw which regulates the flow of oil through the piston or by using a different grade of oil. The dashpot is not completely filled with oil so that the end of the stroke is rapid in order to effect quick make or break of the contacts. On release, a one-way valve in the piston permits it to restore quickly to its normal position. Thus it does not suffer from the disadvantage of the thermostat in that even if the control circuit is completed immediately after release the dashpot takes the same time to complete the circuit it is controlling.

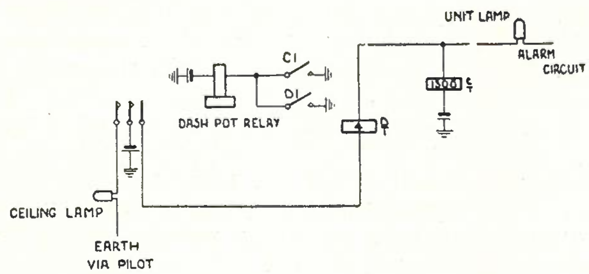

Fig. 6.—"The Dashpot Relay" and alarm control circuit.

The operating time of a dashpot changes with temperature variations in the exchange. In the circuit shown in Fig. 6, when earth is applied to the alarm circuit, relay C operates and completes the dashpot circuit. When the dashpot operates, the circuit of relay D is completed and C is shunted and releases. The unit and ceiling lamps then glow until the earth is removed from the alarm circuit.

Valve Control (Fig. 7).—This method is described in detail in Journal, Vol. 1, No. 6. The timing element is a charged condenser connected to a charge dissipating resistor, the time of discharge being dependent on the respective values of the condenser and resistance. If the condenser is charged and afterwards connected to a resistor the charge on the condenser maintains a negative potential to the grid of the valve, so preventing the flow of current to the anode. As the condenser discharges the negative grid potential decreases and the grid bias will reach a point where anode current commences to flow and later to reach a suitable value to operate the alarm control relay. On the release of the control relay, the condenser will be recharged practically instantaneously and the circuit will be ready for reoperation and will again provide the normal delay period.

Uniselector Method (Fig. 8).—A method which is used frequently is to provide three pulsing relays X, Y and Z. When earth is connected to the start lead, one of the relays (say Y) will operate first and open the circuit of X. Then Z will operate and open the circuit of Y which releases and closes the circuit of X which then operates, completes the uniselector D.M. circuit and opens the circuit of Z which release and the cycle is repeated. By this arrangement the magnet receives 5 pulses per second, i.e., a circuit connected to any one bank contact of a 25-point uniselector will be energised every 5 seconds. To provide even less frequent operation, the D.M. circuit of a second uniselector can be operated via bank contact of the first switch. As the second switch will step once every 5 seconds, a circuit connected to any one bank contact of a 25 outlet bank will be energised approximately once every 2 minutes. This arrangement is used for controlling the stepping of ringing and time

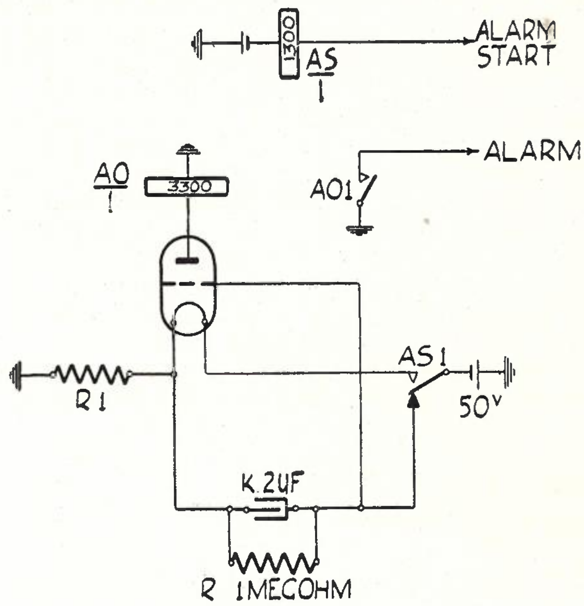

Fig. 7.—Valve circuit for delayed alarm control.

pulse switches in Type "C" and "CA" P.A.B.X.'s.

Some typical examples of the use of slow release relays may be of interest.

(a) **The Guarding (B) Relay** in the group selector circuit (Fig. 9a) depicts the elements

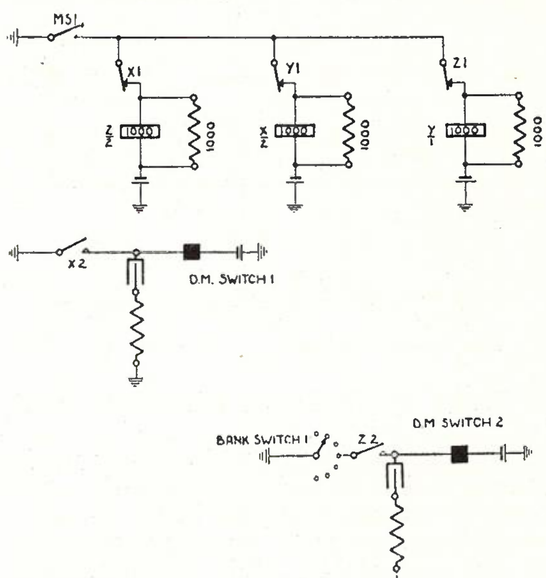

Fig. 8.—Uniselector method of delay control.

of the pre-2000 and Fig. 9 (b) shows the 2000 type circuit. On the earlier type the release lag is obtained by the use of a copper slug. Whilst this relay has functioned satisfactorily over many years, some difficulty has been experienced with relays with heavy spring loads in that they could not be adjusted to hold operated during an infinite train of impulses of 79.5% break at 12 I.P.S. without reducing the residual to such an extent that the armature had a tendency to stick. For type 2000 circuits, the short circuit method has been adopted. The operation of the A relay removes the short circuit from B relay and B operates in series with spool YA and rectifiers MRA. Relay C then operates with both windings in series and connects its 5 ohm winding in series with the V.M. and the B relay coil. The small current flowing through the V.M. and 5 ohm coil of C has no appreciable effect at this stage. The pre-energisation of C gives a definite improvement in impulsing since the first impulse given to a magnet tends to be short due to the saturation of A relay before dialling. Impulsing occurs in the normal way and at each break, direct ground is applied to

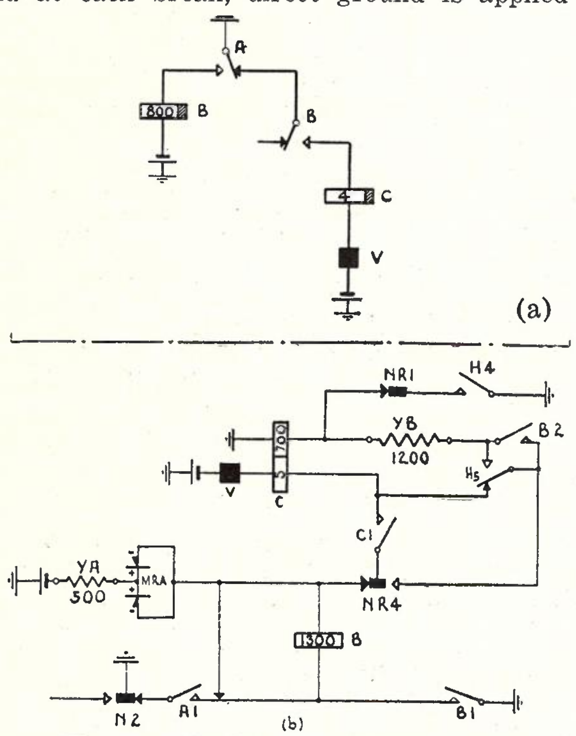

Fig. 9.—Portion of group selector circuits.

relay C and the V.M. and relay B is short circuited. The rectifiers MRA oppose the back E.M.F. from the magnet, which is set up during the make period of each impulse and so prevent the consequent surge current in YA from becoming sufficiently great to prolong the magnet release time appreciably. This precaution is necessary to reduce the possibility of the failure of the vertical magnet to release after each impulse break under conditions of long line or high dial speeds. Two rectifiers in parallel are used to reduce the possibility of deterioration produced by the overloads carried during the bunching time of the A relay contacts during the release lag of B on clear down.

It may be noted, also, that relay C is fast operating, but after the first train of impulses it is slow releasing. The release lag is controlled by the operation of H which is operated by N contacts on the first vertical step and which short circuits the 700 ohm winding of relay C. Although the leak current and the magnet surge pass through the 5 ohm coil of C, the effect on the release lag of C is generally negligible. The 700 ohm winding of C is short circuited only during impulsing and the relay releases in an unslugged condition on the release of the selector. This arrangement provides a means of providing the private guard on release, which was accomplished by the use of release magnet springs on pre-2000 type switches.

(b) An interesting example of the use of a relay with a **copper sleeve** is the C.B. extension switch, in which the relay functions also as an indicator (Fig. 10). In the extension to exchange position of the switch, the indicator relay is in series with the extension line. When the extension calls, the relay operates and the indicator shows the main station that the line is engaged. The extension switch bell is disconnected and the condenser shunt across the relay is increased to 3 M.F. to reduce the transmission loss. The relay will function satisfactorily on

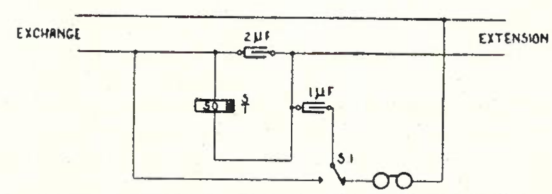

Fig. 10.—C.B. extension switch circuit (through position).

lines of up to 750 ohms resistance. The conditions with which the relay conforms are:—

(i) The contacts shall not break when an extension is rung from the exchange on a zero line with maximum generator E.M.F.

(ii) The signal shall operate over a line of maximum resistance and minimum P.D. on the exchange main battery.

(iii) The relay, having operated as in (ii), shall retain during dialling at a minimum speed, i.e., the bell shall not tinkle.

(iv) The relay shall release after operation as in (ii) and (iii), on a 10 ohm line and with maximum P.D. on the main exchange battery.

(v) The relay contacts shall not break when the extension rings the main station in series with a condenser, the switch being in the through position.

In the April, 1940, issue of the P.O.E.E. Journal "A New Subscriber's Intercommunicating Table Telephone Set" is described. In this set, the main telephone and extension switch are combined and there are some circuit improvements, but reference is made here only to the fact that a type 3000 relay has been used for an indicator relay. The relay used in the extension switches in service is of the pendant armature type.

(c) Fig. 11, which is portion of the exchange line circuit for a Type "C" P.A.B.X., shows an **application of the metal rectifier.** When an incoming call is received, relay AC is operated by the exchange ringing current, as described previously. After the call is switched to an extension and the conversation completed, the extension replaces the handset, but it is necessary to guard the exchange line against out calls until the exchange subscriber has cleared. This is accomplished by making the clearing condition dependent on a further operation of relay AC. Under speaking conditions, there is a balanced termination at the exchange, i.e., the battery feed relay in the final selector. When the extension clears, either ringing current or 40V., 50 cycle A.C. is applied to the centre point of the YE, YF resistances, but with a balanced ter-

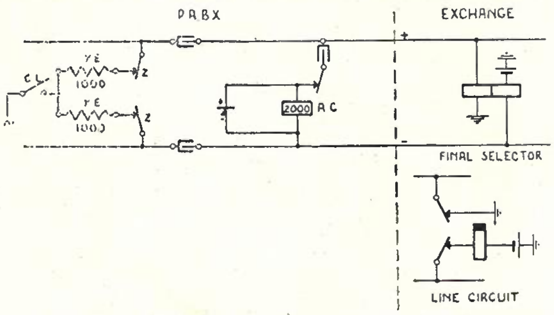

Fig. 11.—Portion of the exchange line circuit of a type "C" P.A.B.X.

mination relay AC is not affected. When the exchange subscriber clears, the line is connected to a uniselector at the exchange, thus providing an unbalance. Relay AC now receives a pulse and the rectifier ensures that it remains operated for a sufficient period to complete the circuit conditions necessary to clear the line at the P.A.B.X.

(d) The condenser method of slow release has been used in some P.A.B.X.'s, whilst the use of non-inductive resistances was shown on the pulsing relays in Fig. 8.

(e) The delayed action devices referred to have many uses, but perhaps one of the most interesting is shown in Fig. 12, which is the extension line circuit for a Type "C" P.A.B.X. On small installations, it is essential to ensure that the major switches are not held unnecessarily due to handsets being left off the cradle switch, etc. If there is a permanent loop on an extension line the connecting circuit must be forcibly released. In these units, the uniselector method is used. After 30 seconds, the Z earth pulse, which is controlled by the uniselectors shown in Fig. 8, short circuits relay K, which releases and restores the link circuit to normal. Earth is removed from the lower windings of relays L and K in the extension line circuits, but whilst relay L releases, relay K remains operated over the back contacts of relay L and the extension loop. The line will test busy to inward calls and an alarm circuit is completed, but as soon as the fault is cleared or the handset restored, relay K will release and the circuit is then normal.

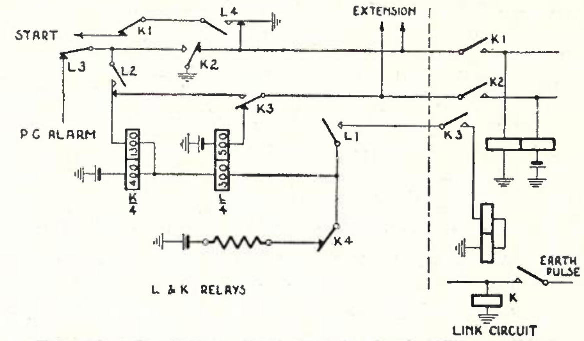

Fig. 12.—Extension line circuit, type "C" P.A.B.X.

It is not always convenient to apply a forced release in the manner shown in Fig. 12. Another method which is used in some equipment is to provide a relay with two windings, one of which is used as an operating winding, and the other, which is wound in opposition to the operating winding, will provide the forced release on the application of the Z pulse (see Fig. 5).

Conclusion.—The slow release relay and delayed action devices have proved indispensable in telephone exchange operation and it is hoped that these notes will serve as an introduction to a most interesting field of study. The development of automatic exchange equipments necessarily increases the complexity of the circuits, and for a full understanding of any particular circuit it is essential to dissect it into elements in which the salient features can be appreciated.

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The New Melbourne Trunk Exchange

C. L. Hosking

CALL ROUTING

Introduction.—The new Melbourne Trunk Exchange is highly specialised in all aspects of its design and application. It is evident that the operating methods are novel; reference to previous articles in this Journal will confirm the unique nature of the service offered by the new system. But the exchange equipment is correspondingly unusual in character. In itself, the application of automatic switching practice to trunk connections presents some unusual viewpoints, but, when amplified by such features as call queueing, call storing, four-wire switching and discriminating pad switching, a combination is produced which definitely enhances the distinctiveness of the Trunk Exchange equipment.

The Siemens motor uniselector was selected as a switch especially suited to meet the needs of the exchange. The switch has characteristics such as multi-wiper provision and a high speed of search with a large bank capacity, which offers distinct advantages for use with the system, but, nevertheless, the adoption of the motor uniselector serves to emphasise the distinctive character of the exchange. The equipment was necessarily costly to produce, hence every effort was made in the plant design to reduce switch quantities to a minimum. To this end the fullest possible advantage has been taken of the high bank capacity of the motor uniselector. Many devices have been developed in the interests of economy and efficiency to exploit the capabilities of the switch to the limit. These features all add to the special attributes of the system.

Therefore it is not to be expected that call routing through the exchange would be on conventional lines nor that the routing diagrams would follow familiar outline. A glance at any of these diagrams reveals that many new conventions have been introduced, most of these being consequent on the advent of the motor uniselector as the major switching unit in the system. Thus symbols, designed to distinguish the type and purpose of particular motor uniselectors, are included in the diagrams. The significance of these and other symbols must necessarily be appreciated before the routing may be properly traced.

Although the motor uniselector was described in Paper No. 25, "The Motor Uniselector and High Speed Relay," by H. E. Humphries, a brief description of some of the relevant features of the switch and an indication of the functions of associated apparatus are desirable in order to introduce the subject of this article.

The Siemens No. 17 motor uniselector (Fig. 1) is a switch of robust design and efficient performance. It is used as a group selector by associating in its circuit, a group of relays or mechanism which prepares "group marking" by which the switch is subsequently controlled when it makes its search. The switch has the high searching speed of approximately 200 outlets per second, a speed made possible by the inclusion in the selector circuit of a high speed relay having operating times in the order of $\frac{1}{2}$ millisecond. Such a high searching rate enables the motor uniselector to cover the 50 contacts of its bank sector (approximately $\frac{1}{2}$ revolution) in $\frac{1}{4}$ second.

As previously indicated, the motor uniselector functions as a searching element, that is, when energised, it moves its wipers across the bank to find a contact on which the correct circuit

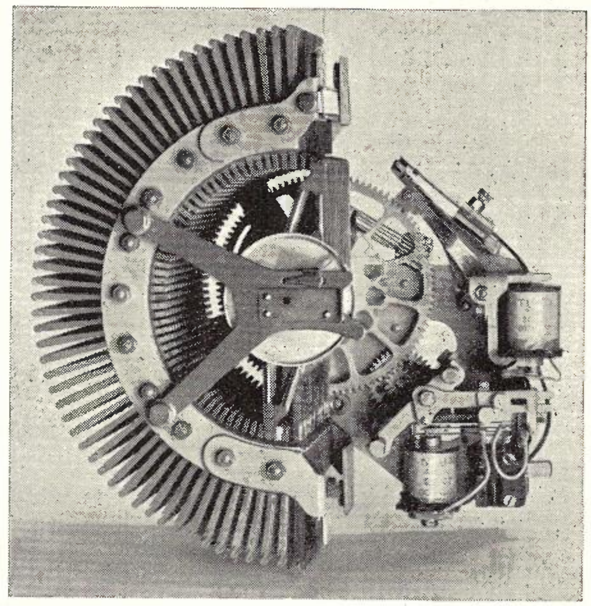


Fig. 1.—The Motor Uniselector.

conditions are pre-arranged to arrest its movement. When a motor uniselector is used as a group selector, the actual **digit** selection is provided by the preliminary operation of a special relay group with contacts arranged in a characteristic order known as a "contact tree," or alternatively by the pre-setting of a minor uniselector, so that a certain group of contacts is "marked" as the outlet group it is desired to call. (This marking of a digit group corresponds to the "level" selection of a group selector of the bimotional type.) When, subsequently, the motor uniselector rotates, its movement is checked on the first contact of the marked group free to take a call. It is important to note that contacts forming a digit group need not be necessarily adjacent or in any particular order, but may be dispersed over the bank. The bonding of contact to contact in a marked group is simplified if adjacent contacts form a group.

The switch has capacity for 16 wipers and the associated bank has 16 rows of 52 contacts. If a circuit requires 16 separate wiper connections, the number of contacts in one complete search is limited to 52. When eight wipers will cater for the circuit needs, the use of two groups of wipers set at 180° apart, each group moving over separate sections of the bank, makes it possible to extend the search to 104 steps. In this case, search is first made by one set of wipers over the first bank section (52 contacts), then this is immediately followed by a search of the second section by the remaining set of wipers. It is usual to provide for a normal ("home") position on the first contact and for the reservation of the last contact for group busy or some similar function, so that the switch has a capacity of 50 or 100 outlets respectively under the two conditions mentioned above. It is further possible, where the circuit requirements are not more than four wipers, to increase the

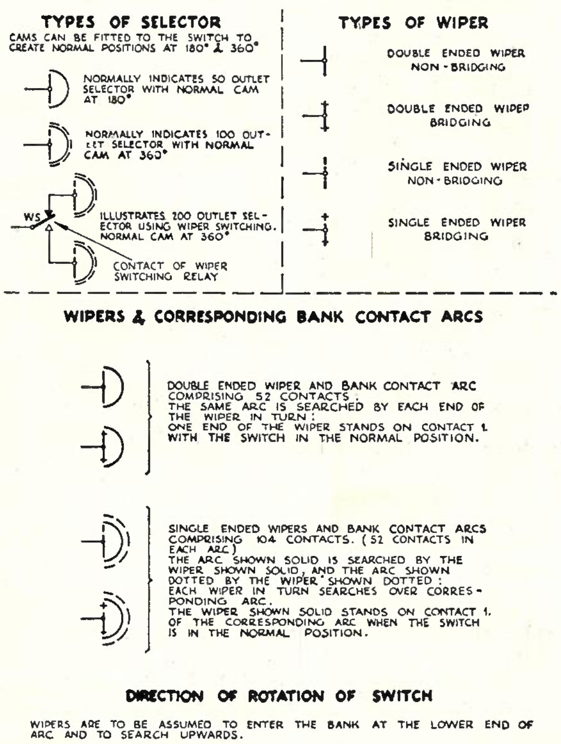


Fig. 2.—Motor Uniselector Conventions.

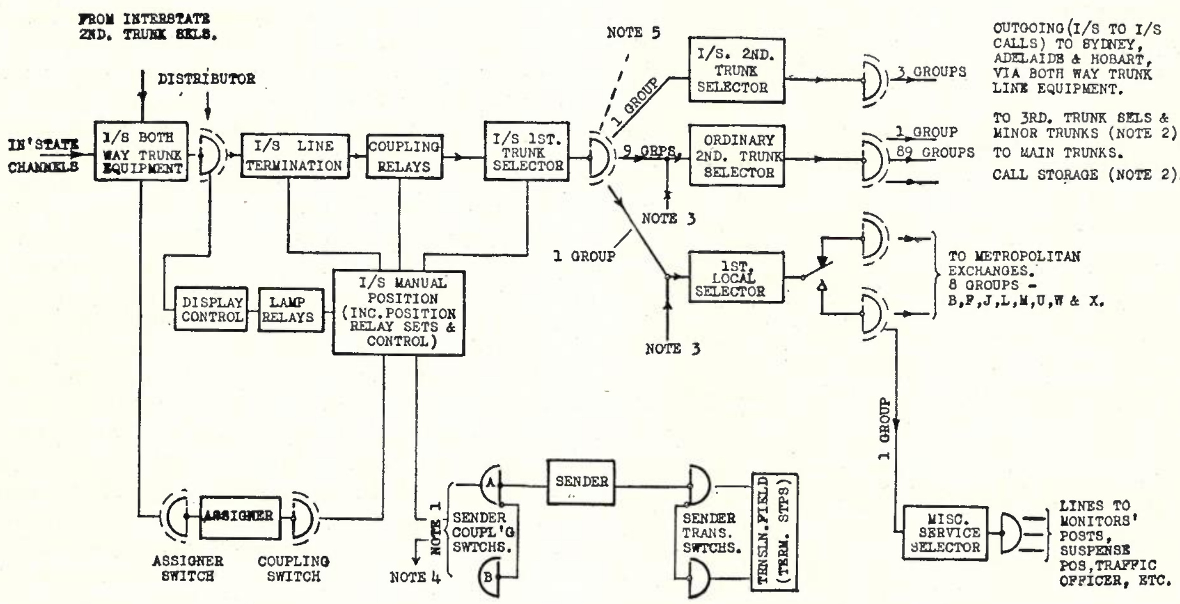
outlet capacity to 200 outlets per bank by wiper switching. This is arranged by distributing the outlet groups over four sections of the bank, and two of these sections are swept simultaneously by eight single-ended wipers, in two sets of four wipers each; the remaining two sections are tested as the other two wiper sets are brought around in the second half revolution of the switch. Either one of the two sets of four wipers engaged in simultaneous search is preselected before the search commences, by the action of a wiper switching relay under the control of the digit marking arrangement, and, of course, only this set of four wipers is electrically effective in the search. Conventions used to represent motor uniselector types are shown in Fig. 2.

The motor uniselector ranks and groups are designated more or less appropriately according to their routing functions. Group selectors are distinguished by the terms "trunk" selector or "local" selector. A trunk selector is any one of a train of switches used in the establishment of a call from the trunk exchange to a trunk line station, whilst a local selector deals with calls from the trunk exchange to metropolitan subscribers. A numerical prefix indicates, as usual, the rank of a selector in a switch train. The term distributor has been applied principally to switches which direct calls to accepting connecting circuits on manual positions after such calls have been "queued" in order of their receipt. In some instances, motor uniselectors are utilised to provide for the "coupling" of common equipment to individual circuits.

To economise in plant provision common control equipment is used wherever applicable. Common control is a scheme devised to reduce the amount of equipment in an exchange by extracting those functions which are confined to the setting up and positioning of a switch, and transferring these functions to special apparatus common to a number of switches, on the basis that the time of establishing a connection is only a fraction of the total holding time. The elimination of these initial functions from selector switches reduces the number of relays and marking equipment per switch with resultant economies in space and provision of plant. Relays individual to a switch are usually provided to couple common control equipment to selector switches, but, as indicated above, motor uniselectors also serve in this capacity.

It is of interest to note that two distinctive methods of digit signalling are used in the trunk exchange. One is the usual loop impulsing over two wires—a well-established means of switch control in automatic exchanges. This system of signalling applies in the trunk exchange to switches influenced by impulsing from dials at country exchanges. The establishment of a connection by this method is, however, relatively slow when compared with the system of "code" signalling over four wires, which is the second method adopted for controlling motor uniselectors. The code system transmits a digit selecting signal to a switch by a battery connection on one of the four wires for the numerals one to four, or a simultaneous battery connection on two of the four wires, to form numerals five to ten. Thus, with the code system the time of transmitting the digit which determines the selecting movement of the switch is reduced to the response time of relays which accept the code signal in the selector. The adoption of the code system was, no doubt, influenced by the fact that four speech conductors were required to meet the conditions of four wire switching of trunk-to-trunk connections. (Vol. 2, No. 4, Page 203.) Four conductors were, therefore, available, over which the code could be transmitted from switch to switch. The code signals which operate the trunk selectors are formed at the senders, the latter being set up by similar code signals from the position key plates. Senders also generate loop impulses where such are required and, in fact, many connections are established with a combination of code signalling and country exchanges. (D) Trunk inquiries, Delay supervisor, etc.

The routing diagrams are designed to illustrate the relationship between types of apparatus used in the trunk exchange, and the association of one type of equipment with another is indicated in the customary manner by a single line connecting related equipment, although the actual connection between the two points may involve a number of conductors for each circuit. To clarify the diagrams, equipment which is relevant to more than one call route may not be necessarily included in each diagram. In cases of omission, a note is made which indicates the diagram on which representative equipment is shown. To further simplify the diagrams and



NOTES.—1. Positions are connected to senders via A or B switch banks. 50 positions can be accommodated on each switch.
2. See Demand routing diagram.
3. Calls from other types of 1st trunk selectors, e.g., Demand, Through, Suspense, etc.
4. To other types of manual positions, e.g., Demand, Through, Suspense, etc.
5. Special group reserved for future 2nd Trunk Selectors serving Secondary Zone Centres.

Fig. 3.—Interstate Routing.

of loop impulsing; code signals to operate switches within the trunk exchange and loop impulses to operate switches over junction lines to metropolitan automatic exchanges. Incidentally, in addition to the above, V.F. impulses are produced by sender action when these are required to operate selector switches at country exchanges over trunk lines from the main trunk exchange. Battery pulses for simplex signalling are also available from the senders if such a method of impulse signalling over trunk lines is desired.

Routing Diagrams.—It is proposed to deal with call routing in four sections: — (A) Interstate calls. (B) Calls originated at demand positions for country subscribers. (C) Country demand calls to metropolitan and through calls to other to prevent undue importance being given to subsidiary leads such as start and control wires, where these leads do not follow the main routing, they have not been specially lined in. Owing to this omission, the diagrams will not serve as complete cable routing plans, neither can they be used to accurately determine all wiring between types of switches. That portion of the equipment which is directly concerned with the actual call routing is shown in heavy line, whilst control and supervisory connections may be identified by lighter lines. The direction of the call is shown by arrow heads in the main routing. Notwithstanding the fact that the subject has been completely covered in previous issues of the Journal, some indication of the relevant operating procedure appears to be inevitable in an explanation of call routing in the trunk exchange, and brief references are, therefore, made of the operating methods in the following notes.

(A) Interstate Calls (Fig. 3).—The interstate routing is distinguished by the fact that it is designed specifically for delay working. To provide a convenient method of operation under this system, an interstate trunk line is extended and held connected to one of four trunk "terminations" equipped on each manual position for this purpose. This trunk line is subsequently switched to another trunk or to a metropolitan subscriber's connection, either of which may be independently established through a calling circuit or first trunk selector; five of these selectors are provided per position. The act of associating trunk line with trunk line or trunk line with metropolitan subscriber is the function of the coupling relays and the provision of this apparatus is a feature exclusive to interstate equipment. A particular trunk line may be kept associated with a certain termination throughout the day, being coupled in succession to different subscribers according to the order indicated by the booking of the calls.

A trunk line may be connected to a termination as a result of an inward call (in slack hours) or by the use of the assigner. It is convenient to first consider the case of the inward call. Associated with each interstate trunk line is apparatus known as interstate both-way trunk line equipment. This includes a motor uniselector serving as a distributor, on the banks of which are accommodated the terminations of all interstate positions. The first ten outlets of this distributor are concerned with the signalling of an inward call on lamps of the display panels of the positions, so that the initial effect of an inward call signal from a trunk line is the rotation of the motor uniselector to the bank contact associated at that time with the first vacant position in the display or "queue," and the calling signal is indicated by the glowing of the relative lamps, one on each staffed position served by the distributor. When a telephonist accepts such a call, the distributor moves from the display position and rotates to locate the marking produced on the bank by the accepting termination, this termination being distinguished by the operation of the speaking key in accepting the call. The marking arrests the movement of the uniselector, and the trunk line is then connected to the termination. It should be noted that, in the case of the Melbourne switchboard, as the number of terminations exceeds the capacity of the bank of a single distributor, an auxiliary distributor is provided. This operates after search of the primary distributor has failed to locate the nominated termination. The auxiliary distributor has no display section on its bank.

To obtain connection via an assigner, the appropriate key is depressed on the position, and the assigner coupling switch will rotate to find the position calling. The switch now couples the control leads to the position, thus providing for the association of the assigner with the position key plate, etc. A two digit number, being the call number of the trunk line required, is next set up from the position by key operation, and the assigner responds to the code sent out, moving its wipers to the contact corresponding to the trunk line called. The final result of the assigner's selection is that a start signal is transmitted to the required trunk line circuit, and this signal causes the distributor of the latter to rotate. With a connection established by medium of an assigner, the distributor passes the display section of the bank, and drives to the contact of the nominated termination which is waiting for connection. The assigner releases immediately the connection is established between the trunk line equipment and the termination.

The function of the first trunk selector is such that, when operated from the first digit code forwarded from the sender, it selects one of the groups of outlets leading from the selector's banks. Codes (with two additions, triple combinations) provide for 12 such groups; the first nine of these cater for calls to main trunk routes via ordinary second trunk selectors. Group ten leads to the first local selectors and serves for connection to metropolitan automatic subscribers. One special code is reserved for calls interstate to interstate, which must be completed by the **interstate** second trunk selectors. The remaining code is reserved for a future group leading to special second trunk selectors and is concerned with routing to secondary zone centres.

Ordinary second trunk selectors are divided into sections, one section for each of the nine digit groups leading from the first trunk selectors. From the multiple banks of each such section are ten digit groups, making 90 groups in all; 89 of these represent the accommodation for main country trunk routes, while the remaining group provides for outlets to third trunk selectors which in turn accommodate lines to minor trunk routes.

The first local selectors are arranged for 200 outlets by the aid of wiper switching, and each can accommodate ten digit groups, only nine of which are in use. Eight will be absorbed in junction groups to each of the metropolitan main automatic exchanges, B, F, J, L, M, U, W, and X, the junction lines in each case terminating on incoming second selectors at the respective exchanges, whilst one group is required for miscellaneous services, such as lines to Traffic Officer, monitors' posts, suspense positions, etc., and terminates on a rack of switches known as miscellaneous service selectors. These switches have a capacity which is limited to 50 outlets in a maximum of 20 groups.

Senders are provided on the basis that they are not normally associated with any particular position, whether interstate or otherwise, but are available as required for connection to a position when called into service by the action of a telephonist operating the appropriate key on the position. Such a key operation causes one of the senders to start its motor uniselector coupling switch searching for the calling position, the control leads of which are connected to contacts on the bank of this and other coupling switches. Having located the calling position, the wipers of the coupling switch connect the control leads through to the sender, and the latter will then respond to the key setting by the operator. A number of wires form the control leads between the position and the sender. Of these, four represent the code wires accepting the code from the digit keys on the position. A second set of four wires convey the output of the sender to the first trunk selector, via the position relay set, and serve as operating wires for establishing the connection. As previously mentioned, the transmission circuit of a trunk exchange call may require four conductors and these are available to extend the connection from the sender through selector after selector as the call is progressively set up.

It should be mentioned that with a call to a main trunk group, the sender code output need not necessarily be identical with the number set up on the key plate, as it is one of the functions of the sender to provide conversion or translation of such calls under certain circumstances. This conversion is the purpose of the translation switches and translation field which provides the means of setting up an output code for any number keyed on a position.

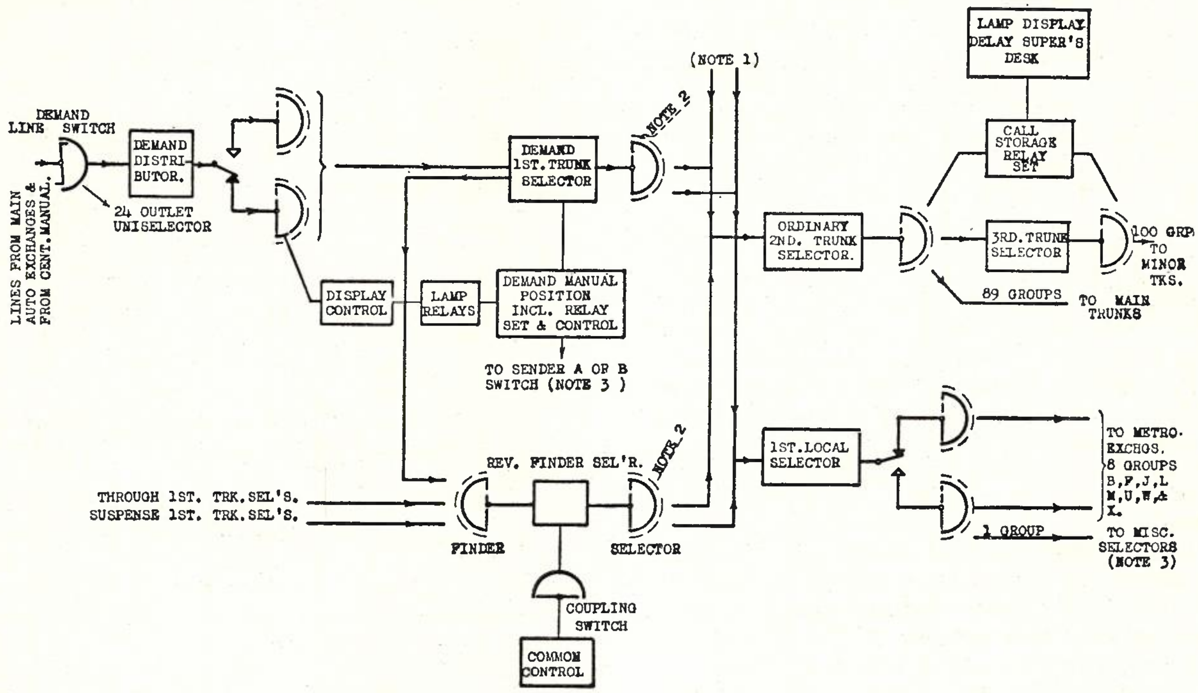
The translation facility enables the telephone operating staff to reserve and retain a particular call number for each main trunk whilst the corresponding switching number or code may be varied by the engineering staff when occasion demands, to cope with overload or some similar traffic handling condition. Perhaps an example of the necessity for a variation of a switching route may assist in making this translation function clear. It has already been indicated that main trunk lines are accessible for outgoing calls from the trunk exchange via banks of the second trunk selectors. On these banks, the lines are arranged into varying sized groups according to the routes served by the selector group or section. The arrangement is somewhat similar to the connection of PBX lines on final selectors in subscribers' automatic exchanges. Here the final selector banks take the connection of lines formed into groups by the allocation of lines with successive numbers to the respective PBX's. For any switch group there is obviously a limited line capacity which is dependent on the number of contacts in a switch bank. At the outset, groups of lines are allotted so that group expansion may take place to a forecasted maximum. When, however, this maximum is exceeded in any one case, it becomes necessary to remove one or more line groups from the final selector bank and to redistribute the remaining line groups on the bank.

In the case of the final selector quoted, the call numbers of all rearranged line groups must be altered to vary the switching route to the new switch and line groups. In the trunk exchange system, however, the original call number is preserved and the switching number varied in accordance with the requirements of the new route, by suitable alteration at the translation field. It is interesting to note that the facility of the motor uniselector is such that no restriction is placed on the number of bank contacts in a marked digit group so that the necessity for change is not controlled by the attainment of the limit in any one line group, as is the case with the PBX final selector, but rather by the limit of the whole bank capacity being reached. And since the contacts in a digit group need not be adjacent to one another, a redistribution of the lines over the bank can be effected (up to the point where the bank capacity is reached) without change of either call or of switching numbers.

It is also a function of the sender translation to make available, when desired, a choice of two alternative switching numbers or codes to one call number. One of the switching codes is the normal code to direct a call over the ordinary or primary trunk route. The second code is sent out by the sender when all trunks in the primary route are engaged and a line is free in a route nominated as alternative to the direct route. This alternative may be reached via a secondary zone centre (see Volume 2, No. 4, Page 203).

(B) Demand Calls to Country Subscribers (Fig. 4).—Demand calls are routed to the trunk exchange via junctions from metropolitan exchanges. These calls are routed from the main automatic exchanges, and from Central manual exchange, so that the trunk junctions appear at the trunk exchange in groups. To amalgamate these groups, the lines are connected to line switches of 24 outlet homing uniselector type. The outlets of these line switches are graded and distributed to motor uniselector switches known as demand distributors which function similarly to the distributors in the both-way line equipment mentioned in the interstate section.

The distributors arrange for the signalling of calls in queue order to the lamp display on the demand positions, and as telephonists assign connecting circuits to accept calls, the distributors rotate to locate these connecting circuits. Demand distributors can accommodate a larger number of connecting circuits than interstate distributors, as the circuit requires but four wipers, and by the aid of wiper switching these switches cater for a maximum of 188 connecting circuits. Initially, the connecting circuits of 25 demand positions will appear on the distributor bank and these, with the connections of three special relief or "link" positions, form a complete demand load group of 168 connecting circuits. In the case of interstate, the smaller number of positions in the suite permits all connecting circuits (terminations) to be arranged in one load group, but the demand positions total 68, with groups, each group serving a number of connecting circuits. Each R.F.S. includes two motor uniselectors, one of which serves as a finder and, as is the case with the demand distributor, has the answering side of connecting circuits on its bank. This finder economises in the provision of revertive switches by making a group of these switches accessible to a large number of connecting circuits. The second motor uniselector of the R.F.S. functions as a first trunk selector, and has access to second trunk selectors and first



NOTES.—1. Calls from other types of 1st Trunk Selector, e.g., Interstate, Through and Suspense.
2. Special group reserved for future 2nd Trunk Selectors serving Secondary Zone Centres.
3. See Interstate Routing Diagram for details.

Fig. 4.—Demand Routing.

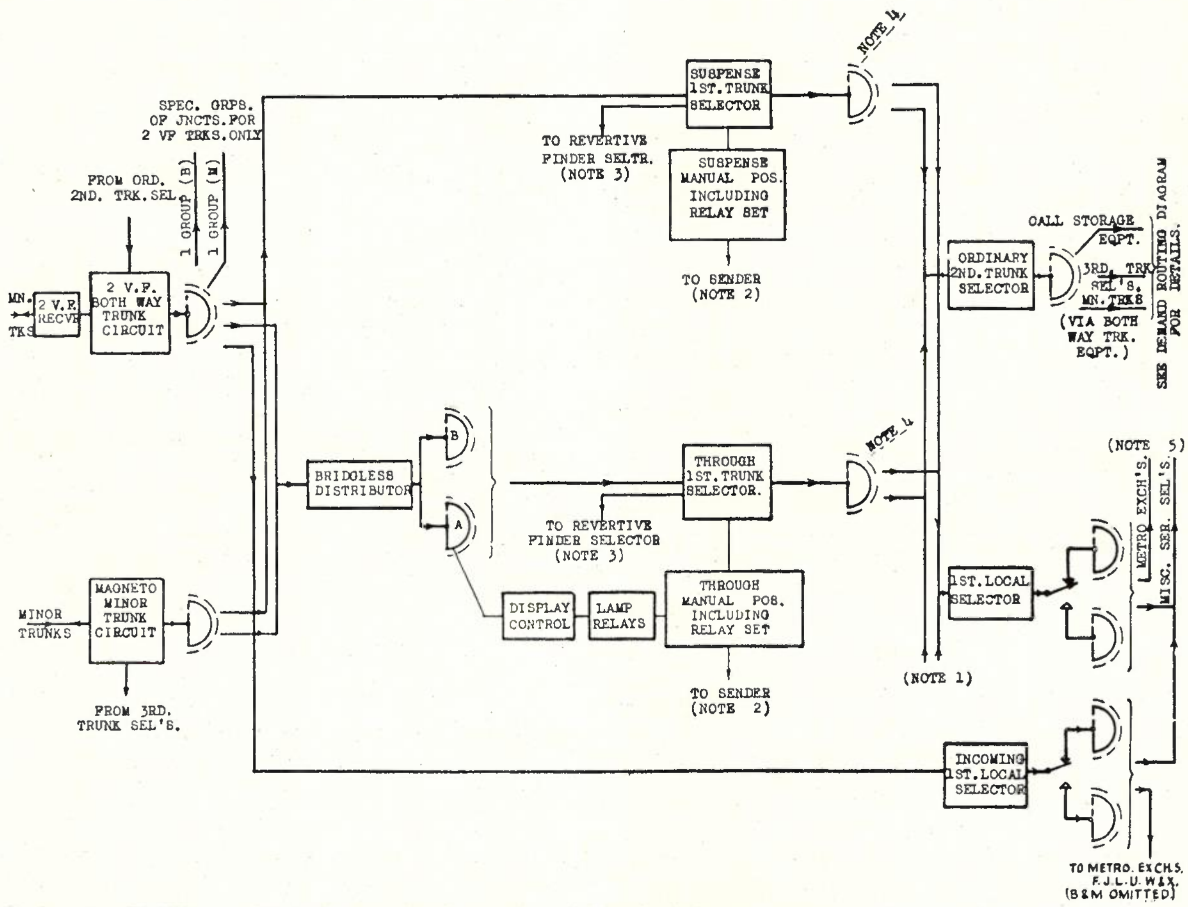
six connecting circuits each, so that three such groups are provided, two complete and one partial, with the initial installation.

At the demand manual positions, the connecting circuits have combined calling and answering facilities. On the answering side, are routed calls from the demand distributors, whilst the calling equipment consists of a first trunk selector having similar functions to the interstate first trunk selector, but omitting access to the interstate second trunk selectors, since all interstate calls are dealt with by ticket at the interstate positions.

Some calls may need to be reverted; for example, a subscriber after making a request for a trunk call, releases from the answering side of the connecting circuit (perhaps at the request of the telephonist, in view of probable delay in giving service), and thus needs to be recalled when the trunk call is available. Special switches are installed for this purpose known as revertive finder selectors (R.F.S.); these are arranged in local selectors in the same manner as the demand first trunk selector. Common control equipment for these switches is also made available by a motor uniselector which functions as a coupling switch, the common control being connected to the 16 wipers of the motor uniselector, whilst the control wires of the selectors are attached to the bank contacts. Four common control switches are equipped for each rack of 30 R.F.S.'s.

To associate a connecting circuit with an R.F.S. a telephonist operates the relative speaking key and then depresses the "send ans." key, which, in addition to the usual action of bringing a sender into association with the position calling, also sets a common control coupling switch searching for an idle R.F.S. After this coupling is established, the selected revertive switch proceeds to operate its finder to locate the connecting circuit marked by the operated speaking key. When the R.F.S. is associated with the connecting circuit, the telephonist sets up the required number on the keyplate, and the connection is then made by medium of the revertive first trunk selector and succeeding ranks of switches. Revertive calls are made on the answering side of connecting circuits as call timing apparatus only applies to this portion of the circuits.

Outlets from demand first trunk selectors to ordinary second trunk selectors are similar to those from interstate first trunk selectors, with nection when this switch encounters congestion on a trunk group. Bank contacts are provided which are similar to the overflow or eleventh contact at the end of levels of bimotional type switches, and one such storage contact is equipped for each group of outlets (trunk lines) leading from ordinary second or from third trunk selector banks. This contact is multipled throughout the rank of switches. When a switch, after having tested for a particular group,



NOTES.—1. Calls from other types of 1st Trunk Selector (Interstate, Demand, etc.).
2. Positions are connected to senders via "A" or "B" switches of latter. (See I/S Routing Diagram.)
3. 1st Trunk Selectors have access to Revertive Finder Selectors via Finder Bank. (See Demand Routing Diagram.)
4. Special group reserved for future 2nd Trunk Selectors serving Secondary Zone Centres.
5. Details of groups are similar to that shown on Interstate Routing.
6. MN is abbreviation for "main trunk."

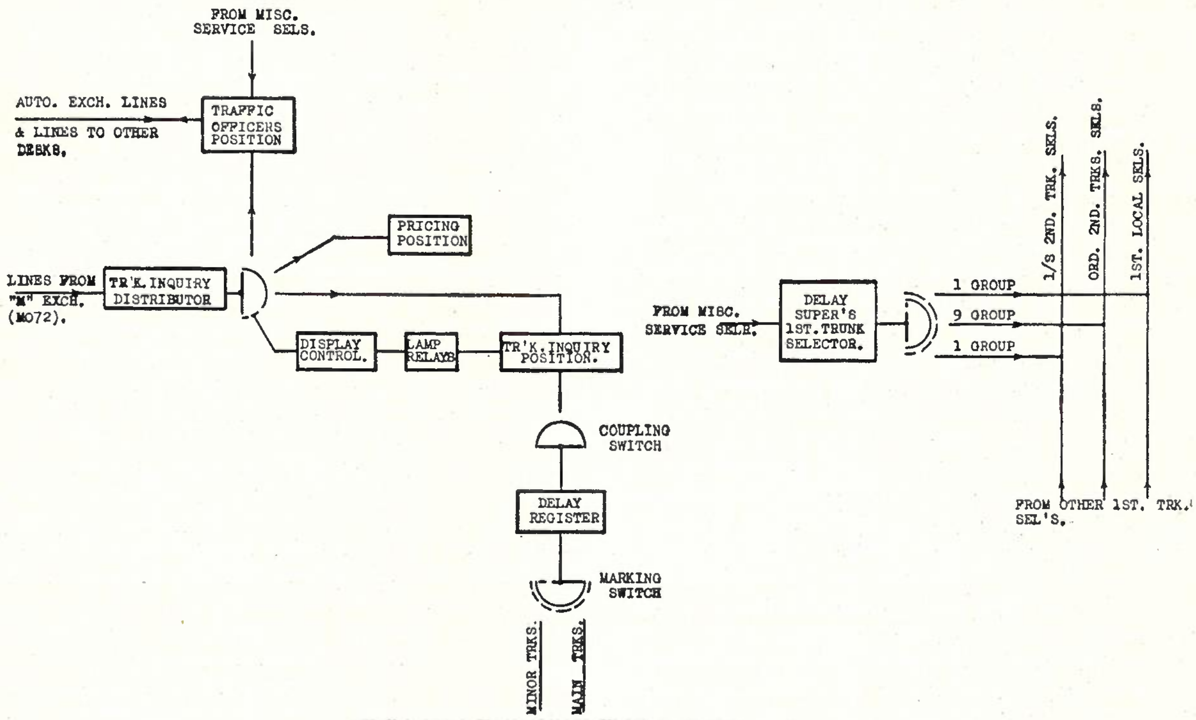
Fig. 5.—Incoming Calls from Country Exchanges.

the exception that access to interstate is not possible from the former. The first local selectors are identical with those shown in the interstate routing diagram, and the same outlets to metropolitan exchanges, etc., are used.

Call storage equipment is included in this diagram. It is accessible from special overflow outlets on both ordinary second and on third trunk selectors. The term storage as applied to this equipment is really a misnomer, as the apparatus is designed really as an indicator of the **number** of calls in storage, storage being the overflow condition of the ultimate switch in a trunk connection when this switch encounters congestion — reaches the storage contact associated with this group, an indicating lamp glows on the delay supervisor's position, recording the fact that a call is held in this condition. Each subsequent call to storage for that group is marked by the glowing of an additional lamp in the vertical display strip provided on the supervisor's desk. In this manner the delay supervisor is kept informed of the number of waiting calls in the various trunk routes. When a trunk route becomes free after overflow conditions have prevailed, a signal flashes the supervisory lamps of all connections routed to call storage on that trunk route. A telephonist is thus advised that a trunk line is available, and may operate the speaking key associated with any connecting circuit awaiting trunk service to the group concerned. The operation of this key causes the relative second or third trunk selector to leave the call storage contact and research the group, taking the free line if this is still available, but returning to call storage if the line has been seized in the meantime.

(C) Country Exchange Calls to Metropolitan and to Other Country Exchanges (Fig. 5).—Calls from country exchanges are received at the trunk exchange either over main trunks which signal on the Voice Frequency (V.F.) system, or over minor trunks which are operated by ringing signals.

The majority of country calls are transmitted on the V.F. system, and calls for metropolitan subscribers from main country exchanges are dialled direct from the country exchange, V.F. impulse signals being transmitted over the trunk lines. These signals are received on V.F. receivers, one such receiver being fitted per trunk line. Incoming V.F. signals at the trunk exchange are converted by the receiver into D.C. equivalents, and transferred to the 2VF both-way trunk line equipment. This equipment includes a motor uniselector which functions as a group selector, and which is positioned by the first digit dialled from the country exchange. Five groups are available from the bank on the selector. Digit "one" group provides for the extension of calls via bridgeless distributors to the "through" positions. These positions handle calls routing from one country exchange to another. Digit two (B) group gives access to a direct group of junctions to Central manual exchange. Digit three group routes calls to the suspense position. Digit six (M) group is a direct group to City West automatic exchange, whilst digit group O provides the means of obtaining any other metropolitan exchange and leads to a special group of first local selectors known as incoming first local selectors. The banks of these switches have junctions to exchange groups F, J, L, U, W and X, but omit connection to the B and M exchanges, which have the direct provision mentioned above. Calls to the exchange groups first mentioned will need to be prefixed by O, whilst those to B and M will not require any such initial digit.



DELAY MARKING IS CONTROLLED BY DELAY SUPERVISOR.

Fig. 6.—Trunk Enquiries and Delay Supervisor, etc.

Calls, country exchange to country exchange, appear in the first instance at the through position on a lamp display after operating a distributor in a manner similar to that of interstate and demand inward calls. These distributors are distinguished by the title bridgeless, as they are not fitted with a transmission bridge and isolating condensers such as are interposed in other distributor circuits which include equipment for trunk terminations. Such terminal equipment is included in the both-way trunk line apparatus in the case of country calls. Up to 90 through position connecting circuits can be accommodated on the bank of a single distributor A. If the number of connecting circuits exceeds this figure, a second switch B is required, and as the latter does not require a display section, an additional 100 circuits can thus be handled. B is switched into action after switch A has completed a search of its bank. It should be noted that as only 70 connecting circuits are provided initially on the through positions at the trunk exchange, switch B will not be fitted at the outset. Calls may be extended from the through position by medium of the associated first trunk selectors which have the same facilities as the demand first trunk selectors.

An incoming minor trunk call (ringing signal) is received on the associated magneto minor trunk line equipment, and this includes a motor uniselector which functions to select an outlet to a bridgeless distributor, where the call is extended to a through position as explained above. However, provision is made by means of a transfer key on the through position that, if required, the selector can be caused to release from the outlet to the through position and drive to a section on the bank having outlets leading to a suspense position, and the call is then dealt with on the latter position. It should be noted that all calls originated at country exchanges over minor trunks will be dealt with by the through positions, as it is not intended that dialling facilities be provided at these exchanges.

Suspense positions are provided to deal with the type of call which it has not been possible for some reason to complete at the position on which the call originated. Calls to suspense positions will be originated solely by telephonists, either in the trunk exchange or at country exchanges, and calls are not queued, but once such a call appears on a particular position the call can be answered from that position only. Suspense positions are similar in other respects to demand positions, and have the same routing facilities. Incoming calls are indicated as flickering lamp signals on the answering side of connecting circuits, and are extended on the calling side via first trunk selectors, etc., in the usual manner.

Incoming first local selectors are operated by dialled impulses, and not by code signals, as they are provided to enable country telephonists to obtain access by direct VF dialling to metropolitan automatic subscribers. These selectors also enable these telephonists to reach special service facilities via the miscellaneous service selectors which respond to dialled impulses for the same reason.

(D) Trunk Inquiries. Delay Supervisor's Service (Fig. 6).—Trunk inquiry calls are received at the trunk exchange over a group of lines leading from the M exchange (M072). This group is accessible to junctions incoming at M from all metropolitan exchanges. The calls appear on a distributor with a display section similar to demand or interstate, and each call is accepted on an answering circuit on an inquiry position. The initial installation includes five of these positions, which are each equipped with three answering circuits. Normally, calls cannot be extended beyond the inquiry position, but nevertheless provision has been made for the transfer of calls to one of two other points in the trunk exchange; the first is to the pricing position, and the second to the traffic officer's position. This transfer is effected by movement of the distributor uniselector, under the control of transfer keys on the inquiry position, from the section of the bank serving the inquiry positions to other sections dealing with lines to the pricing and to the traffic officer's position respectively. A further facility permits the trunk inquiry lines to be diverted by the operation of a night switching key so that callers for inquiry in slack hours will be immediately directed to the traffic officer's desk.

The traffic officer's position has ordinary exchange line facilities for both inward and outward service, but it is also accessible for inward calls from the trunk exchange via the miscellaneous service selectors.

The trunk inquiry positions are equipped with means of obtaining information relating to the probable duration of delay, if any, on the various trunk routes. This information is derived from the delay signals normally available to the manual positions, and access to these signals is provided on the trunk inquiry service by two delay registers. Each register comprises two motor uniselectors; firstly, a coupling switch which enables a register to be coupled to any inquiry position, and secondly, a marking switch or selector which responds to the setting up on the inquiry position key plate of the call number of the trunk route about which the delay information is desired. The "delay marking" wires originate on keys at the delay supervisor's position, the delay supervisor setting these keys according to the estimated delay on any route. The marking wires carry signals according to the setting of these keys and connect them to the sender switch banks, thus the sender may cause lamps to flash on any position calling for a trunk group on which delay conditions apply, the type of flashing signifying the probable waiting time before service can be given. The same marking wires are also represented on the banks of the delay register marking switches, and corresponding lamp signals are furnished to the trunk inquiry position when the delay registers are operated from these positions.

Equipment for the delay supervisor's position includes a first trunk selector which enables calls to be made over all outward routes from the trunk exchange, including interstate routes. Calls to the delay supervisor are directed from the miscellaneous service selectors.

THE VICTORIAN 2VF SIGNALLING SYSTEM

A. E. Bayne, (Siemens Bros. & Co. Ltd., London)

Introduction.—The increased demand for long distance telephonic communication has shown the need for a signalling system capable of providing facilities similar to those used in automatic and CB manual switching. This demand has led to the development of voice frequency signalling over trunk lines. In the development of the new Melbourne Trunk Exchange, the need for an improved signalling system was recognized and the order placed with Siemens Bros. & Co. Ltd. covered the supply of a 2VF signalling system as well as the trunk exchange equipment. The fundamental requirements of the 2VF system were described by Mr. McHenry in the first article on the new Melbourne Trunk Exchange, Vol. 2, No. 4, page 201.

By using frequencies within the range passed by repeater and carrier equipment, these signalling facilities become possible over any connection in which speech itself is possible. No modifications are required to line equipment, such as transformers, repeaters, etc., in fact, it is possible in certain circumstances to simplify line equipment, as by the elimination of ringing control elements in carrier systems.

One of the main advantages derived from VF signalling is that the paid time ratio of trunk lines is improved, and it is largely from the provision of a full range of positive supervisory and control facilities that this becomes possible. It means that the operating facilities which hitherto have been confined to metropolitan areas are now available to complete trunk networks.

A further and highly important facility is that dialling can be done over trunk lines, which includes every type of channel over which speech can be passed. This enables telephonists to select distant automatic subscribers without calling upon the services of a distant trunk telephonist. In the Victorian trunk network where, for example, most of the traffic is converged to the Melbourne metropolitan area, this restriction of call control to the originating telephonist can give rise to operating savings of considerable magnitude.

Nature of Signals.—The system used is of the simple frequency type using two frequencies only and each signal is represented by a pulse or pulses of definite duration of one or other of the two frequencies. The length of signals will vary according to the nature of the function they have to perform and obviously the length of dialled signals must conform with the length and ratio of dialled impulses at present used in the Metropolitan area, etc. Some signals occur at a stage in the setting up of a call when speech cannot be present on the line and therefore no special guard against speech interference is needed. Other signals occur when speech may be present and must therefore be not easily simulated by speech nor prevented from performing their proper function.

It is necessary in the case of some signals that they should not be effective beyond a certain receiving point in a connection. This is achieved by an arrangement whereby analysing elements at receiving ends regard such signals as each comprising two parts.

The signal passes right along the connection until such time that the first receiving point has recognized it as being the first part of a legitimate signal. This first receiving point thereupon splits the connection beyond itself, with the result that the remainder of the signal, representing its second part, is cut off from subsequent receiving points.

The first part of such a signal is termed the "prefix" and the second part the "significant signal." The splitting action also is necessary at the end of each 2VF signalling link to prevent more than the minimum of signalling frequency being heard by the subscriber.

A guard element, external to the receiver, has to be introduced to prevent splitting from occurring, during speech, on X or Y speech components which succeed in operating the receiver output relays. The external guard consists of a time delay, splitting then occurring only if the receiver output relay is maintained operated for that time. If the delay is made sufficiently long, the system can be completely guarded against operation by speech for the reason that a steady signalling frequency cannot persistently be simulated by speech for an indefinite period.

Were the aim in the design of a VF system to be **complete** freedom from voice operation, it would be necessary to provide a delay period of considerable length. Such a course would lead to very slow signalling sequences, particularly on tandem connections. In practice, such a high aim is not warranted as the delay period can be fixed at a value which, whilst not making the system completely immune from voice operation, will prevent all but occasional splitting taking place. Experience has shown that a small amount of splitting has a negligible effect on conversation and that, in fact, much of this occasional splitting is undetectable even when observers deliberately set out to listen for it. The splitting delay period which has been adopted is—

160-210 milliseconds

the limits being the variation permitted in the lags of the timing relays concerned.

Tests have been made with circuits to the above timings and using different 2VF Receivers of the same type: the results showed a frequency of splitting varying between 1.1 and 4.0 times per hour of actual speech time.

Other tests made to find the effect on conversation indicate that a splitting frequency many times in excess of this has a negligible effect on intelligibility.

Signalling Frequencies. — The signalling frequencies used are 600 and 750 cycles per second. For convenience in description, the two frequencies have been given a reference letter, viz.,

Y — 600 p.s.
X — 750 p.s.

The frequencies of 600 and 750 p.s. are those adopted by the C.C.I. for use on international circuits.

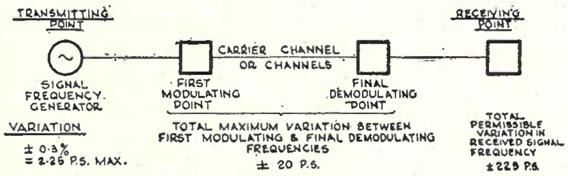


Fig. 1.—Frequency Limits in Diagrammatic Form.

The sending level which has been adopted is 3 decibels above zero level applied to the line (zero level being one milliwatt). The sending power should be maintained within 1 db of the figure stated above.

The variation in generated frequencies allowed for in the design of the signalling system is ± 0.3%. This represents a variation of ± 2.25 cycles per second at 750 p.s. and 1.8 p.s. at 600 p.s. No difficulty should be experienced in maintaining the generated signalling frequencies within these limits.

The received signalling frequency will be subject to variation when passed over carrier circuits, due to differences in the modulating and demodulating frequencies at the carrier terminals. It is usual on carrier channels to suppress the carrier frequency; that is, it is not transmitted over the circuit. At the receiving end it is therefore necessary to re-introduce the carrier frequency and it is done by means which are not controlled from the transmitting end. The speech frequencies passed via the carrier channel can thus be changed in frequency by the difference between the generated carrier frequencies at the sending and receiving ends. In some carrier systems, a difference of only two cycles per second is permissible between the modulating and demodulating frequencies, but in others a wider range of frequency difference has to be catered for.

Further, it may be necessary to send signals over two or more carrier channels in tandem, with the result that the received signalling frequency may be varied by the algebraic sum of the modulating and demodulating frequency differences of the channels concerned. For maintenance purposes, the maximum drift should be maintained within ± 15 p.s. for any possible tandem connection.

A total signalling frequency modification of ± 20 p.s. by carrier channels has been catered for in the design of the VF system. With the possible generated frequency variations added to the maximum carrier drift, a permissible overall variation of ± 22.5 p.s. in the signalling frequencies has been allowed for in the design of the receiving equipment. For reference purposes, the derivation of the variation is set out diagrammatically in Fig. 1.

Access to trunk lines. — A feature of VF signalling is that trunk lines can be marked engaged, at each end, so long as a busy or off-normal condition pertains at either end. It thus completely eliminates the operating confusion sometimes encountered in systems where the facility cannot be exercised.

Each end of the trunk line terminates on both-way equipment necessary for the connection of the line to a subscriber and capable of control by the originating telephonist on an outgoing call and by the Voice Frequency Receiver on an incoming call.

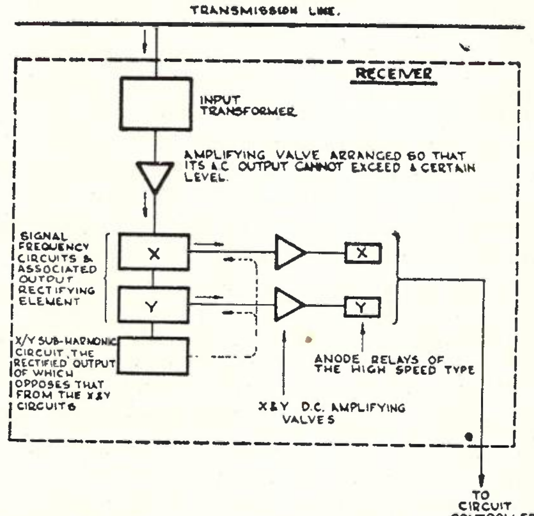


Fig. 2.—2VF Receiver Elements.

At the Melbourne end the trunk line equipment incorporates a distributor of the high speed motor uniselector type giving access as follows:—

Digit 1—Melbourne Trunk Exchange "Through" positions.

Digit 2—Melbourne Central manual exchange.

Digit 3—Melbourne Trunk Exchange "Suspense" positions.

Digit 6—Melbourne City West automatic exchange.

Digit 0—Local selectors and thence direct to all other exchanges in the Metropolitan area.

Further particulars are included in the series of articles on the new Melbourne Trunk Exchange.

Access to the trunk line equipment on an outgoing call is obtained via 2nd Trunk selectors from the various trunk exchange positions and for this purpose each group of trunks has been allocated a number as shown in table 1.

TABLE 1.

10 Albury, N.S.W.	39 Euroa	70 Romsey
11 Alexandra	40 Ferntree Gully	
12 Ararat	41 Flinders	72 St. Arnaud
13 Bacchus Marsh		73 Sale
14 Bairnsdale	43 Frankston	74 Sassafras
	44 Geelong	75 Seymour
16 Ballarat	45 Hamilton	76 Shepparton
17 Bayswater	46 Healesville	77 Sorrento
18 Belgrave	47 Horsham	78 Stawell
19 Benalla	48 Kerang	79 Sunbury
20 Bendigo	49 Kilmore	80 Swan Hill
		81 Tatura
22 Birchip	51 Korumburra	
23 Broadford	52 Kyabram	83 Tocumwal, N.S.W.
24 Camperdown	53 Kyneton	
25 Canberra, A.C.T.	54 Leongatha	84 Trafalgar
	55 Lilydale	85 Traralgon
26 Castlemaine	56 Lorne	86 Wagga, N.S.W.
27 Chelsea		87 Wangaratta
28 Colac	58 Mansfield	88 Warburton
29 Corowa, N.S.W.	59 Maryborough	89 Warracknabeal
		90 Warragul
30 Cowes	61 Mildura	91 Warrnambool
31 Croydon	62 Mornington	92 Werribee
32 Dandenong	63 Morwell	93 Wonthaggi
33 Daylesford	64 Mt. Macedon	94 Woodend
34 Deniliquin	65 Murtoa	95 Yarram
	66 Numurkah	96 Yarrawonga
36 Dimboola	67 Olinda	97 Yea
37 Dromana		
38 Echuca	69 Queenscliff	

This represents an alphabetical-numerical order having obvious advantages, but the flexibility of the numbering scheme is such that the order could be quite easily changed without disturbing the 2nd Trunk multiple allocation. For instance this would enable the numerical order to follow a geographical layout.

It is assumed that the number of lines to each exchange would tend to increase in the future rather than an increase in the number of exchanges. The numbering scheme as at present does not, however, represent the limit of the system and the numbering is capable of whatever expansion is needed.

The trunk line equipment at the country exchanges terminates on jacks and lamps multipled where necessary except in two cases—Geelong and Wagga, where the termination includes automatic selectors for direct access to subscribers. Each line requires incoming and outgoing jacks with associated lamps functioning as CALL/-CLEAR and ENGAGED/SUPERVISORY respectively, also a pull out Dial key. Each position is fitted with a dial and also a Recall key, the latter only being used on calls routed via Melbourne Through or Suspense positions.

2VF Receiver—Brief Description

Refer to Fig. 2. The Voice Frequency receiver is designed to convert pulses of voice frequency to pulses of direct current for signalling and dialling, and at the same time to avoid as far as possible the operation of the equipment from currents of the signalling frequencies which may be present in speech. Voice frequency signals

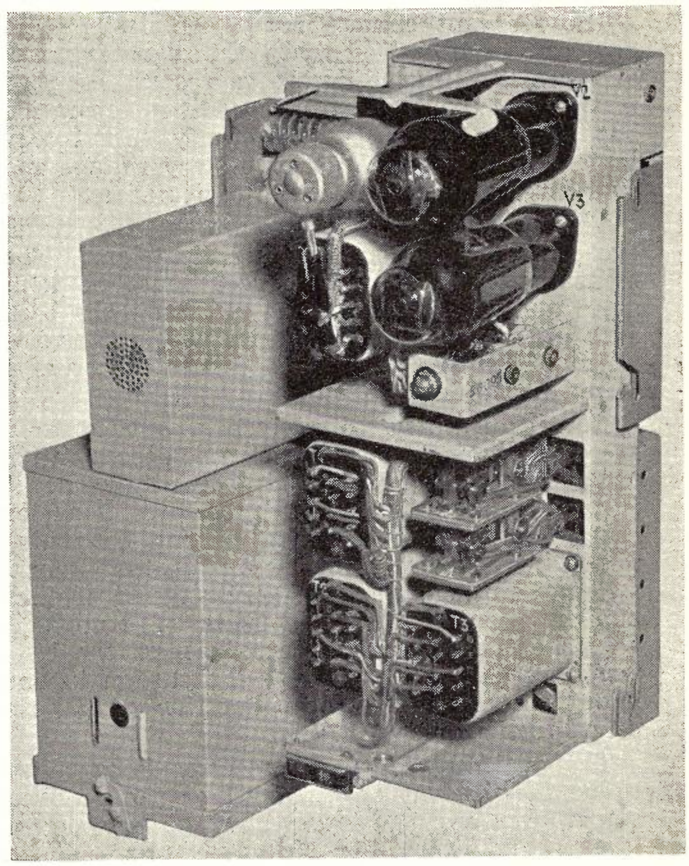


Fig. 3.—2VF Receiver (covers removed).

are taken from the line via a high ratio transformer to an amplifying valve V1, arranged to limit the output in such a way that variations in the level of the applied signal have little or no effect on the performance of the receiver. In the anode circuit of this valve, are three resonant circuits tuned to 750 p.s. and 600 p.s. for selecting the signalling frequencies, and to 340 p.s., which is about midway between the subharmonic of the two signalling frequencies, for counteracting the tendency of the receiver to operate on signal currents present in speech.

The output of each signal resonant circuit is rectified by copper oxide rectifiers and is used to drive the grids of the signal relay valves V2 and V3 positive, while the output of the sub-harmonic circuit is rectified and is used to drive both grids negative. In the anode circuit of these valves are the signalling relays X and Y, which actually repeat the signal to the signalling equipment.

Since these valves are biassed to have practically zero anode current, the signalling relays are normally released, but operate when a legitimate signal arrives, because this drives the grids of the signal relay valves positive. If speech containing the signalling frequencies is received, however, a voltage is developed across the subharmonic circuit which neutralizes the tendency of the voice currents to operate the receiver.

The resonant circuits have been designed to give correct operation when the signalling frequencies are off-tune due to causes as described in the preceding section. In addition, operation has been arranged to be entirely satisfactory with the normal variation of battery voltage and over a reasonable variation in temperature.

The receiver is connected across the trunk except during the local sending of a signal. The transmission loss so introduced must be kept small and a maximum figure of 0.3 db has been adopted, covering any frequency within the voice range of 300-2800 p.s. when connected across a 600 ohm non-reactive line.

In certain cases, a receiver is applied to a speech network having two balanced speech paths, the receiver being connected across only one of them. The case is where a repeatered trunk or carrier channel is capable of having both Line and Network pairs from the terminating hybrid switched through the trunk exchange to another similar circuit. On such types of trunks, a balancing network is connected across the Network speech path to balance the change in line impedance caused by the connection of the receiver to the Line path.

The performance of the receiver is arranged to be independent of the level of the received signal over a range from + 10 db above zero level (1 milliwatt into 600 ohms) to —12 db below zero level. Since the sending level is nominally + 3 db above zero level, the receivers will work within their distortion limits over a line loss of 15 db. In practice they will be found to operate on a line loss greater than 15 db but their distortion limits might then be exceeded. The receivers will operate satisfactorily on a circuit whose overall gain is 7 db.

The receivers are designed to respond satisfactorily over a band width of 22.5 p.s. either side of the nominal signalling frequency. That is—

Y. 600 p.s., from 577.5 to 622.5 p.s.
X. 750 p.s., from 727.5 to 772.5 p.s.

In practice it may be found that they will operate for a few cycles outside the extremities of the specified bands but it is likely that the output distortion will then exceed the permissible limits.

Signals

The following signals are required by the system:—

(a) Seizing	To pick up the trunk and prepare it for signalling.
(b) Impulsing	To select required number.
(c) Answer	Sent when called party answers.
(d) Answer Acknowledge	Sent when answer signal has been registered at the receiving end.
(e) Clear Back	To indicate to a telephonist when the called subscriber has replaced the telephone receiver.
(f) Ring Forward (or Recall)	To attract the attention of distant manual telephonists, or to ring or re-ring.
(g) Clear Forward	To initiate release; sent when route is to be released.
(h) Release	To effect full release. Is an acknowledgment of (g).
(j) Re-Route	To effect re-routing of a call which has been alternatively routed, only to find branch trunk congestion.
(k) Test Busy	To busy the distant end without calling. Used when routine testing, or to busy the distant end when a fault exists.

Each of these signals will be described separately.

Seizing Signal (750 p.s.).—Where the distant end is manual, it is the signal which lights the calling lamp. Where the distant end is automatic, the signal prepares the distant end for the reception of impulse trains. Where impulsing can follow immediately after the signal, the response at the receiving end should be such that the circuit is ready to accept impulsing as soon as the signal ceases.

The length of the signal can be quite short as there is no possibility of it being interfered with in any way. Where the end sending the signal can be picked up by a selector, the length of the pulse actually must be kept as small as possible, since the minimum interdigital pause may be largely if not entirely used up by the selector searching time prior to the trunk becoming engaged. It must, however, be long enough to operate, with safety, one relay at the distant end. The signal is transmitted immediately the trunk line circuit becomes engaged.

The limits have been set at—minimum 60 mS; maximum 100 mS. The maximum figure need not be strictly maintained where dialling cannot **immediately** follow the signal; that is, in all cases where the outgoing end is not preceded by a selector.

Impulsing (750 p.s.).—The higher frequency is chosen for this signal being in preference to 600 p.s. as distortion decreases with increasing frequency. The reason for this is that an impulse may commence when the signalling frequency voltage is at zero and finish also at a similar point. Alternatively, it may commence at a point of peak voltage and finish at a similar point. There may therefore be a discrepancy in the received impulse length in the two cases quoted above equal to one cycle, although the actual impulse length be the same. It follows that the higher the frequency, the less will be the actual distortion introduced by the haphazard point at which an impulse may commence and finish. At 750 p.s., the distortion introduced in this way is very small. The frequency is applied for 67% (nominal) of the impulse length. That is, the signal appearing on the trunk line is "2M : 1 B."

The impulsing performance of the 2VF system is obviously of great importance as in some cases, the DC route following the VF stage may be approximately ± 3% at 10 IPS, which by itself is hardly appreciable, being less than the variation usually permitted in dials.

The distortion introduced by DC-VF and VF-DC conversion has been kept to a very small figure by the use of **high-speed relays at all points concerned.** In some cases, this distortion will add to that produced by the receiver (if any) and in other cases it will tend to correct receiver distortion. In the case of addition, the amount added will not be more than 1 millisecond per relay.

At the impulse-receiving point, the circuit response must be immediate if the impulse distortion is to be kept at a minimum. It follows

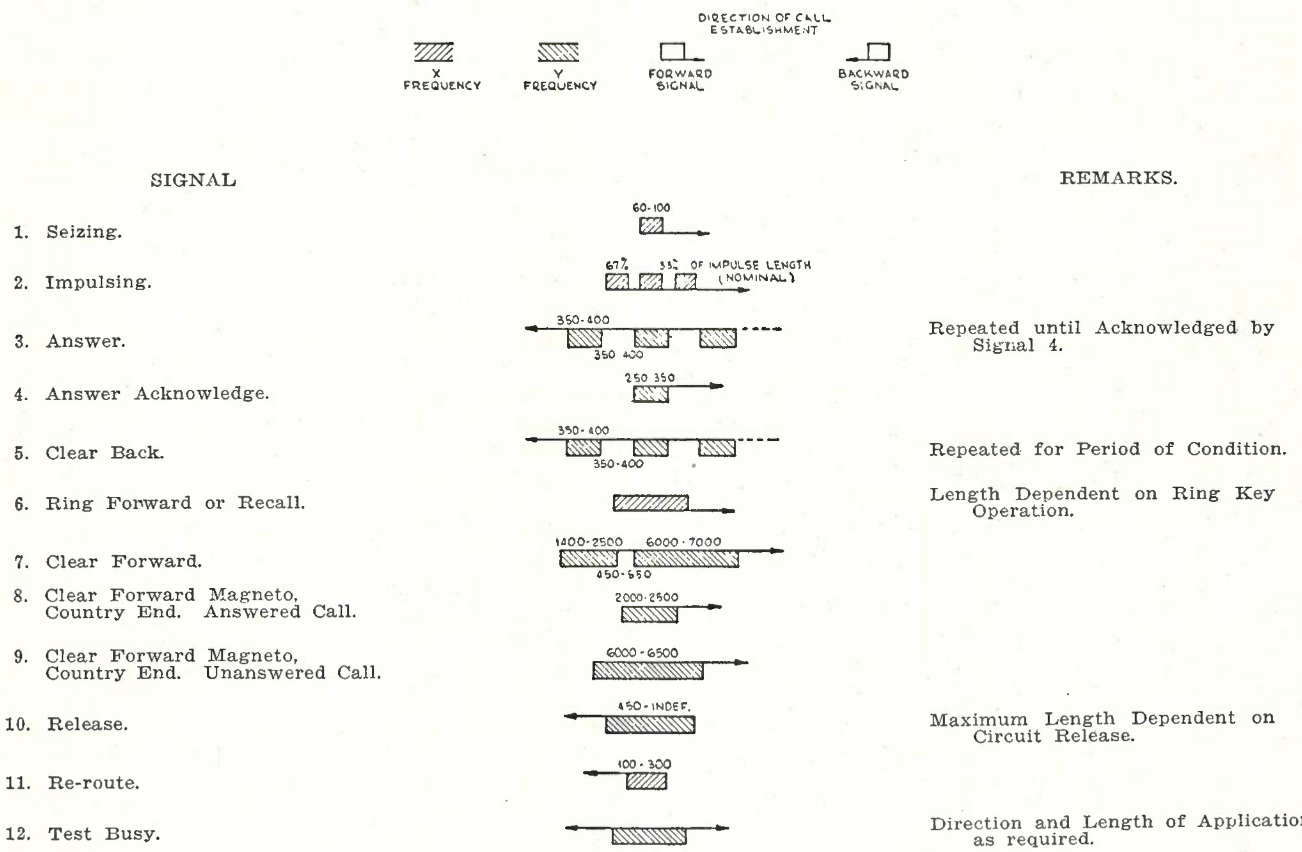


Fig. 4.

working very close to its permissible distortion limit. In such instances, the introduction of even a comparatively small amount of additional impulse distortion by the VF system might result in breakdown or wrong numbers, entailing in turn the installation of impulse correctors to safeguard against such occurrences. Care has therefore been taken to limit the amount of impulse distortion produced by the 2VF system to a minimum, so that the case where the additional distortion would cause trouble can be practically disregarded. The distortion introduced by the 2VF receiver should not exceed

from this that speech or noise of any sort should be kept off the line both prior to and during the whole necessary impulse transmission. If this is not done, speech may produce a false impulse, or noise, by blocking the receiver, may prevent the impulses being recorded.

The best method is to split the lines at the sending end as soon as the plug is inserted into the outgoing jack, and to maintain the split condition until all trains of impulses have been sent. This is the arrangement which has been adopted for all such dialling cases. It prevents, in the simplest and most straightforward manner, speech and surges reaching the line until after the full number has been dialled.

Where the signalling frequency can be connected direct to the impulsing contacts, as is the case with senders in the Melbourne Trunk exchange, no precautions are necessary as the sending end is automatically kept clear of interference.

Answer Signal (600 p.s.).—The lower frequency has been chosen as certain circuit advantages can be gained by using the non-dialling frequency for supervisory signals. The signal is transmitted from the called to the calling end of the circuit when the called subscriber answers. When received at the calling end, it causes the telephonist's supervisory lamp to be extinguished. It also determines the stage at which a voice immunity guard is to be introduced on the X circuit elements, which elements have hitherto been in the sensitive state necessary for impulse reception.

The answer signal is subject to interference from the calling end by the originating telephonist or subscriber talking. It is therefore repeated until acknowledged by the answer acknowledgment signal. The timing of the answer signal is—

350 to 400 mS on.
350 to 400 mS off.

The called subscriber is disconnected from the trunk during signal transmission, until such time as the answer acknowledgment signal has been completely received.

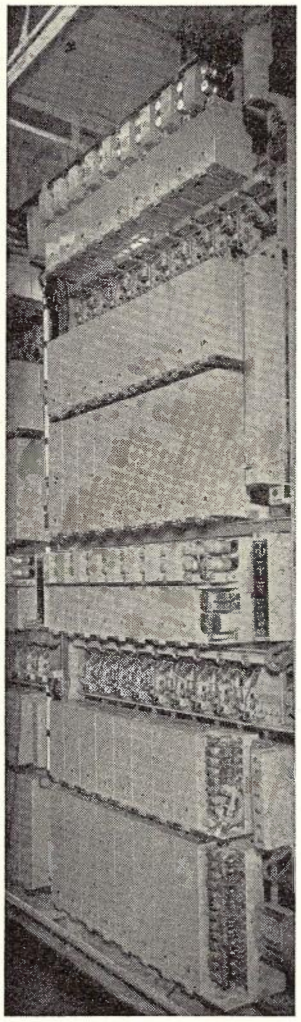


Fig. 5.—2VF Trunk Line Rack at Melbourne End.

Answer Acknowledgment Signal (600 p.s.).—The signal is sent from the end receiving the answer signal, after the lapse of the guard pause. On receipt at the far end, the signal causes the answer signal repetition to cease temporarily. When the signal has registered, that is, when the voice immunity guard has been overcome, the answer signal transmission is completely locked off. When the answer acknowledge signal has been transmitted, the speech part is restored at that end. When completely received, the speech path is restored also at the receiving end.

The signal consists only of a single pulse since, at the stage when it is sent, the line will have been split at both ends. At the transmitting end, the split is caused by the reception of the answer signal; at the receiving end, it is caused by the transmission of the answer signal. The signal is therefore sent on a clear line so that it cannot fail to take effect.

The signal has to be sufficiently long to provide reasonable immunity against false imitation by the call-originating end prior to the answer signal registering at that end. The stage at which such imitation could cause a false signal is naturally critical, occurring as it must at a certain stage in the pause following an answer signal. Normally, there will be no speech on the line at this stage unless, of course, the calling subscriber or telephonist is speaking. This should occur only rarely. The signal has therefore been made somewhat shorter than the answer signal, namely—

Minimum 250 mS. Maximum 350 mS.

The circuit response to the signal at the receiving end occurs after —

Minimum 170 mS. Maximum 230 mS.

Clear Back Signal (600 p.s.).—The signal is applied when the called subscriber restores the telephone receiver. At the receiving end it causes the supervisory lamp to glow steadily as an indication of the condition. Where the called subscriber is connected to a magneto trunk exchange, the signal will be given when the called subscriber rings off (or should the magneto telephonist withdraw the answer plug).

The signal is of a repeated nature, as is the answer signal, but in this case it is not acknowledged. The signal is interrupted to allow of signals in the reverse direction to break through during pulses and thus take effect. The signal repetition continues for as long as the condition persists or until it is stopped by a signal in the reverse direction.

At the receiving end the signal causes splitting to occur, and this condition is maintained for the duration of the signal; that is, the split is held over the pulses. Maintaining the split means that the calling subscriber hears only the prefix of the first effective signal pulse. This prevents the signal being mistaken, for example, for busy tone. The timing is the same as for the answer signal, namely—

350-400 mS on. 350-400 mS off.

Ring Forward (or Recall) Signal (750 p.s.).—As the name indicates, the signal is passed in a forward direction for the purpose of ringing or attracting the attention of the distant telephonist, either directly or indirectly. An example is the flashing of a supervisory lamp on a distant exchange cord circuit.

The transmission of the signal causes the condition of the connection to be restored to that appertaining before the answering signal had been passed. Acknowledgment of the signal by the terminal telephonist on a magneto exchange (or the answer of another subscriber in non-magneto cases) causes a fresh answering signal sequence to occur, thus extinguishing the calling supervisory lamp at the originating exchange; this lamp came alight when the ring forward signal was initiated. This facility is of particular value when delay working is in force as it allows calls to be worked off without releasing the trunk, and at the same time it enables correct supervisory conditions to be displayed on each call in the series. On tandem calls involving intermediate trunk exchanges, the signal will also attract the attention of the tandem "B" telephonists, but their entry into connections will not cause an answer signal to be transmitted, only terminal "B" telephonists or subscribers being able to do so. When no answering signal has been given, the ring forward signal will still attract the attention of distant telephonists.

On calls which are dialled direct to an automatic subscriber, the signal has no function as it cannot control the subscriber's ringing circuit. Further, it should not be used in such cases as it may cause release of the distant automatic switches if the signal is applied long enough. The reason is that the signal is indistinguishable from a long impulse and would cause the loop to the automatic switches to be opened, in turn causing release. When the called automatic subscriber has answered, the connection can be guarded against release by a ring forward signal since the fact of answering establishes that no more impulsing is required. The X receiving elements can therefore be given a guard from that stage onwards. The fact remains, of course, that the ring forward signal can serve no useful purpose in these cases of distant full automatic routings.

The signal is applied in all cases by the operation of a key by a telephonist. The length of the signal is determined by the operated time of the key. A minimum operation of about 2 seconds is advisable.

The telephonist should temper the length of the ring in accordance with whether or not tone is on the line. When, for example, N.U. tone has been encountered, it will be necessary to send a signal of about 6 seconds to ensure that it catches a break in the tone. The break in the N.U. tone is for a minimum period of 350 mS and occurs once every five seconds in the N.U. tone supply at exchanges to which the 2VF system has access. A 2-second application will register in the face of busy tone.

The signal causes splitting to occur at the receiving point in order to prevent it passing beyond as a VF signal, and also to prevent more than its prefix portion being heard by the telephonist or a subscriber. Following splitting, the signal registers after a further delay of about 100 mS. When transmitted in the face of clear back signals, the ring forward signal takes effect during a pause between two clear back pulses, and by causing the circuits at each end to revert to the pre-answered condition, it stops the clear back signal.

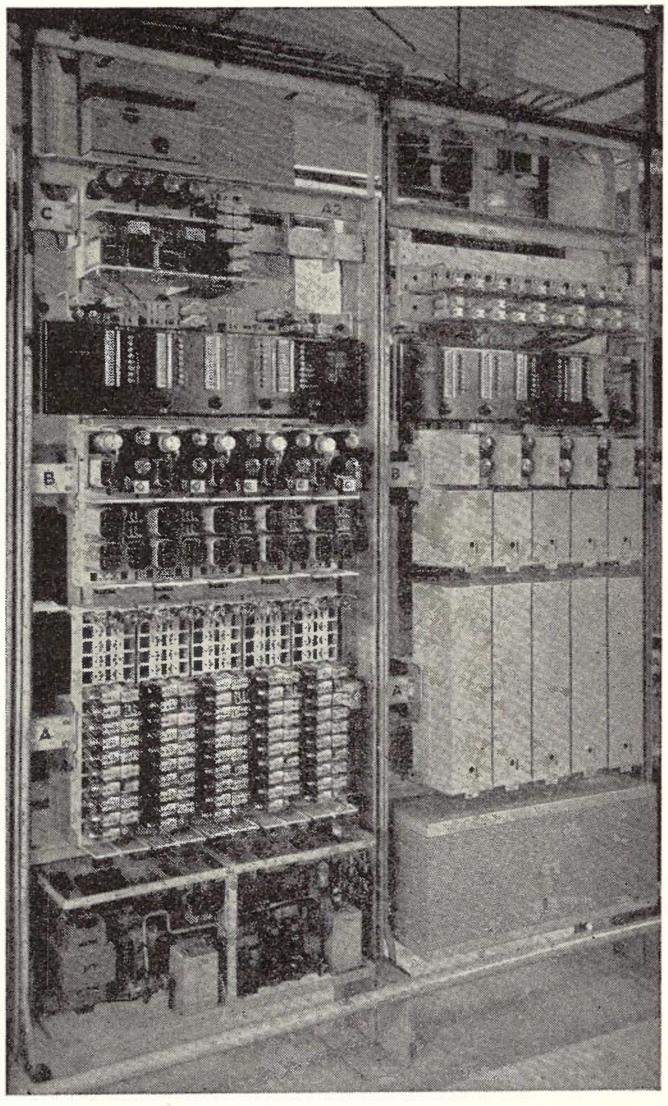


Fig. 6.—2VF Trunk Line Racks at Country Exchange showing a Typical Arrangement for Ten Trunk Lines, i.e., 5 Ccts. per Rack.

Clear Forward Signal (600 p.s.).—The clear forward signal is sent from the calling end when the connection is to be released. It is started by the withdrawal of the calling plug or equivalent action. Its purpose is to initiate release at the distant end. If that end comprises a fully-automatic routing, then when the signal ceases, distant release conditions should be well advanced. The cessation of the clear forward signal is then followed by the distant end reverting a release signal (which is really an acknowledgment of the clear forward) until full release is accomplished. Where a distant end comprises a manual routing, release conditions are of course not complete until the answer plug has been removed from the incoming jack, in which circumstances the reverted release signal persists until plug withdrawal.

At the originating end, the circuit releases as far as possible during the transmission of the signal, holding on after signal termination only for long enough to guard itself pending the arrival of the release signal.

The length of the signal must naturally be long enough to ensure that it will take effect without fail. When N.U. tone is encountered, the signal may be held out for 5 seconds since this is the maximum length of the N.U. tone pulse. The signal must therefore be longer than 5 seconds by an amount sufficient for it to cause registration at the receiving end.

The time taken for the signal to register at the receiving end has been fixed at a considerably higher figure than for other signals since in no circumstances should it be possible for a voice-produced signal to cause the release of a connection. A further reason for a longer registration delay is concerned with tandem-switched traffic. Inclusive of splitting time, the period taken for the signal to register at the receiving end is—

Minimum 530 mS. Maximum 710 mS.

When N.U. tone can be encountered, the length of the clear forward signal has been fixed at a minimum of 6 seconds. N.U. tone, however, should very seldom be encountered and it would be wasteful to send such a long signal on **all** calls, owing to the time representing unproductive occupancy of the trunk. Where possible, the signal has therefore been arranged as follows: —

On 2.0 seconds: Off 0.5 seconds: On 6.5 seconds. If the call has not encountered N.U. tone, the signal registers during the 2-second pulse. During the subsequent 0.5-second pause, the release signal is received from the distant end, which thus prevents the sending of the 6-second pulse.

In the case of N.U. tone, the same action will occur if a tone break happens to occur during the application of the 2-second pulse. If not, the fact that the release signal is not received during the pause will cause the 6-second signal to be sent, which will, of course, break through the first N.U. tone gap encountered.

This two-part clear forward signal arrangement does not apply at country magneto exchanges; the signals sent are as follows:—

Answered call, 2.0 secs. min. 2.5 secs. max.

Unanswered call, 6.0 secs. min. 6.5 secs. max.

The different principle used in this case is due to the fact that at country magneto exchanges there is no secondary battery available for supplying the needs of a uniselector for producing the 2 + 6 second signal. The Mains Unit equipped at such exchanges for supplying the 2VF circuits cannot stand the heavy current demands of uniselectors, and consequently a simpler method using relays to produce the signal is necessary.

Release Signal (600 p.s.). — To ensure that, when the signal ceases, both ends of the trunk are fully released and that the trunk is capable of immediately accepting another call in either direction (if a bothway circuit). The minimum length of the release signal has been fixed at 450 mS, the maximum length of the signal cannot be stated as, when the signalling end is a manual exchange, the application will persist until the answering plug is withdrawn.

In the case where the call is routed direct to an automatic subscriber, the release signal will be prolonged owing to the introduction of a guard period at the auto. end for preventing switches being caught on release under immediate re-engagement conditions, — unless a sufficient time had already been measured off for this purpose whilst the clear forward signal was in control. When the release signal ceases, the circuit sending it should be completely released. The same applies to the other end when the signal ceases.

Re-Route Signal (750 p.s.).—The signal is reverted from the country 2VF Trunk Line Circuit when the Main Trunk is used for an alternatively routed call and when the associated trunk-terminating selector finds all outlets to the required branch exchange engaged. The receipt of the signal at the originating exchange causes the Sender circuit to drop the connection and to set up the call for the country exchange primary route, so that it may be stored.

The signal length is not of vital importance as it cannot be subject to voice interference. A figure has been adopted of—

Minimum 100 mS. Maximum 300 mS.

Test Busy (600 p.s.).—This signal, the purpose of which is to busy the distant end without calling, when applied to one end of a free trunk, prevents calls being made from the other end. The chief use is when routine testing is in progress, particularly with an auto routiner. The distant end remains engaged as long as the signal is on the line.

(To be continued.)

AERIAL LINE CONSTRUCTION

A. S. Bundle

PART III.: PLANNING OF POLE ROUTES

This section deals with:—

Choice of Route.
Measurement of Route.
Preparation of Field Book.

CHOICE OF ROUTE

The proper choice of a route for a pole line requires careful planning, and investigation in respect to the initial cost, subsequent costs, accessibility and the trend of future development of the district. Usually the cheapest route between two towns will be alongside the most direct road or railway line joining the towns. However, there are various other aspects which must be considered before the actual position of the route is determined. It is important for the engineer to visualise as accurately as possible what the surrounding locality will be like during the ensuing twenty years and how it will be given telephone service. The close settlement of certain areas, the development of new roads, railways, etc., or the establishment of an exchange, may materially affect the desirable position of a pole line, as well as the length of poles, etc. A study should be made to determine the number of trunk line channels required for the present eight and 20-year periods. Whenever practicable, this should be supported by a proper survey by a special telephone survey officer or an engineer, to determine as closely as possible the telephone development of the district.

Armed with information about the number of channels required for trunk line purposes and the local subscribers' development and some knowledge of the local geography, it is then possible to lay out on a scale map the most suitable routes of the pole lines required to serve the district, having regard to proper co-ordination of pole and cable lines to cater for future telephone requirements and also to other factors such as providing cost, accessibility for economical and speedy maintenance, freedom from hazards, etc.

Preliminary Inspection. — Having planned the route or routes and any possible alternative, it is advisable to confirm the choice by traversing both the route and the alternatives and to take into account the various practical considerations such as:—

(a) The best side of a road or railway for the pole line.
(b) The extent and cost of clearing.
(c) The nature of the ground for the setting of poles and stays.
(d) The probable extent of staying required.
(e) The need for crossing private property.
(f) Easy access to all points for maintenance.
(g) Presence of electric transmission lines and service mains or other sources of electric hazard or inductive interference.

When either side of a route is available, thought must be given to the number of road or railway crossings, either of line wires or stay wires, that would become necessary, bearing in mind the height of poles required to provide the requisite minimum clearances over the (a) roadway, 18 ft.; and (b) the railway, 22 ft. It is advisable to avoid positions alongside ornamental trees.

Consultation with Interested Parties. — After tentatively selecting the route of a new pole line, the local authority and land owners should be consulted to ascertain if they have plans which might affect the decision. It may happen that their plans will necessitate reconsideration of the proposed route. These enquiries should include information regarding proposed new roads, deviation or widening of existing roads, proposed gateways, culverts, proposed or existing drains, boundaries and bridges, water and electric supply mains, etc., knowledge of which is essential for proper planning.

Economic Comparisons. — It may occur that several alternative routes or methods of providing service are available, and in such a case the deciding factor would be cost. An economic comparison is made, in which the full costs of each scheme are brought to the same basis (i.e., to Present Values), in a similar manner to that described in Part II. of these notes dealing with steel or wooden poles.

Stages of Setting Out. — Having selected the general route for a pole line, the next stages are to:—

(a) Set out the precise alignment;
(b) carefully measure the route;
(c) prepare field books;
(d) divide the route into transposition sections;
(e) set out pole locations in the field book;
(f) peg the pole positions;
(g) grade the route.

Alignment. — The determination of the alignment of the route must be given very careful consideration and as far as practicable any future need for shifting must be anticipated, because a subsequent alteration may vary the length of the route. This is important from the transposition aspect, and any appreciable alteration subsequently in the length of the route may necessitate the complete remeasurement and respacing of the transposition poles over at least a whole transposition section.

The line of the route should be marked out by inserting pegs at each angle and making a blaze or other suitable mark on a nearby tree or fence. Any grass in the vicinity of the peg should be knocked down with boot-heel or axe to make a cleared area. This clearing will remain noticeable for several weeks or even months and assist considerably in the subsequent location of the peg. As markers for such pegs, surveyors frequently set small stakes about 5 ft. long over the pegs and affix pieces of white paper to the tops and these can be readily seen by the chainman when the route is being measured up. Any scrub or undergrowth which prevents a clear view along the route, should be cleared.

The information about proposed roads, building and fence alignments, gateways, etc., will all be required in order to be sure that the route, as pegged, will be final. Without further evidence, the positions of existing fences should not be accepted as being on the correct property alignment. At this stage it is advisable to take the local municipal or shire engineer over the route in order to obviate objections being raised at a later date. Apart from his official support, this officer's local knowledge may often prove of assistance on matters such as the true position of property alignments, etc.

MEASUREMENT OF ROUTES

Importance of Accuracy.—The measurement of the route must be as accurate as practicable because of the necessity for accurate spacing of transposition poles. Moreover, the subsequent setting out of the pole locations practically involves a remeasurement of the route and unless both measurements are made accurately they will not agree, and quite appreciable differences may result, necessitating further measurements and repegging.

It is, therefore, advisable to take proper precautions in the first place. Briefly, these consist of:—

(a) Accurately marking chain lengths and taking every care to ensure that the measurements are made along the line of the route;
(b) marking reference points not less frequently than every ½-mile;
(c) in difficult country, remeasuring the sections between reference points (as much as three or four times may be necessary, if there is any doubt about the exactness of the measurement).

The initial measurement is most important, as it is upon this that the layout of transposition sections and transposition poles is based. An error in this measurement may, if not detected until the setting-out stage, upset practically the whole of the work.

Measuring Accuracy. — Surveyors normally work to a minimum accuracy of 1 in 5,000, while for rough work they would usually be accurate to 1 in 3,000. For the purposes of transposition layout an accuracy of not worse than 1 in 1,500 is sufficient and this should be obtained, by even a relatively untrained staff, with little difficulty. The following paragraphs describe, in greater detail, how to measure up a route within the accuracy required.

Reference-Points. — The reference-points may be painted arrow-points on trees, fences, rocks, poles, etc., or other suitable markings, and must be recorded in the field book. These marks can then be checked on the second through measurement associated with the setting out of the pole positions, and if the second measurement does not coincide with the first to the accuracy required, it can then be rechecked over a distance not greater than ½-mile.

Continuous Chainage. — In measuring up the route, it is important to take a continuous chainage and to record the positions of existing poles, obstructions and check points by showing their distance (along the line of the route) from the starting point. If these points are not on the true line of the future route their distance from it should be separately recorded. This overall measurement will consist of what is termed a "running measurement," i.e., a series of full-tape lengths with perhaps an odd length at the end of the section. In this way, the chance of faulty calculations is reduced to a minimum, as any miscalculation at an intermediate point will apply only to that point and not be carried on to affect the overall measurement.

Staff.—It is desirable for the survey party to consist of four men. The party-leader makes out a field book and records all measurements therein. Two men called "chainmen" handle the measuring tape or "chain" as it is sometimes called. The fourth man usually drives the truck and assists in various ways wherever an additional hand is required, such as carrying gear, clearing scrub and giving a line to guide the chainmen, etc. If a little time has elapsed between the initial pegging out and the measuring up, one of this man's tasks would be to proceed ahead and see that markers are set up at each of the angle pegs setting out the line of the route. When the pegging out is being done, a fifth man may be required to drive the pegs home and paint and mark them.

Equipment. — The following equipment will usually be required:—

1. Surveyor's tape.
2. Two plumbobs.
3. An optical square (with tripod).
4. One (and possibly 3) lining rods.
5. Prismatic compass.
6. Field glasses.
7. Lumber crayon or brush and paint.
8. Steel arrows, 10 with red tabs and 3 with blue tabs.
9. Brush hooks (1 to 3, according to nature of country).

The most suitable type of tape is a surveyor's steel tape ⅛ in. wide and 300 ft. long marked with brass clips every 10 ft.; and the first and last 10 ft. sections are further divided by brass clips at every foot. For holding each end of the tape, boot laces should be slipped through the loops which form the tape-ends. The lace at the leading end may be in the form of a loop, but at the trailing end the centre of the lace should be secured to the tape and the two ends left free to prevent them catching in obstructions as the tape is being drawn along the ground.

Brass plumbobs, steel pointed, weighing approximately ½ lb., and provided with an easy method of attaching a cord, are the type required.

The optical square is a device used to set out lines at right angles to one another and is mainly required in connection with offset work, which is described later. Optical squares without provision for attachment to a tripod are frequently supplied, but the additional cost of providing an attachment so that the square can be used with a light metal tripod such as a camera tripod, is amply justified by the greater ease and accuracy in using the square. Failing this, the square may be set on the flat top of a lining rod or other stake.

Lining rods are 6 feet long with steel tips. For each foot of their length they are painted with contrasting colours (usually white with black and red), which make the rods show up clearly at a distance. By having a colour-change at every foot the rod can be used as a measuring stick.

The prismatic compass is used to measure the bearing of each straight section of route and thus to provide a measure of each angle in the route for calculation of anchoring materials. It is also useful for direction finding when making the initial layout for a new route over rough or timbered country. The prismatic compass should also be attachable to the tripod. These compasses are not reliable in ironstone country, and when being used in other country should be held at a distance from iron or steel objects such as steel poles. The observer should ensure that there are no large iron or steel objects about his person while using the compass.

When using the prismatic compass to determine the angles on the route, it is usual to take the bearing of each straight section of route and the angles can then be found in the office when required. Information regarding the bearings of each straight section of route is sometimes handy when plotting a route on to a map. When using the prismatic compass the observer stands over the line, the bearing of which is required, and sights the compass towards another point on the same line. The bearing, read in degrees measured in a clockwise direction from the magnetic north pole, appears opposite the sight mark.

The steel spikes or "arrows" are used to indicate to the rear chainman where the leading end of the tape came in the previous measurement. If practicable, the arrow is pushed into the ground at the exact point indicating the end of the measurement. In very hard ground or rock a scratch is made to indicate this point and the arrow laid alongside.

Coloured strips of bunting attached to these arrows serve to make the arrow more prominent and also as a check against the number of tape-lengths measured. The leading chainman starts off with 10 red "arrows" and three blue ones. He will insert one red arrow to mark the end of each tape-length. When the rear chainman reaches the first arrow and a measurement is made, he then recovers the arrow which indicates that behind him there is one complete tape-length. This process is continued and the number of red arrows with the rear chainman indicates the number of full tape-lengths behind him. When ten full tape-lengths have been marked the leading man will have no red arrows and will wait for the rear chainman to come ahead and will give him a blue arrow in exchange for the 10 red ones. Thus, when he has reached the end of 10 full tape-lengths the rear chainman will have 10 red arrows or one blue one. This procedure is continued until 10,000 feet have been measured, i.e., 100 ft. on from the point where the rear chainman has all three blue arrows and three red arrows (assuming that a 300-ft. tape is used).

At each 10,000 ft. a special datum mark should be made and the counting commenced afresh. In this way the continuous chainage measurements shown in the field book will be limited to four figures. The full chainage of each datum point should be shown in the field book.

Field glasses may be unnecessary in some circumstances, such as when measuring along an existing route, but on new routes they are often useful or even necessary in picking out distant pegs or markers.

METHOD OF MAKING THE MEASUREMENT

When making a chainage it must be fully appreciated that the object is to measure **the length of the wires** and not necessarily the distance over the surface of the ground or the horizontal distance between points. Thus, in crossing gullies the tape would be held up in simulation of the line wires, while in crossing roads and gateways the wire must also be raised in accordance with the increased heights of the wires to provide regulation clearance. On existing routes the tape would be supported at each pole so that it is the same distance from the wires, e.g., if on a 30-ft. pole the tape is at ground level, then it will be 2 ft. above ground level on a 32-ft. pole.

The first care in making a measurement is to be certain of the correct starting point or datum and the party-leader must see to this, as the near chainman will not know what is in the party-leader's mind. Thereafter, the measuring points will be indicated to the near chainman by the "arrows." This care is also necessary at special points where the regular method of measurement may have to be interrupted.

Wherever possible (e.g., in level country) the tape is laid on the ground and pulled lightly to a tension of 2-4 lb. Where, however, the end or ends of the tape occur at a depression in the ground, or to follow the line of the wires, or to clear obstructions, it is necessary to hold the end or ends above ground, the measurement must be "plumbed." That is to say, in the case of the leading end of the tape a mark, vertically under the end of the tape, must be made on the ground; in the case of the trailing end of the tape this end must be held vertically over the mark made by the leading chainman at the end of the previous measurement. Where necessary, intermediate measurements are "plumbed" by holding a plumbob against, or opposite the object, the chainage of which is required, and reading the chainage opposite the plumbob cord.

The general procedure in chaining is for the leading chainman to draw the tape and the rear chainman to leave his end of the tape free. He then moves at a quicker gait than the leading man to reach the flagged arrow set at the previous measurement. As the end of the tape approaches him, the rear chainman picks the tape up, giving it a gentle but firm pull to warn the leading man that he is reaching the end and gradually increases his pull until the leading man has drawn the tape to the mark. When the rear man has his end of the tape over the mark, he signals the forward man, who takes his measurement and inserts a flagged arrow to mark the point. When plumbing, the tape and plumb-lines must be held steady, the object of each chainman being to have his mark within $\frac{1}{4}$ in. of the true point. The leading chainman should knock down any grass or undergrowth in the vicinity of the mark, using either the heel of his boot, axe or other heavy tool.

It must be borne in mind that steel tapes have a certain elasticity and will stretch in proportion to the tension applied. On the other hand, if the tape is held above the ground the sag will tend to nullify the effect of the stretching. Thus, if the tape is allowed to be on the ground only a light tension (2 to 4 lb.) should be applied, to straighten it, but if the tape is suspended above ground a tension of 12 lb. must be applied to a 300 ft. by $\frac{1}{8}$ in. tape to nullify, at normal air temperatures, the effect of the sag within the desired accuracy of measurement.

When measuring with the tape clear of the ground, surveyors often use spring balances to ensure that the tapes are pulled to the correct tension and a balance of this type should be used by the chainmen until they become able to judge the proper tension. With a little practice it should be possible to dispense with the spring balance and rely upon judgment for tension within the required accuracy.

It may be found difficult to hold the plumbob steady, especially in a strong wind, and for this reason the chainman should stand so that his body will act as a break. To steady a plumbob quickly two methods are available and are set down in the writer's order of preference:—

(a) Move the hand holding the cord firmly in the **direction of the swing** of the plumbob and then bring it steadily into the desired position. It will be found that with a little practice the plumbob can be quickly steadied.

(b) With one hand hold the tape-end and the plumbob cord and use the other hand to steady the plumbob. The effectiveness of this method is limited by the distance between the plumbob and the tape-end and the pull required at the end of the tape. It is the better method when making measurements with the tape held high off the ground.

Measurement of Intermediate Points. — The tape should be drawn out so that the zero is at the near end, and any intermediate measurement taken along the tape will then be additional to the chainage at the end of the previous full 300-ft. measurement.

Experience shows that there is always a greater possibility of miscalculation where mental calculations are made in the field and so one of the following methods of measuring is used:

(i) The chain used may have brass tabs at every foot of its length, the intermediate tabs being smaller than those marking the 10-ft. sections. The 10-ft. tabs are completely numbered and the 5-ft. tab of the intermediate tabs in each 10-ft. section is numbered. This enables the party-leader to read the chainage of any object after reference first to the 10-ft. tab and then the foot tab. Tapes marked in feet are not met with as frequently as those with 10-ft. marks, and so it is often necessary to use one of the other methods listed below.

(ii) A short 10-ft. length of tape (sometimes called a "leader" or "trailer") marked in feet and, possibly, in inches, may be carried by the party-leader and clipped to the 10-ft. tab before the object. The chainage is then found by adding to the figure on the 10-ft. tab the measurement in feet and inches shown on the "leader."

(iii) A short 10-ft. "trailer" is attached to the rear end of the tape with its zero coinciding with the zero of the full tape. To obtain the chainage of an object the party-leader draws the tape ahead until the 10-ft. tab is opposite the object. The near chainman then reads the measurement on the trailer and calls it to the party-leader, who adds it to the figure on the 10-ft. tab of the long tape.

(iv) The party-leader draws the chain back slightly so that the first 10-ft. clip, past the point to be measured, is opposite the point and the near chainman draws back his end of the tape and measures the distance in feet and inches from the 10-foot mark on the tape. The party-leader adds the measurement called by the near chainman to 10 less than the figure shown on the 10-ft. clip he is holding opposite the point. Thus, if the near chainman calls out 6 ft. 8 in., the party-leader is holding the 140-ft. clip he will record "130 ft. + 6 ft. 8 in. = 136 ft. 8 in."

It will be seen that methods (i) and (ii) require little mental effort. Method (iii) has the additional hazards of (a) another man reading and (b) calling a measurement and (c) of the party-leader hearing the called measurement. Method (iv), in addition to the hazards of method (iii), requires rather more mental effort in the form of an additional stage of subtraction (of 10 ft.).

In addition, the measurement must usually be added to some multiple of 300 ft. to record the full chainage. The full chainage is necessary in the office field book, but the party-leader may avoid this mental calculation in the field by recording in the field book merely the measurement from the previous 300-ft. mark (which itself must be recorded). The addition can then be made in the office or during an off period when the party-leader is not concerned with the many other details of measurement, alignment and recording.

Obstructions.—It is important, when making measurements, to follow closely the line of the route as any divergence will increase the measurement length. In some circumstances, it is difficult or impossible to measure along the line of the route, while in others it is actually more suitable not to do so.

In such circumstances measurements can be made by offsets. That is, the measuring tape is taken along a line parallel to, but a convenient distance from, the true line. It is advisable to keep this line as close as possible to the true line, and it is important to ensure that along the offset line the tape follows the grade of the line wires. Where angles occur, each straight section of route must be measured by separate offsets from the angle point. For a through measurement passing B (Fig. 22) the chainage of "b" should be recorded and the point on the tape then transferred to "c."

The best and quickest way to determine the starting and finishing points for offsets is to use the optical square. This is a modified form of sextant and very simple to use. The observer, when standing over the point where the

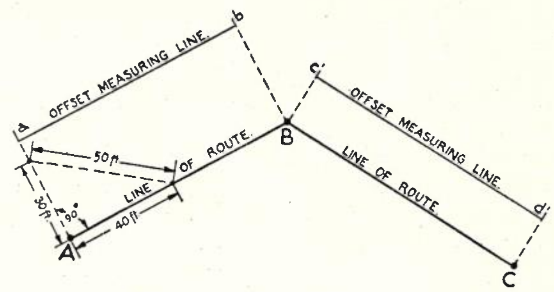


Fig. 22.—Offset Measurement.

right angle occurs, sights along the instrument towards one of the lines forming the right angle and sees simultaneously (by an arrangement of mirrors) objects along the line which is at right angles to the one which he is facing. Thus, an observer at "A," Fig. 22, would appear to see "a" in line with "B." In establishing "a" it is the observer's task to line up a man (standing with lining rod in the vicinity of "a") with another lining rod along the line A-B.

Other methods available for establishing offsets are:—

(a) Theodolite;
(b) prismatic compass; and
(c) by setting out an angle with the 3, 4, and 5 ratio as indicated in Fig. 22.

Care of Equipment. — Every care must be taken of the equipment. It is important to see that the tape is carefully handled and, when finished with for the day, is run through a greasy rag and wound up. Special care must be taken to prevent vehicles running over the tape. It is advisable to have at least two tapes, one of which can be retained as a standard for emergency use in case of damage to the regular tape. Cloth tapes, even with metallic reinforcement, are unsuitable for survey work to the required accuracy of 1 in 1,500. The stretch of a new 100-ft. cloth tape under working conditions is of the order of 4 or 5 inches and will cause serious errors.

Tie Measurements. — Experience shows that pegs indicating angles or pole positions can quite easily be lost because of either intentional or accidental removal or covering up. In other instances, much time may be lost simply because there is insufficient information available to enable the searcher to know just where to look and the peg is not sufficiently distinctive. These pegs are often very important, and it is advisable to record the position of each important peg, such as those at angles, by taking at least two measurements to different reference objects or alignments which can reasonably be expected to exist when the peg has subsequently to be located. These measurements are termed "tie measurements" and must be recorded in the field book.

Measurement of Existing Routes.—The foregoing remarks upon measurement have been based upon the provision of a new route. With the rapid increase in the numbers and frequency ranges of carrier systems operating over open-wire routes extensive review and improvement of the transposition arrangements on existing trunk routes is necessary. In such cases the procedure will be similar in many respects. It will be necessary to carefully inspect the existing alignment of the route and anticipate subsequent alterations as mentioned previously. The route is then measured as for a new route in the manner described, except that the positions and certain details of the existing poles would also be recorded in the field book. It is important to adhere to the method of continuous measurement taking full tapelengths as described. The chainages of existing poles are obtained as intermediate measurements.

PREPARATION OF FIELD BOOK

A field book must be prepared to:—

(a) record the details of the route measurement;

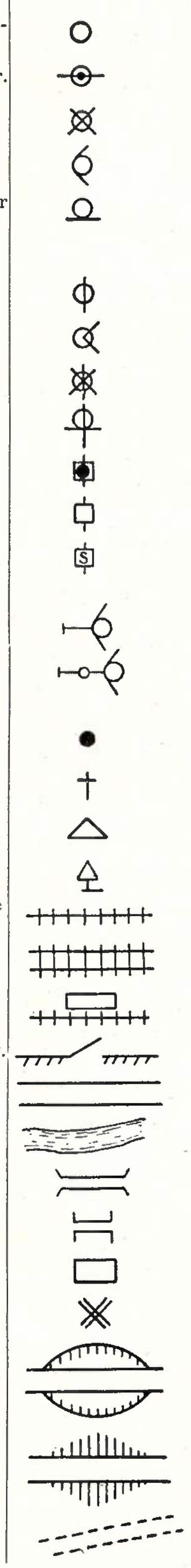
(b) provide a diagrammatic representation of the route and include the locations and nature of obstructions, discontinuities, etc., to enable the transposition scheme to be prepared and the locations of all transposition poles determined;

(c) show the proposed positions of all poles for the guidance of the officer who has to peg out the pole positions.

The usual method is to make out a rough field book while carrying out the actual measurements and then to prepare a neater one in the office, to act as a record of the route. This book will be required principally for determining the layout of transposition sections and poles, and information such as tie-measurements to angle pegs. The compass bearing of each "straight," etc., may be omitted for the sake of clarity, as a field book can easily become overcrowded.

When completed, the field book should give a comprehensive picture of the route and clearly indicate the locations of all obstructions to the erection of poles, e.g., creeks, roads, gateways, etc.; points of discontinuity, e.g., branch routes,

TABLE 6.



Symbol	Object	Remarks
Telephone Construction.		
Pole in straight section.		Where required, class of pole to be indicated (a) by letters in case of wood poles (e.g., R.I. = red ironbark), or (b) by words in case of steel pole (e.g., rail, beam, tubular, etc.). Height to be shown alongside. Staying to be indicated by symbols.
Pole with E.L. raiser.		
Transposition pole.		
Pole at angle.		
Terminal or Anchor Pole.		
Electricity Supply Construction.		
Pole in straight section.		
Pole at angle.		
Pole with transposition.		Staying to be indicated by symbols where likely to affect telephone construction.
Terminal or Anchor Pole.		
Transformer Pole.		
Tower.		
Substation.		
Stays.		
Ground Stay.		Shown attached to angle pole. Indicate direction of each stay.
Head Stay.		Do.
General Items.		
Peg.		
Reference Point.		
Survey Mark.		Indicate B.M. for bench mark or T. for trigonometrical point.
Tree.		
Railway line—single track.		
Railway Line—double track.		
Railway Station.		Indicate name of station.
Fence—with gateway.		
Road alignment—unfenced.		
Stream.		
Bridge.		
Culvert.		
House or building.		If of special nature (e.g., church, hall, etc.) indicate in words.
Telephone exchange.		
Cutting.		
Embankment.		
Special tracks.		

end of power parallels, etc.; readily identified landmarks, such as houses, schools, railway lines, stations, and mileage pegs, etc.; and a general idea of the topography of the country.

Symbols. — The use of symbols will simplify the preparation of a field book and reduce the tendency to overcrowding. To be of full use the symbols should be understandable by those who have need to refer to the field book and should also be as close as possible to a diagrammatic representation of the objects they are used to indicate, so that a glance at the field book will convey a reasonably good idea of the route. Table 6 shows a set of symbols which have been prepared with these objects in mind, as the writer has not been able to obtain any complete set of standard symbols suitable for the purposes of this class of work. Whenever practicable, the more usual symbols, such as those used for Army Ordnance Maps and Electricity Supply Organisations, have been shown, but some departure and additions were made to suit the special requirements. To obtain the maximum use of the space on the field book pages the general line of the telephone pole route should be shown as straight and parallel to the longest edges of the sheets. Angles in the route will be indicated by symbols for angle poles.

The separation between electric transmission lines (especially of high voltages) and telephone wires is of special importance and should be recorded in the field book. Fig. 23 is a specimen page of a field book and is provided to show, as far as possible, the method of preparation.

(To be continued.)

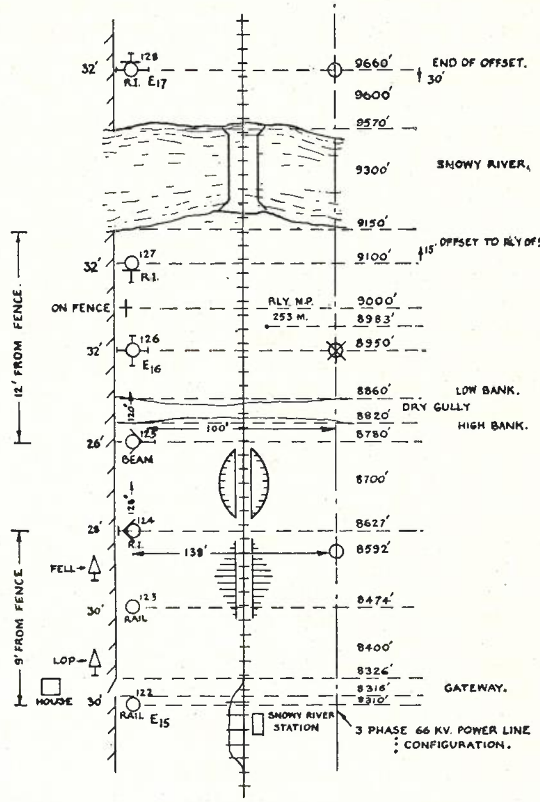


Fig. 23.

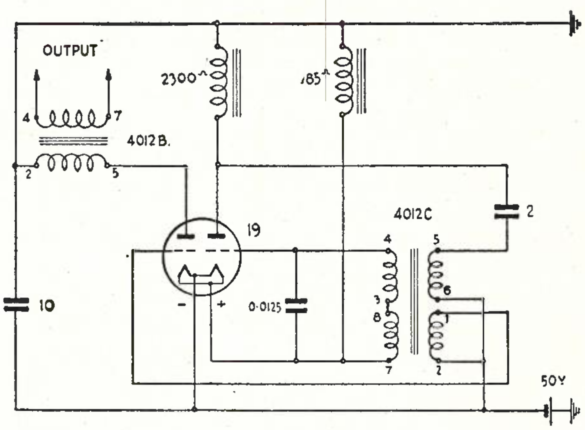
INFORMATION SECTION

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

A 400 CYCLE GENERATOR FOR P.A.B.X.s AND R.A.X.s

On unit type P.A.B.X.s and R.A.X.s, the 400 cycle tone for busy and N.U. signals, is generated by a special relay which has close adjustment limits. In an unattended exchange particularly, it is desirable to provide equipment which will function reliably over long periods, and in order to overcome the difficulties experienced with the 400 cycle tone relay, a valve oscillator circuit has been developed and installed at P.A.B.X.s and R.A.X.s in Western Australia.

It was thought that a cheap and reliable oscillator could be constructed, using a triode valve and a 4012A transformer. This was tried out but it was found that although the output was adequate, variations in the load produced similar variations in the frequency. A buffer valve was inserted and after satisfactory tests the two valves were replaced with a Type 19 as depicted in Fig. 1. No difficulty was experienced in tuning to 400 cycles. The .0125 mF. condenser was inserted to reduce the frequency from about 430 to 400 cycles. The correct frequency is reached in a fraction of a second after switching on.



The output of the generator is more than adequate for a 200 line P.A.B.X. It was originally intended to connect the output in lieu of the 20 : 1 transformer in the existing tone supply equipment. The level of the tone, however, was too high and gave rise to inductive interference. Satisfactory operation was obtained when the 4012B transformer was connected to the 20 : 1 transformer and thence to the load.

A repeater base will just accommodate the transformers, coils and valve. The 2 mF condenser is mounted externally. The 10 mF condenser is optional, depending on the power supply. The current drain is a little over a quarter of an ampere. The quality of the note is a little purer than the output from the standard exchange ringing machine. However, this is not noticeable unless the two tones are heard simultaneously.—K.H.

HONOUR BOARD—VICTORIAN LINEMAN-IN-TRAINING SCHOOL

The distinctive Honour Board shown in the photograph, has been provided in the Lineman-in-Training School to record the names of trainees and ex-trainees who have joined the Fighting Forces. It was considered appropriate for each instructor and trainee to assist in the manufacture of the Board, which was designed by Mr. V. Walters of the Instructional Staff in collaboration with Mr. H. Levick of the Draughting Section. Mr. Walters also supervised the construction.

The design features of the Union Jack and Australian flags are set up in such a way to produce a waving effect. The veneers chosen to represent the colours Red, White and Blue are Queensland Maple, Silver Ash and Queensland Walnut respectively. Silver Ash and Birds-eye Maple are used for the stars. Surmounting the flags, the map of Australia is inlaid with Queensland Maple into rays depicting the rising sun, the veneers for the rays being selected from Walnut and Rock Maple. Immediately below the map of Australia a scroll of ribbon stretches across the flags; this effect is produced with quilted Maple, whilst on top of the scroll rests the island of Tasmania (Queensland Maple). Maple and Walnut veneer is used for crossed staffs to which the flags are fixed. The flags are united with a bow of cord to which tassels are appended (Maple and Walnut) symbolizing the bond that exists between the Motherland and the Commonwealth.

All concerned in the construction displayed a very keen interest, for not only was precision cutting necessary for accurate fitting, but the correct cutting and matching of the veneers was most important. From the working plan a duplicate was transferred to brown paper and from this, paper patterns were cut. Each participant was then given his pattern, and to this pattern the veneers were cut and matched, then glued face downwards to the paper ready for transfer to the base. The base is 6 ft. high x 5 ft. wide and is built up with 11 in. x 1 in. red pine jointed and glued. On the surface, plywood was glued, fixed,

dressed and prepared for glueing the veneers. The pattern was then transferred to the prepared base, the outlines marked, then cut to shape. The veneers were then glued on the bottom face and pressed in position, then cleaned off to give a level surface. The polishing was executed with white shellac, and throughout this operation staining was not resorted to, thus preserving the natural colours of the veneers. In all, over 400 separate pieces of veneer were used.—T.W.

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. 2324.—MECHANIC, GRADE 2, BROADCASTING

F. VIOL

Q. 1.—What is meant by the terms self-inductance and reactance?

Two coils have inductances of 40 millihenries and 80 millihenries respectively. What will be their reactance at 5,000 radians when connected—

(a) in series;

(b) in parallel?

A.—Self-induction.—When a coil of wire carries an electric current the lines of force produced set up a magnetic field. The lines of force of this magnetic field cut these conductors and so produce an E.M.F., generally defined as the back E.M.F., which tends to prevent a change in the value of the current flowing. This property of a circuit is known as self-induction, and the unit of measurement is the Henry.

Reactance is the factor opposing the flow of an alternating current by virtue of either inductance or capacity without resistance. In the case of inductance, the reactance is given by $2\pi fL$ and is denoted by X_L. In the case of capacity it is $1/2\pi fC$ and is denoted by X_C. Where f is the frequency in cycles per sec., L the inductance in henries, and C the capacity in farads, $2\pi f = \omega$ radians.

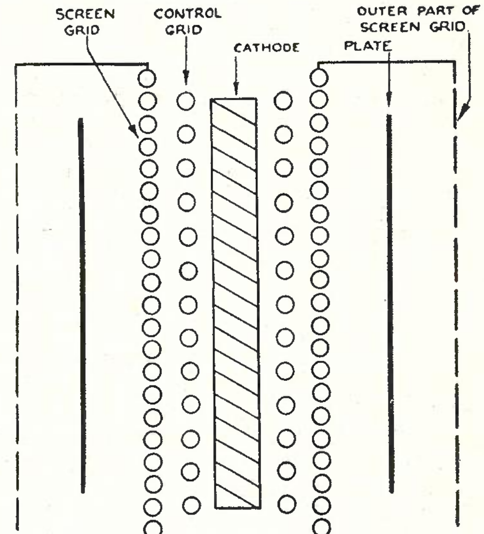
$$\text{Inductive reactance } X_L = 2\pi fL = \omega L$$
$$\text{1st coil } X_{L^1} = 5000 \times 40/1000$$
$$= 200 \text{ ohms}$$
$$\text{2nd coil } X_{L^2} = 400 \text{ ohms.}$$
$$\text{Reactances in series} = X_{L^1} + X_{L^2}$$
$$= 600 \text{ ohms.}$$
$$\text{Reactances in parallel} = \frac{X_{L^1} \cdot X_{L^2}}{X_{L^1} + X_{L^2}}$$
$$= (400 \times 200)/600$$
$$= 800/6 = 133\tfrac{1}{3} \text{ ohms}$$

Q. 2.—Discuss the characteristics of the screen-grid type of tube as a radio-frequency amplifier. What advantages are obtained by incorporating the variable-mu feature?

A.—The screen-grid tube is essentially a 3-electrode tube to which has been added a second grid located between the plate and the normal grid. The potential applied to the screen grid is usually slightly less than that applied to the plate, and this serves to accelerate the electrons flowing from the cathode, thus reducing the space charge and improving the amplification of the tube.

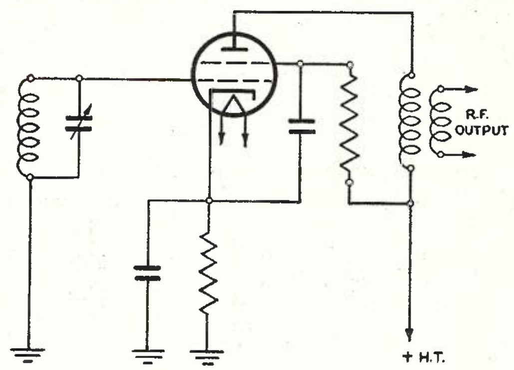
For radio-frequency purposes it is necessary that the grid-plate capacity be small to prevent feedback and self-oscillation, otherwise full use could not be made of the high gain of the tube. The grid-plate capacity of this type of tube is small, due to the reduction of the space charge.

The variable-mu tube is designed so that the lower end of the grid voltage plate current characteristic



Q. 2, Fig. 1a.
Section of Screen Grid Tube.

curve tapers off, and cut-off is only reached at a relatively high negative grid voltage. This feature permits the amplification factor (mu) of the tube to be varied over a wide range of values, thus making the application of automatic volume control feasible. Further, when the input voltage falls to a low value, the distortion of the wanted signal is prevented, and cross-modulation from unwanted signals is reduced to a minimum.

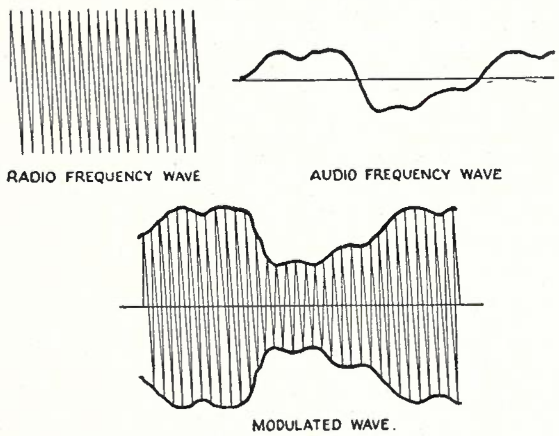


Q. 2, Fig. 1b.
Typical Circuit of Screen Grid Tube.

Q. 3.—Explain what is meant by a modulated wave. Describe the grid-bias method of producing modulated radio-frequency current.

A.—A wave is said to be modulated when its periodic functions are varied by impressing upon it another wave of different characteristics. One wave which is generally termed the carrier is usually of a relatively high frequency, and the other is termed the modulating wave.

In broadcast practice there are two types of modulated wave, the first in which the amplitude of the carrier is varied (Fig. 1), and the second in which the carrier frequency is varied about a fixed point, this fixed point being the nominal unmodulated fre-



Q. 3, Fig. 1.

quency of the carrier. In each case, the wave transmitted from the station is a complex one, first consisting of the carrier frequency plus two sidebands which form the sum and difference frequencies resulting from modulation, and the second is a wave, the frequency of which varies according to the frequency of the modulating wave in a predetermined manner.

A schematic circuit of a typical grid-bias type of modulator is shown in Fig. 2. The audio-frequency transformer is arranged so that the secondary winding is in series with the grid circuit of the tube, while the radio-frequency input, which is of constant amplitude, is also in series with the grid circuit. The condenser across the transformer is the radio-frequency by-pass, and the radio-frequency choke completes the audio-frequency circuit. When a signal is applied to the

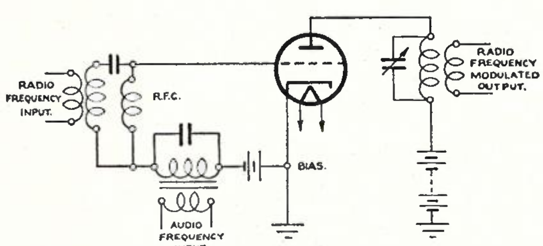


FIG. 2.

Q. 3, Fig. 2.

transformer, the audio-frequency voltage adds to and subtracts from the tube bias—hence, the plate current is in the form of radio-frequency pulses, or envelopes, which vary in amplitude in accordance with the applied signal.

Q. 4.—Why is it necessary that a broadcasting station should adhere strictly to its assigned frequency? What features of a transmitter determine its frequency and are designed to ensure the minimum possible deviation therefrom?

A.—It is necessary for a broadcasting station to adhere strictly to its assigned frequency for the following reasons:—

(1) To ensure that the stations will not interfere with one another.
(2) To enable the maximum number of stations to be allotted in the frequency band.
(3) To prevent distortion in radio-frequency receivers due to drift of the station frequency.

The features of a transmitter which determine its frequency are:—

(a) The radio-frequency oscillator;
(b) The circuit constants of the succeeding stages.

The source of frequency in a broadcast transmitter is the radio-frequency oscillator, and careful design of this unit is, therefore, of great importance. To reduce frequency deviation to a minimum, as is now required, the frequency source is controlled by a quartz crystal with inherent characteristics which make it suitable for this purpose. The following measures are taken to reduce deviation:—

(i) The crystal is cut in such a manner as to have a minimum temperature coefficient.
(ii) The crystal is placed in a temperature controlled oven.
(iii) The crystal and holder are mounted to avoid mechanical vibration.
(iv) Buffer stages of amplification are used to isolate the crystal oscillator from the main amplifier stages. This prevents the effects of tuning of the latter stages of the transmitter affecting the stability of the oscillator.
(v) The oscillator is operated at low power.
(vi) The power supplies are stabilised.

Q. 5.—Why is it desirable that the radiator of a broadcasting station be placed some distance from the transmitter? Describe one method of connecting the output of a transmitter to the radiating system.

A.—The radiator of a broadcast station is placed some distance from the transmitter for the following reasons:—

(1) Near the base of the radiator the field strength is very high, and it would be difficult to screen efficiently the transmitter to prevent feed-back and self-oscillation.
(2) The field pattern of a radiator is dependent on the earth system, and it follows that if the transmitter were built near the radiator the pattern would be distorted.

One method of connecting the output of a transmitter to the radiating system is to use a coaxial transmission line. This is primarily one copper tube inside another, so arranged that insulators, generally of the porcelain type, space the inner tube to the centre. The coaxial line is usually buried, and it is necessary that the outer tube be waterproof. For this reason a gas such as carbon dioxide is used to keep the transmission line at pressure to prevent the ingress of water should a leak develop. Pressure gauges are fitted at convenient points, and should a leak occur a difference in pressure along the line would indicate the general location of the trouble.

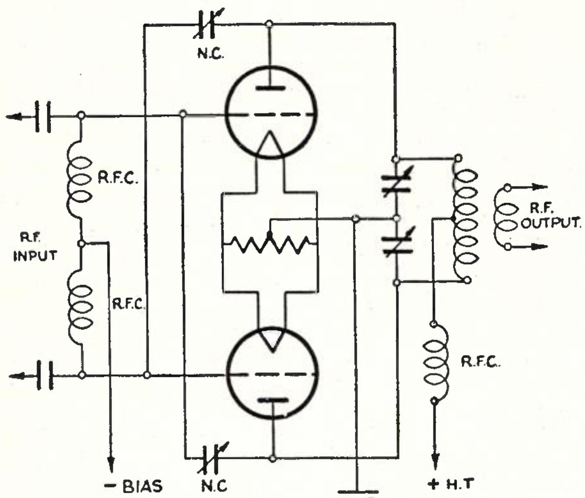
In the transmitter and at the radiator, tuning units are used to couple to the low impedance coaxial transmission line.

Q. 6.—Explain the push-pull and parallel operation of tubes in a transmitter, discussing the advantages and disadvantages of each.

A.—Fig. 1 shows a schematic circuit of a push-pull radio-frequency stage of a broadcast transmitter. The grids of each tube are excited with equal voltage 180°

out of phase, and the outputs of the two tubes are combined by means of the radio-frequency transformer fitted with a centre tap. The stage is neutralised by the condensers connected from each grid to the plate of the adjacent tube.

Advantages.—The circuit is symmetrical, and when properly balanced there are no radio-frequency cur-

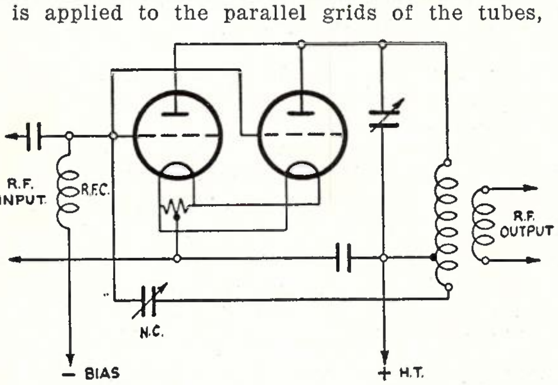


Q. 6, Fig. 1.

rents in the earth or common leads. This balanced condition is also of assistance when the amplifier stage is neutralised. In push-pull operation even harmonics are balanced out so that greater output power is available for the selected frequency.

Disadvantages.—For efficient operation of a push-pull stage each tube should be fully driven, and this requires the total input power to be twice that required for a single tube. The tubes of the circuit as a whole must be well balanced and symmetrical, and more tuned circuits are required than in a single-sided amplifier. The total output impedance is high as the impedance of each tube is in series.

Fig. 2 shows the circuit of a parallel-operated radio-frequency amplifier. The operation is the same as for a single tube circuit, but there is a difference in the component values. At the input the full signal voltage is applied to the parallel grids of the tubes, and



Q. 6, Fig. 2.

since each output has the same phase relationship a common output circuit is used. A single condenser is connected from the plate circuit to the grid to neutralise the stage.

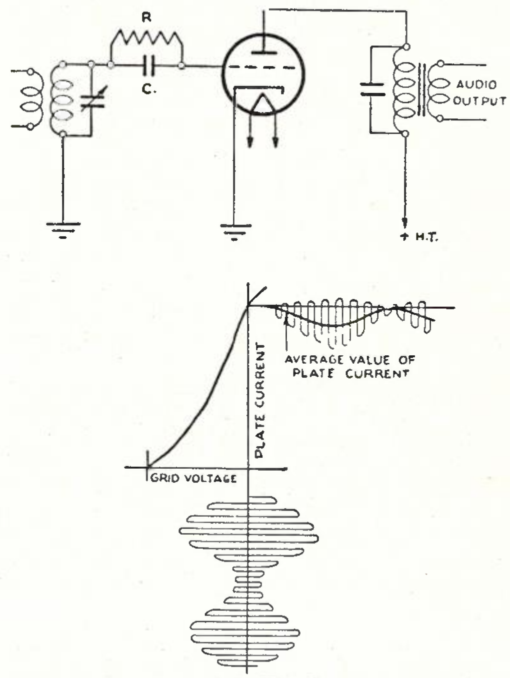
Advantages.—At the input the power required to operate the tubes is less than that required for push-pull operation. The tubes do not have to be closely matched, while the output impedance is half that of a single tube. In addition, it is not necessary to use as many tuned circuits as in the push-pull stage.

Disadvantages.—Since this circuit is not symmetrical, radio-frequency currents can flow in the earth or common leads, and parasitic oscillation is possible. The second and other even harmonics are present in the output so that a high Q tuned circuit is necessary to permit selection of the desired frequency.

Q. 7.—Describe two methods by which detection of modulated radio-frequency currents may be effected by a 3-electrode tube. Indicate over what portions of the characteristic curves the operations occur.

A.—The following is a description of the grid leak and anode bend detectors:—

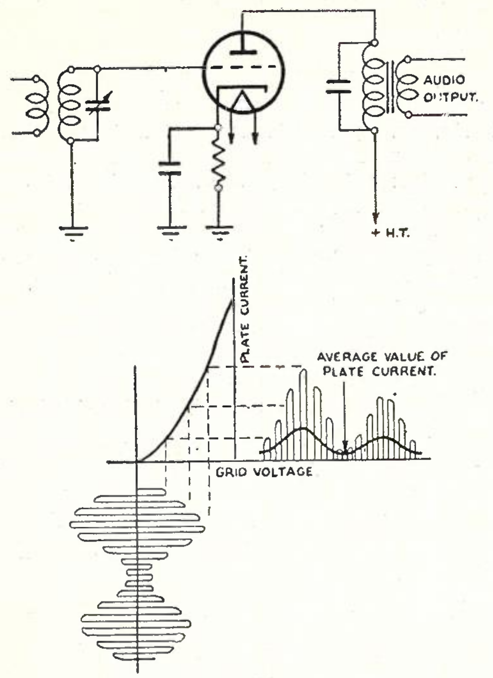
In the circuit, Fig. 1, of a typical grid leak detector, the grid has zero bias and the tube operates at the upper bend of the characteristic curve. During



Q. 7, Fig. 1.
Grid Leak Detector.

the positive peaks of the input signal, current flows from the cathode to grid, and the grid condenser receives a negative charge. On the other hand, the negative peaks of the signal increase the negative potential on the grid, and current ceases to flow. Some of the charge on the condenser leaks off through the grid resistance, and the component values are chosen so that the positive current is sufficient to keep the condenser charged between peaks. As the radio-frequency envelope varies with modulation, so does the negative potential on the grid, thereby producing in the plate circuit the audio-frequency signal.

In the anode bend detector shown in Fig. 2 the amplifier tube is biassed approximately to cut-off, and when a signal is applied to the grid there will be a pulse of current during each positive half cycle, and no plate current during the negative half cycles. The amplitude of these current pulses is proportional to the radio-frequency signal applied to the grid, so that if the input were a modulated wave the average value



Q. 7, Fig. 2.
Anode Bend Detector.

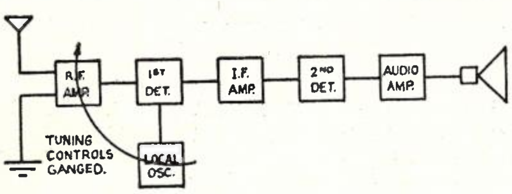
of the plate current would vary as the modulated envelope and the audio-frequency signal would be heard.

Q. 8.—Explain the superheterodyne principle of reception and discuss its advantages and disadvantages from a broadcasting point of view.

A.—A modern superheterodyne receiver consists of the following stages:—

(1) Radio-frequency amplifier.
(2) 1st Detector or mixer and local oscillator.
(3) Intermediate frequency amplifiers.
(4) 2nd Detector.
(5) Audio-frequency amplifier with loud-speaker.

In the radio-frequency amplifier, the selected signal is amplified and passed to the 1st detector, where the output of the oscillator is mixed with the radio-



Q. 8, Fig. 1.
Block Schematic of Superheterodyne Receiver.

frequency input. Various sum and difference frequencies result, and of these a difference frequency is usually used. The intermediate frequency stages amplify the signal, and at the 2nd detector demodulation takes place. The audio-frequencies at the output of this detector are amplified by the next amplifier before being passed to the loud-speaker.

It is an advantage to use a radio-frequency stage before the 1st detector so that the weak signals are amplified to a satisfactory level before mixing, and to minimise the effects of cross-modulation and the production of spurious frequencies. The tuned circuit of this stage permits efficient selection of the desired frequency, and reduces the possibility of interference from signals higher than the oscillator frequency. A difference frequency equal to the I.F. frequency would cause interference.

The superheterodyne receiver has the advantage of excellent selectivity, is constant over the frequency band, and variable selectivity can be applied if desired. The overall gain is high over the intermediate stages, but the receiver as a whole is somewhat complex, and requires careful design in the early stages, particularly in the mixer and oscillator circuits.

Q. 9.—Explain the terms amplification factor and plate resistance (or impedance) of a thermionic tube.

The voltage amplification given by a 3-electrode tube with a plate resistance of 10,000 ohms and a load resistance of 100,000 ohms is 20.

What is the amplification factor of the tube? Explain how the answer is arrived at?

A.—The amplification factor of a tube is the ratio of the change in plate voltage to a change in grid voltage, necessary to produce the same change in plate voltage. Hence, the amplification factor (μ) = Change in plate volts/change in grid volts. The factor μ is useful for calculating stage gain.

Plate resistance of a thermionic tube is the resistance of the path between the cathode and plate to the flow of alternating current. When a change in plate voltage gives a change in plate current, the

$$\text{plate resistance in ohms} = \frac{\text{Change in plate volts}}{\text{Change in plate current}}.$$

Let plate load $= R_L$

and plate resistance $= R_p$.

Then ratio of voltage across $R_L = R_L/(R_L + R_p)$

Voltage amplification $=$ Amp. factor $R_L/(R_L + R_p)$

$\therefore$ Amp. factor $=$ Volt. Amp. $(R_L + R_p)/R_L$

$= 20 \times 110{,}000/100{,}000 = 22.$

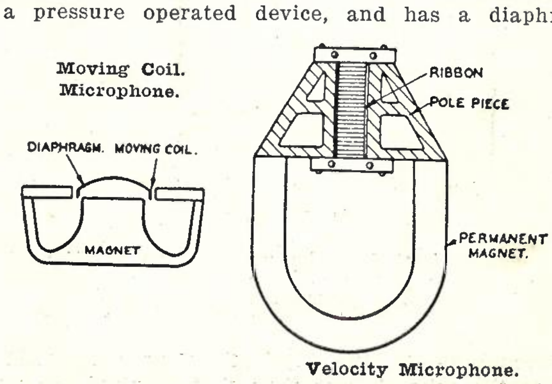
Q. 10.—Compare the basic principles by which the electrical response is produced in—

(a) a pressure microphone;
(b) a velocity microphone.

Discuss the requirements of a modern broadcast microphone in respect of—

(i) sensitivity;
(ii) frequency response.

A.—The moving coil microphone as shown in Fig. 1 is a pressure operated device, and has a diaphragm



Q. 10, Fig. 1.

free to move with variations of air pressure produced by sound waves. The conductors which form a part of the diaphragm cut the lines of force between the magnet poles, thus inducing in the coil a voltage proportional to the sound pressure.

A sketch of the velocity microphone is shown in Fig. 2. Both sides of the ribbon are open to the free air so that it moves when there is a difference in sound pressure between the back and front. The voltage produced by the ribbon when it cuts the lines of force of the magnetic field is proportional to the frequency and the pressure gradient or particle velocity of the sound wave — hence, the name velocity microphone. The sound waves arriving from the sides cancel out, thus making the microphone bi-directional.

Microphones of the type described are used extensively, and the frequency response of both types is practically flat from 20 to 15,000 cycles/sec. The power output of these types is small, and it is usual to keep the impedance low and to use screened cable to prevent interference pick-up. In the case of the velocity microphone, the voltage across the ribbon is very small, and a transformer mounted with the microphone is used to step the voltage up to a value which will ensure a low noise level.

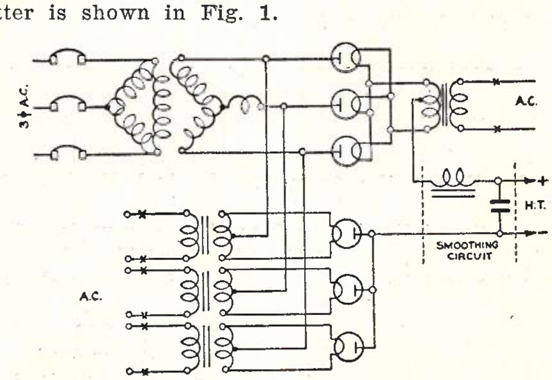
Q. 11.—Describe an instrument suitable for the measurement of high voltages in broadcasting transmitters.

A.—An electrostatic voltmeter is an instrument suitable for use in broadcasting transmitters, and it has the advantage that in D.C. and low-frequency A.C. circuits the current flow is negligible, while in radio-frequency circuits the capacity of the instrument not only permits a small current flow, but must be considered as a part of the total capacity of the circuit in which it is used.

A description is not given as the instrument has been described in detail in the Telecommunication Journal, Vol. 3, No. 4, June, 1941—"Measuring Instruments," A. A. Lorimer, M.E.E., A.M.I.E.(Aust.).

Q. 12.—Describe with the aid of a circuit diagram a typical 3-phase full wave rectifier suitable for delivering anode voltage to the tubes of the final stage of a transmitter. What characteristics of a tube are important in determining its suitability as a rectifier of high voltage?

A.—The circuit diagram of a typical 3-phase full wave rectifier suitable for use in a broadcast transmitter is shown in Fig. 1.



Q. 12, Fig. 1.
Full Wave Rectifier.

Three-phase A.C. is connected to the high tension transformer through a circuit breaker. A delta star method of connection is used to take advantage of the voltage step-up obtained with this type of connection. Three of the rectifier tubes are arranged so that a common filament supply is used, while the other three tubes have individual transformers. In both cases they are of the single phase type fed through switches. The positive high tension connection is made to the centre tap of the common filament transformer, while the negative side is connected to the lead common to the plates of three of the tubes. A choke and condenser are used to smooth the D.C. output.

A rectifier of this type is very efficient, and the D.C. voltage is at least double the A.C. output of the high tension transformer. The maximum peak inverse voltage applied to the tubes is only 4¼% greater than the average output voltage. The output wave form of this rectifier is a 6-phase ripple, which is easy to filter.

The following characteristics of a tube are important in determining its suitability as a rectifier of high voltage:—

(1) Long life;
(2) High efficiency;
(3) High inverse peak voltage;
(4) Good regulation.

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

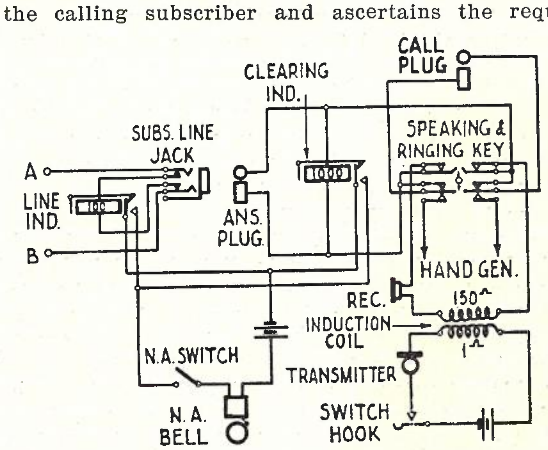
(Continued from Vol. 3, No. 4, June, 1941.)

O. C. RYAN

Q. 7.—Give diagrams of the line and cord circuits of a magneto wall pattern switchboard (Cord Type) and explain the operation.

A.—The line and cord circuits of a magneto wall pattern cord type switchboard are indicated in Fig. 1 and the operation of the circuits is explained in the following description of a call:—

When a calling subscriber operates the generator the line indicator drops and if the night alarm switch is operated the night bell will ring until the indicator is restored. The telephonist inserts the answering plug into the subscriber's line jack and operates the speaking key. On the removal of the receiver from the switchhook, the telephonist's transmitter and receiver are connected to the cord circuit, the telephonist speaks to the calling subscriber and ascertains the required



Q. 7, Fig. 1.

number. The calling plug is now inserted into the line jack of the called subscriber, the ringing key depressed and the hand generator operated. This rings the called subscriber, the calling subscriber's circuit is opened at the inner contacts of the ringing key. When the ringing key is restored the connection is completed and the two subscribers can converse. On completion of the call both subscribers should ring off. This will operate the clearing indicator which is connected across the cord circuit. An alarm will be given if the NA key is operated.

Q. 8.—(a) Describe briefly the functions of an Automatic to Automatic Repeater (Relay Set, Repeater Auto-Auto).

(b) What routine tests should be performed on this type of equipment and at what frequency?

A.—(a) Briefly, a repeater is a piece of apparatus which will repeat trains of impulses over a junction, and at the same time hold the local switches operated and which contains a transmission bridge. The functions are as follows:—

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

(ii) Repeats impulses from the calling subscriber over the junction to the switches in the distant exchange.

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

(iv) When the called subscriber answers and a reversal of current takes place over the junction from the distant exchange, the repeater will reverse battery back to the calling subscriber for metering purposes, or in the case of booster exchanges supply a booster pulse to operate the calling subscriber's meter.

(b) The routine tests which should be applied to this type of repeater are:—

(i) Repeating test under long and short line impulsing conditions.

(ii) Test for the reversal of battery over the junction and the correct operation of the reversing relay in the repeater.

(iii) In the case of Booster Type exchanges, test for the booster pulse on the release trunk.

The above tests should be performed daily.

Q. 9.—Explain briefly the Automatic Call Back and Transfer facilities provided on Type C or CA Unit Type P.A.B.X.'s.

A.—If an extension telephone is fitted with a non-locking press key which, when depressed, earths one side of the line, an exchange call may be held and information obtained from any other extension by dialling the relative number. Alternatively, the exchange call may be transferred to the extension number dialled without calling the manual switchboard. The call back and automatic transfer circuit is common to all exchange lines and is extended to each line by the operation of relays in each line circuit.

To make a "call back," an extension momentarily depresses the press key. Dial tone is heard and the required extension number is dialled. If it is desired to return to the exchange call, the press key is depressed again, thereby releasing the local connection and reconnecting the exchange line. Alternatively, if it is desired to transfer the call to the other extension, after this extension has been advised that the exchange call is to be transferred, the first extension replaces his handset on the rest (instead of again depressing the key) and the call is connected automatically to the second extension.

The manual switchboard telephonist can be recalled by depressing the key twice. This causes the particular exchange line lamp to flash until the telephonist answers

Q. 10.—Describe briefly the functions of one of the following switches:—

(a) Switching Selector Repeater (Pre-2000 Type) (also known as Discriminating Selector Repeater).

(b) Discriminating Selector Repeater (2,000 Type).

(c) Discriminating Selector (Siemens No. 16 Type).

A.—The functions of a Discriminating Selector Repeater (2000 type) are as follows:—

(a) When seized, to cause the associated junction hunter to select a disengaged junction to the parent main exchange.

(b) To return dialling tone back to the caller locally, or from a distant exchange.

(c) To step wipers automatically to first level.

(d) If the call is for another main exchange in the network, to step its wipers around the first level according to the digit dialled, and acting as a repeater, to repeat the impulses through the parent exchange to the required exchange.

(e) If the parent exchange is required, to step its wipers around the first level to the contact representing the prefix of the parent exchange and restore, the first selector at the parent exchange being held. To respond to the second digit and act as a repeater.

(f) If the call is for a local number, to absorb the first digit as indicated in (e). On dialling the second digit to step the wipers to the required level, search for a free trunk to the third selector, and release the outgoing junction to the parent exchange. To function as a selector.

(g) Calls for branch exchanges connected by direct junctions are as indicated in (f), except that the second digit dialled causes the wipers to step to the level allotted for the branch exchange. To function as a selector repeater.

(h) If the call is for "trunks," to rotate its wipers on the first level to the contact represented by the digit called and restore. Automatically raise the wipers to the first level and hunt for a free qunction to the trunk exchange.

(i) Provide transmission bridge when used as a repeater or selector repeater.

(j) If D.S.R. rotates to the 11th contact due to all trunks to selectors being busy, to return a busy tone to the calling subscriber's line.

(k) If all junctions to the parent main exchange are busy, to return local dial tone to the caller, and if a junction to the parent exchange is necessary for the completion of the call, to return a busy tone after the second digit has been dialled.

EXAMINATION NO. 2295.—ENGINEER—NATURAL SCIENCE

(Continued from Vol. 3, No. 4, June, 1941.)

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

Q. 9.—Define the term "Mechanical Equivalent of Heat."

Given the following values for a sample of air, calculate the Mechanical Equivalent of Heat indicating clearly the unit in which the answer is expressed.

Temperature = —23° C.
Pressure = 1,000,000 dynes/cm^2
Density = 0.001 grm/cm^3
Specific heat at constant pressure = 0.30 calories/gm/°C.
Ratio of Specific Heats = 1.5.

A. 9.—(a) The mechanical equivalent of heat is the amount of energy in units of work that is equivalent to unit quantity of heat.

(b)

$$J = \frac{p}{\rho T (C_p - C_v)}$$

and $p = 1{,}000{,}000$ dynes/cm²

$\rho = 0.001$ gms./cm³

$T = 273 - 23$

$= 250°$ C. absolute

$C_p = 0.30$ cals/gm/° C.

$C_v = C_p/1.5$

$= 0.20$ cals/gm/° C.

$$\text{Hence } J = \frac{1{,}000{,}000}{0.001 \times 250 \times (0.30 - 0.20)}$$

$= 4.0 \times 10^7$ ergs/cal. .... (9b)

Q. 10.—State but do not explain the two laws for the regular reflection of light.

An object is placed 30 cm. from a concave mirror, whose focal length is 10 cm., find where the image is. Is it real or virtual, erect or inverted?

A. 10.—(a) 1. The incident ray, the normal to the surface at the point of incidence and the reflected ray lie in the same plane.

2. The angle of incidence is equal to the angle of reflection.

(b) $f = +10$ cms., $u = +30$ cms., and $v = ?$;

and $1/f = 1/u + 1/v$

i.e., $1/v = 1/f - 1/u$

$= 1/{+10} - 1/{+30}$

$= 1/15$

Hence $v = +15$ cms. .... (10b)

The image lies on the same side of the mirror as the object and is thus real and inverted.

Q. 11.—The locomotive whistle of a fast train sounds continuously as it approaches and recedes from an observer, at a speed of 118.8 kilometres per hour. Taking the velocity of sound as 330 metres per second, determine the ratio between the frequencies of the two notes heard by the observer as the train approaches and as it recedes. Indicate which is the higher note.

A. 11.—Doppler's principle states that

$$\frac{f_o}{f_s} = \frac{V - v_o}{V - v_s}$$ where f_s and f_o are the frequencies at the source and the observer whilst V is the velocity of sound and v_s and v_o are the velocities of the source and the observer, all measured in the same direction.

(a) When train is approaching, $V = 330$ metres/sec., $v_o = 0$, and $v_s = 118.8$ km/hr. $= 33$ metres/sec.

$$\text{Thus } \frac{f_o}{f_s} = \frac{330 - 0}{330 - 33} = \frac{10}{9}.$$

(b) When the train is receding, $V = 330$ metres/sec., $v_o = 0$, and $v_s = -33$ metres/sec.

$$\text{Thus } \frac{f^1_o}{f_s} = \frac{330 - 0}{330 - (-33)} = \frac{10}{11}.$$

$$\text{Hence } \frac{f_o}{f^1_o} = \frac{10}{9} \cdot \frac{11}{10} = \frac{11}{9} \quad \text{.... .... (11)}$$

The higher note is heard in case (a), i.e., when the train is approaching.

Q. 12.—(a) Calculate the weight of lime which can be expected from a ton of chalk.

(b) What is the weight of anhydrous sodium carbonate needed to make a litre of tenth-normal solution?

(c) Calculate the volume of ammonia at Normal Temperature and Pressure obtainable from 10 grams of ammonium sulphate.

Use the following values for Atomic Weights:— Ca = 40, C = 12, O = 16, Na = 23, H = 1, S = 32, N = 14.

A. 12.—(a)

$CaCO_3 = CaO + CO_2$

The Molecular Weight of $CaCO_3 = 40 + 12 + 48$

$= 100$

and the MW of $CaO = 40 + 16$

$= 56.$

Hence 100 tons of $CaCO_3$ yields 56 tons of CaO, i.e., 1 ton of $CaCO_3$ yields 0.56 tons of CaO .... (12a)

(b) Na_2CO_3 contains two atoms of Na per molecule and thus a deci-normal solution will contain 1/20 times the molecular weight in grams per litre.

M.W. of $Na_2CO_3 = 46 + 12 + 48 = 106$.

Hence a deci-normal solution of Na_2CO_3 will contain $106/20 = 5.3$ grams/litre of solution .... (12b)

(c)

$(NH_4)_2SO_4 = 2\,NH_3 + H_2SO_4$

MW of $(NH_4)_2SO_4 = 36 + 32 + 64$

$= 132.$

Hence 132 gms. of Amm. Sulphate yields 2 gm. molecules of NH_3, i.e., 2×22.4 litres of NH_3 at NTP.

$$\text{Thus 10 gms. of Am. Sulphate yields } \frac{2 \times 22.4 \times 10}{132}$$

litres = 3.39 litres. .... (12c)

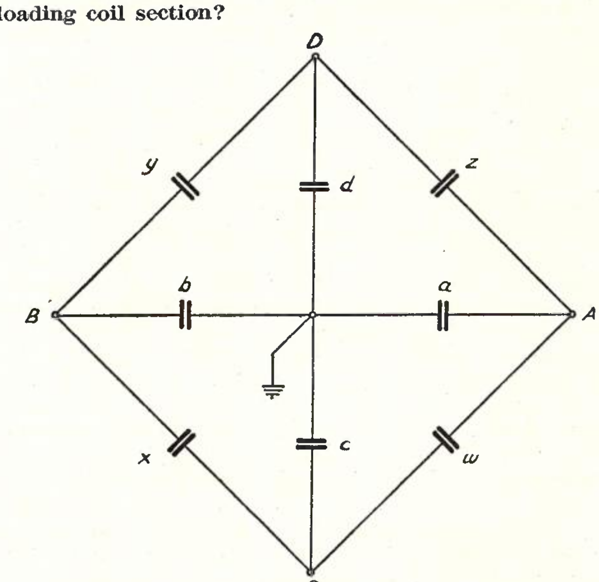
EXAMINATION NO. 2295.—ENGINEER—LINE CONSTRUCTION—(Continued)

W. H. WALKER B.E., A.M.I.E.(Aust.)

Q. 3.—Explain the necessity for the "capacity balancing" of trunk line and junction line cables and show by a diagram the various capacities to be considered.

Describe the procedure and methods of securing satisfactory degree of capacity balance for a cable to be loaded for voice frequency purposes.

What would you consider satisfactory values for the mean and maximum capacity unbalance over a balanced loading coil section?



Q. 3, Fig. 1.
AB = pair; CD = pair.

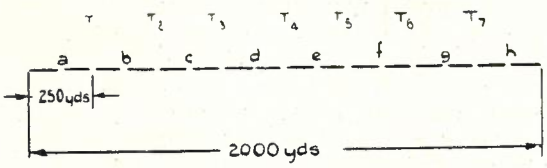
A.—Capacity balancing of the circuits in a trunk or junction cable is necessary to reduce interference, the principal component of which is concerned with crosstalk. The near-end crosstalk between the side circuits of a quad and the side circuit of the phantom depends primarily upon the uniformity of the wire to wire capacities (see Fig. 1). It is impracticable in the manufacturing process for the wires forming the quad to retain their symmetrical formation involving equal wire to wire capacities. The degree to which these capacities vary from symmetry or "the capacity unbalance" is defined as—

"The capacity unbalance between the side circuits of a quad is the unbalance which would be corrected by the insertion of a capacity between one wire of one pair and one wire of the other pair of the quad."

"The capacity unbalance between a phantom circuit and either of its side circuits is the capacity unbalance which would be corrected by the insertion of a capacity between one wire of the side circuit and the two wires short circuited of the other side circuit."

Unless precautions are taken as successive lengths of cable are joined together these capacity unbalances and consequently the crosstalk will build up to intolerable values. It is, therefore, necessary to resort to capacity balancing either by suitable cross splicing of pairs to add capacity balances of similar magnitude and opposite sign or to add balancing condensers to the appropriate wires to counteract the cable capacity unbalance.

In capacity balancing the cable to be loaded for V.F. working, the cable is balanced over lengths of one



Q. 3, Fig. 2.

loading section. The procedure to be followed in capacity balancing the cable is generally as follows:—

(1) The drum lengths should be so selected that the loading section will be divided into 16, 12, 10, or 8 reasonably equal lengths. This will depend upon the size and type of cable and disposition of manholes.

(2) The number of test lengths will be determined primarily by:—

(a) The capacity unbalance limits required.

(b) Whether the cable is to be cross spliced only or partly cross spliced and partly condenser balanced. For trunk cables 8 test lengths are usually provided and 4 test lengths for junction cables. Fig. 2 illustrates an 8 length section.

(3) The cable having been laid and gas pressure and I.R. tests made, any intermediate straight joints (a, b, c—) between test points T1, T2, etc., should be made if practicable by selection from the factory test sheets of capacity unbalance.

(4) The capacity unbalance measurements involving both magnitude and sign are then made by means of a capacity unbalance test set at points T1, T3, T5, and T7. As the closest coupling is between the pairs of a quad the majority of measurements are concerned with unbalances within the quad.

(5) A schedule of the results of the capacity unbalance measurements referred to in (4) is prepared from which is determined the manner in which the quads should be joined together so as to obtain the minimum resultant capacity unbalance.

(6) When the joints T1, T3, T5, and T7 have been completed, similar tests and selections are made at T2 and T6 and finally at T4.

(7) On completion of the jointing, crosstalk tests should be made to check results of the capacity unbalance testing.

The following may be considered as satisfactory values for mean and maximum capacity unbalances for a loading section length. The capacities are expressed in micro-micro-farads:—

	Mean	Max.
Junction cable—Local type star quad.		
Side to side	100	50
Trunk cable—Trunk type star quad.		
Side to side	20	50
Phantom to side	50	200

Q.4.—(a) A main trunk line route carrying a number of open wires on several crossarms is to be "rearranged and retransposed" to render the circuits suitable for superimposed carrier working. Explain the reasons why work of this character is usually required and state what is generally involved in carrying it out.

(b) A main trunk line route carries 30 wires on poles each fitted with five 6 pin 80 inch crossarms. The wires on the top crossarm are of 300 lb. weight per mile, those on the second and third crossarms are of 200 lb. per mile and on the fourth and fifth crossarms are of 100 lb. per mile. Each crossarm carries three physical trunk line pairs, two of which are arranged to provide a phantom circuit. The wire spacing and crossarm spacing were provided to suit voice frequency circuits only.

The wires on this route are to be rearranged on to 8 pin crossarms and sufficient of the circuits retransposed for carrier working to ensure up to nine physical circuits suitable for carrier working immediately, and the means to secure readily a tenth carrier circuit later including another phantom circuit, by erecting and pairing up new 300 lb. copper wires with the odd pair of existing 300 lb. copper wires. All other circuits will be required only for voice frequency working.

Show by a pole diagram the arrangement of crossarms and wires and their spacings that would exist on a typical 6 pin armed route such as described. Allot a distinguishing letter to each pair of wires on this diagram and then by means of a second pole diagram show the arrangement of wires and cross-arms with their spacings and the new positions of the circuits that you would adopt in rearranging the wires on 8 pin cross-arms to provide the requirements described above. Your arrangement should provide for the least number of crossarms and the greatest number of phantom circuits with the least amount of shifting of wires.

A.—(a) The main open wire trunk routes in Australia were originally constructed and transposed to meet the crosstalk requirements of V.F. operation only with a limiting frequency of 3 Kc/sec. Crosstalk between open wire circuits increases rapidly with increase of frequency and considerable alterations to the existing open wire trunk routes become necessary to meet the more stringent crosstalk conditions associated with the operation of high frequency carrier systems. In general, these alterations are associated with:—

(1) The reduction of coupling co-efficients between the circuits by variations in wire and arm spacings.

(2) The transposing of the circuits to a transposition scheme designed to provide satisfactory Far End crosstalk conditions up to the frequencies at which the carrier systems operate.

(3) The reduction of pole and wire spacing irregularities.

(4) The provision of a uniform disposition of circuits on the poles over each repeater section.

(5) The elimination of impedance mismatches which could cause reflection such as the existence of different gauges of wire in one circuit or the existence of short lengths of unloaded intermediate cable along the route.

The work generally involved in meeting the requirements comprises: —

(i) A survey of the route and any desirable revision of the layout of transposition sections to ensure that they conform to the span basis of 256, 128, 64, 32 and 16 spans for E, L, R, short R, and X sections respectively, and that the section lengths conform to the nominal lengths for the type of section concerned. Consideration will also be given to co-ordination with any power parallels on the route.

(ii) Having determined the layout of transposition sections respacing sheets are prepared and the locations of all poles pegged. Where the correct location of a transposition pole is more than ± 45 ft. from an existing pole a new pole is provided for the transposition pole.

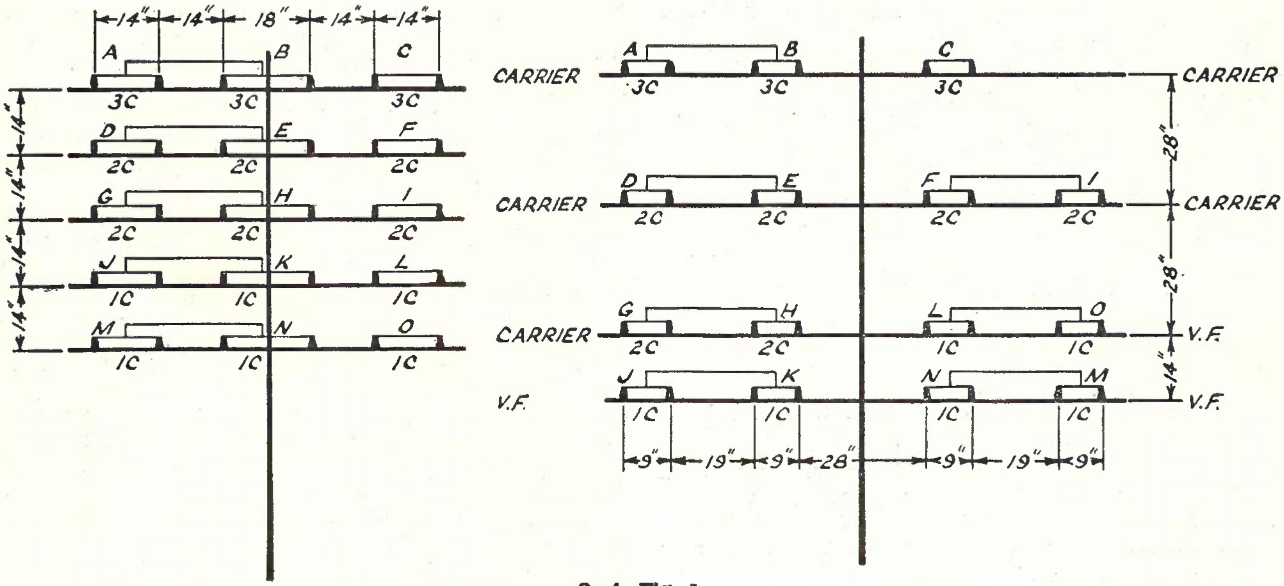
(iii) All new poles are fitted with crossarms bored for a wire spacing of 9 in.-19 in.-9 in. and the arms accommodating carrier circuits are given 28 in. vertical separation. On existing poles the crossarms are rebored to provide 9 in.-19 in.-9 in. wire spacing for circuits transposed for carrier operation and a vertical separation of 28 in. is provided between the crossarms so bored.

(iv) The existing wires are rearranged so that in general the heavier gauge copper wires are accommodated on the upper arms and transposed for multichannel carrier operation while the lighter gauge wires 150 H.D.C. or 100 H.D.C. are placed on the lower arms and transposed for single channel carrier or V.F. working. In conjunction with this rearrangement of circuits any G.I. wires should be replaced with either 200 H.D.C. or 100 H.D.C. wires, whichever size meets the requirements of the route.

(v) The installation of transpositions to the new design for carrier purposes.

(vi) Special provision should be made for any long spans at river crossings.

(b) The rearrangement of crossarms and wires in conjunction with the conversion of the six pin arm route to an eight pin arm route is shown in Fig. 1. Should further carrier circuits be required during the life of the pole route another arm would be fitted 14 in. below the existing bottom arm and 100 H.D.C. circuits L and O shifted thereto. Two new 200 H.D.C. circuits would be erected in the positions vacated by L and O and transposed for carrier operation.



Q. 4, Fig. 1.

CORRECTION

In Vol. 3, No. 4, p. 251, the following corrections are necessary:—

In the table of Capital Expenditure: 1st year should read 2nd year.

In the table of Annual Charges: Factor 5.87 should read 5.78 with corresponding alterations to the Present Values.

DISCUSSION

The factors used in economic comparisons are given in E.A.C., No. 8. They are based on an interest rate of 5%.

The formulae for obtaining them are as under:

(1) P.V. of a sum of money due at the **beginning** of the Nth year—

$$\text{Factor} = 1/1.05^{(N-1)}$$

(2) P.V. of a perpetual annuity when the first payment is due at the **end** of the Nth year—

$$\text{Factor} = 20/1.05^{(N-1)}$$

(3) P.V. of an annuity commencing at the **end** of the Nth year and continuing for M years—

$$\text{Factor} = 20(1 - 1.05^{-M})/1.05^{(N-1)}.$$

The formulae for other rates of interest are obvious from the above.

The coefficient 20 in (2) and (3) is obtained by dividing 100 by the rate of interest.

Note that (2) is a special case of (3) when M is infinite.

EXAMINATION NO. 2295.—ENGINEER—TELEPHONE EQUIPMENT

J. A. KLINE, B.Sc.

Q. 1.—(a) Define the terms—
occupancy,
analysis meter,
pure chance traffic,
grading,
limited availability,
as used in connection with automatic telephone exchanges.

(b) What do you understand by a partial secondary finder scheme? Discuss briefly the advantages or disadvantages of such a scheme and illustrate your answer with a block schematic sketch.

(c) What important factors should be taken into consideration in the design of a grading scheme?

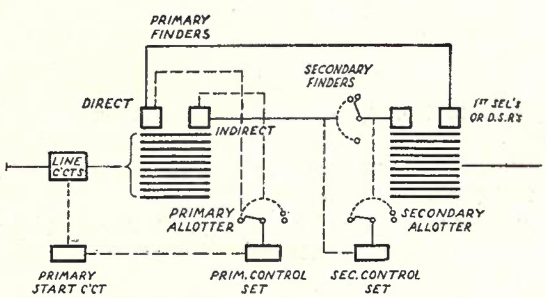
(d) If you know the number of trunks required in any particular case, what formula would you use to determine the number of grading groups? Are there any limitations imposed on the results obtained by the use of the formula?

(e) Show how you would arrange a 12 group grading with 100 trunks and an availability of 20. How would you determine the best arrangement for the grading?

A.—(a) Occupancy is the state of being engaged in the set up or transmission of telephone traffic. The maximum occupancy of a switch or circuit is unity.

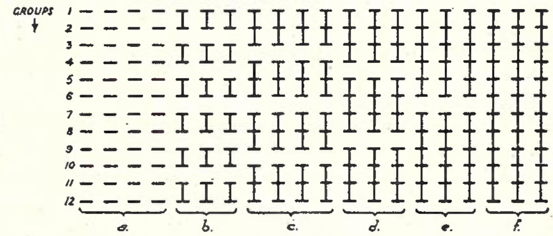
An analysis meter registers some section of telephone traffic separated out by a circuit for special recording. Usually, it is connected to the overflow contact of a level to detect heavily loaded groups of a grading.

Pure chance traffic is made up of telephone calls



Q. 1, Fig. 1.

originated by subscribers or from other sources without control or sorting out. That is, the calls are as likely to arrive at any one moment as at any other. The originating sources are assumed to be infinite in number.



Q. 1, Fig. 2.

Grading is a method of multipling corresponding outlets of a particular level of a number of switches so that a group of these switches is given access to individual trunks on the early choices but share access to trunks with other groups on the later choices.

Limited Availability.—When a switch has access to only a portion of the total trunks on a route, it is said to have limited availability. The number of contacts in a level limits the access of a switch, and when this number is less than the total number of trunks there is limited availability.

(b) A partial secondary finder scheme is one in which calls may be set up either from finders direct to selectors or from primary finders through secondary finders to selectors. The object of the system is the reduction of the number of 1st selectors consistent with the economical introduction of secondary finders.

If all finders were directly trunked to 1st selectors, a maximum number of 1st selectors—the number depending on the grade of service required—would be necessary. The use of full secondary finder trunking will increase the efficiency because of the larger group of 1st selectors to which any call will have access, and therefore, the number of 1st selectors required will be a minimum. This is obtained at the cost of the extra secondary equipment required. If the first selectors are allotted in an invariable order the first choices are used efficiently even if directly connected to primary finders and, therefore, it is unnecessary to introduce secondary finders for calls routed via these early choices. The later choices, however, would carry little traffic and the introduction of secondary finders greatly increases their efficient use with a consequent saving in the number of first selectors which justifies the extra cost of the secondary equipment. Hence, in partial secondary finder working, the directly connected finders must be allotted first. A block schematic is given in Fig. 1. The system has a limited overload capacity, the circuits are not simple, and call tracing difficulties are introduced. There is also the maintenance of the additional equipment to be taken into account.

(c) The important factors to be considered in the design of a grading are:—

(a) Volume of Traffic.
(b) Availability of the switches.
(c) Number of outgoing trunks in the grading.
(d) Number of grading groups.
(e) Limitations of size of gradings.
(f) Formation of grading.
(g) Allocation of selectors to the outgoing trunks.

(d) The minimum number of groups in the grading is given by $g = 2n/a$

where g = No. of groups.
n = No. of trunks.
a = No. of contacts per level.

The figure used should be an even number which will give reasonable factors so that the groups can be multipled evenly. If g, obtained as above, does not satisfy these requirements, it is necessary to take the nearest higher number which does. In exceptional cases, odd group gradings can be used.

The size of gradings is limited in practice:—

(i) To limit difficulties of tracing calls backwards.
(ii) To lessen congestion of tie circuits between double sided selector boards.
(iii) To limit crosstalk.

(e) The level multiples of a 12 group grading can be arranged as individuals, pairs, threes, fours, sixes or commons, and if the number of each of these arrangements in a group is given respectively by a, b, c, d, e, and f, then

$$12a + 6b + 4c + 3d + 2e + f = 20$$
$$\text{also } a + b + c + d + e + f = 100$$
$$\text{subtracting } 11a + 5b + 3c + 2d + e = 80$$

From this can be deduced the possible arrangements, some of which are listed in Table 1.

TABLE 1.

No.	1		2		3		4	
		Trks.		Trks.		Trks.		Trks.
a	6	72	5	60	4	48	4	48
b	1	6	3	18	4	24	3	18
c	1	4	2	8	3	12	4	16
d	1	3	1	3	3	9	3	9
e	4	8	2	4	1	2	3	6
f	7	7	7	7	5	5	3	3
Totals :	20	100	20	100	20	100	20	100
Differences	11		10		7		3	

The best arrangement will be given by the smoothest progression from each grouping to the next. To find this, subtract the number of individuals from the number of pairs, the number of pairs from the number of three, and so on for each successive grouping, then add these differences, disregarding the signs. The grading giving the lowest total will be the smoothest or best grading. The total differences are shown in the last row of the above table and, therefore, arrangement number 4 is the best. This is shown in Fig. 2.

Q. 2.—Prepare a schematic trunking diagram for a branch automatic exchange based on the switch quantities shown below; the figures being the two-year, five-year and twenty-year estimated requirements:—

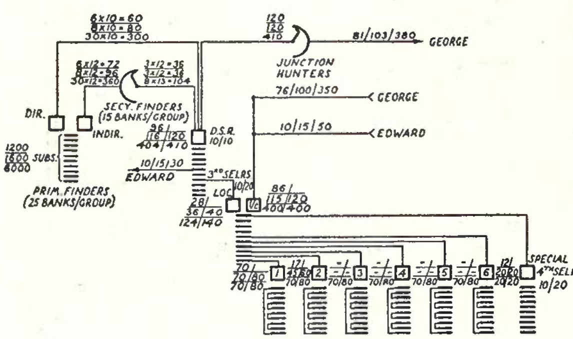
B. Group Numbering

Exchange	Numbering	Type
GEORGE	BA	2000 Type MAIN
JAMES	BX	C.B. MANUAL
EDWARD	BM	Pre 2000 Type BRANCH
WILLIAM	BJ	2000 Type BRANCH

Subscribers lines WILLIAM exchange	**1200/1600/6000**
Primary finders with banks in sets of 25 with 10 direct finders per group	**132/176/660**
Secondary finders with banks in sets of 15 in groups of 12 at two and five year date and in groups of 13 at twenty year date	**36/36/104**
Discriminating selector repeaters	**96/116/404**
Junction hunters for GEORGE route	**120/120/410**
Junctions to GEORGE exchange	**81/103/380**
Junctions to EDWARD exchange	**10/15/30**
3rd Group selector switches 10/20 local	**28/36/124**
3rd Group selector switches 10/20 incoming	**86/115/400**
Junctions incoming from GEORGE exchange	**76/100/350**
Junctions incoming from EDWARD exchange	**10/15/50**
4th Group selector switches 10/20 BJ 1000 group	**70/70/70**
4th Group selector switches 10/20 BJ 2000 group	**17/45/70**
4th Group selector switches 10/20 BJ 3000 group	**—/—/70**
4th Group selector switches 10/20 BJ 4000 group	**—/—/70**
4th Group selector switches 10/20 BJ 5000 group	**—/—/70**
4th Group selector switches 10/20 BJ 6000 group	**—/—/70**
Special 4th Group selector switches 10/20	**12/20/20**

Final Selectors—as per table hereunder.

A.—The trunking diagram is given in Fig. 1. The final selectors are as tabulated in the question.

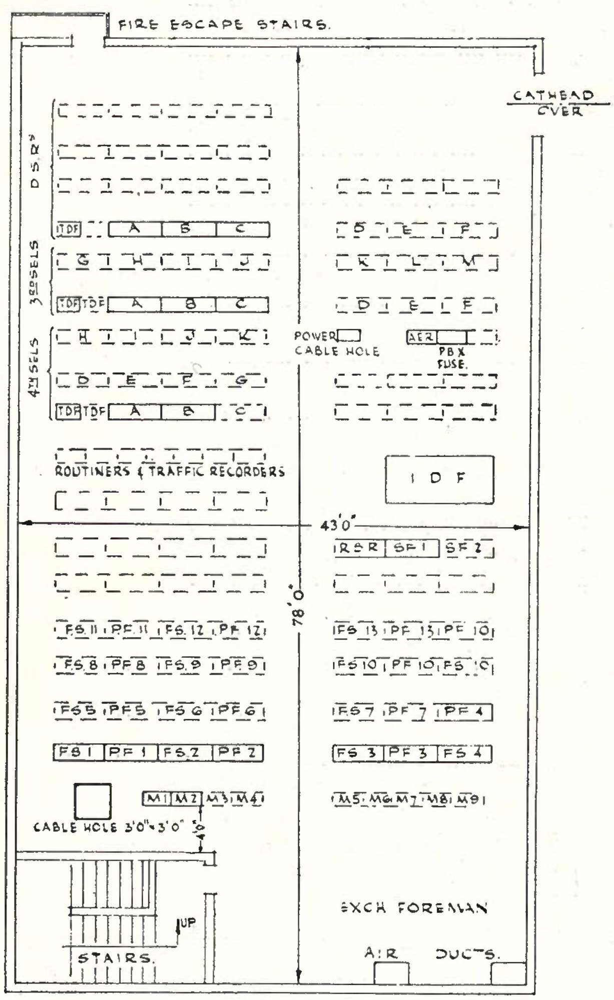


Q. 2, Fig. 1.

Final Selectors		BJ 1000 2 yr.	BJ 1000 5 yr.	BJ 1000 20 yr.	BJ 2000 2 yr.	BJ 2000 5 yr.	BJ 2000 20 yr.	BJ 3000 2 yr.	BJ 3000 5 yr.	BJ 3000 20 yr.
Switches 200 Outlet	Str.	4 x 17	4 x 17	4 x 17	1 x 17	2 x 17	4 x 17	—	—	5 x 17
	P.B.X.	1 x 25	1 x 25	1 x 25	—	1 x 25	1 x 25	—	—	—
	Test	5 x 1	5 x 1	5 x 1	1 x 1	3 x 1	5 x 1	—	—	5 x 1
Banks	Str.	4 x 25	4 x 25	4 x 25	1 x 25	2 x 25	4 x 25	—	—	5 x 25
	P.B.X.	1 x 30	1 x 30	1 x 30	—	1 x 30	1 x 30	—	—	—

Final Selectors		BJ 4000 2 yr.	BJ 4000 5 yr.	BJ 4000 20 yr.	BJ 5000 2 yr.	BJ 5000 5 yr.	BJ 5000 20 yr.	BJ 6000 2 yr.	BJ 6000 5 yr.	BJ 6000 20 yr.
Switches 200 Outlet	Str.	—	—	4 x 17	—	—	5 x 17	—	—	4 x 17
	P.B.X.	—	—	1 x 25	—	—	—	—	—	1 x 25
	Test	—	—	5 x 1	—	—	5 x 1	—	—	5 x 1
Banks	Str.	—	—	4 x 25	—	—	5 x 25	—	—	4 x 25
	P.B.X.	—	—	1 x 30	—	—	—	—	—	1 x 30

Q. 3.—The WILLIAM exchange building is to be erected on a level suburban allotment 65 feet x 117 feet. The main street frontage of the allotment is 65 feet, but the other three sides of the rectangular block



Q. 3, Fig. 1.

of land are bounded by allotments on which are erected residential flats.

Assume the exchange building has two floors. The switchroom occupies the first floor. The battery room, power room and air conditioning room are placed on the ground floor, also the M.D.F., test desk, and miscellaneous apparatus racks. The exchange switch quantities are shown in Question 2.

(a) Derive the size of the switchroom required for the exchange and on ordinary foolscap paper draw a neat block layout plan for the equipment to be installed in the switchroom.

Scale to be ⅛ inch to 1 foot. Extreme drawing accuracy is not necessary. The equipment should be shown in outline, full lines indicating equipment to be installed immediately and dotted lines equipment to be installed at a future date. The racks and ranks of switches should be suitably designated. The position of stairways should be indicated.

(b) The location of the building on the allotment should be indicated by means of a rough freehand sketch on which the outline dimensions of the block of land and building are shown.

(c) Why is a second stairway provided in many cases and in what case do you think the second stairway is not necessary?

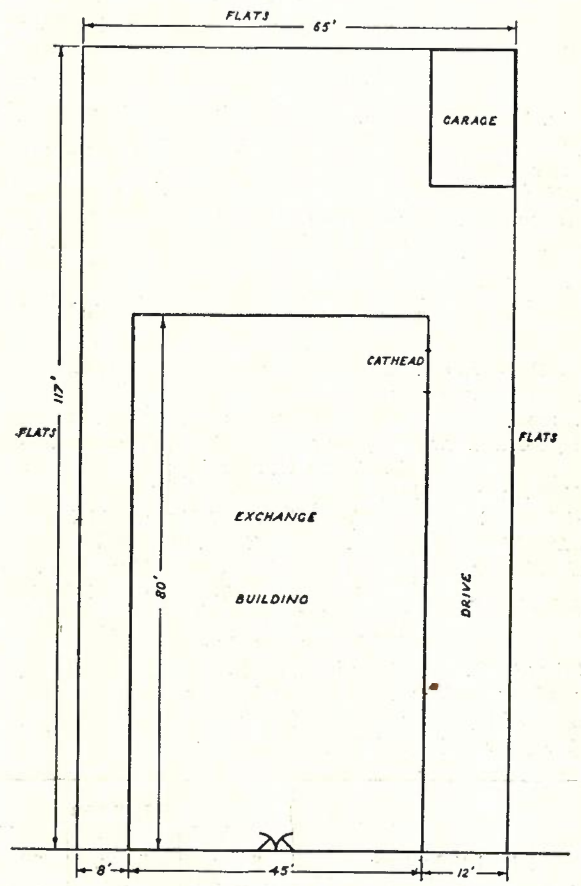
(d) Discuss the points to be watched in selecting a location for the main air inlet.

A.—(a) Size of Switchroom 78 ft. x 43 ft. A sketch of the switchroom layout is given in Fig. 1. The scale has been altered for convenience.

(b) Fig. 2 shows the location of the building on the allotment.

(c) The second stairway is a fire escape. It is essential in a multi-storey building, but in a double storey building where only males are working, it may be replaced by an iron ladder where space is limited, or larger structure would interfere in building extension.

(d) The object is to intake fresh clean air at



MAIN STREET
FIG. 2.

Q. 3. Fig. 2.

equitable temperature. The inlet should be under the eaves and should not be near dusty locations where coal, coke or wood is stored, or on the same side of the building as gas exhaust from boilers or engines, or where prevailing winds would carry the smoke or exhaust from boilers or fires of the adjoining flats. It should not be on the north side because of the high temperature in the summer and the difficulties of cooling the air before use.

(To be continued.)

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All remittances should be made payable to "The Postal Electrical Society of Victoria," and not negotiable.

Ruskin Press Pty. Ltd.
123 Latrobe Street
Melbourne