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The

Telecommunication Journal of Australia

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IMPROVED PROGRAMME SWITCHING CIRCUIT. PROGRAMME ROOM, ADELAIDE TRUNK TERMINAL

A. E. Retallack

In the June, 1941, issue of this Journal (pages 189-200), the complete broadcast programme switching arrangements in use at the Adelaide trunk terminal were described. The circuit used to switch together the various components making up a complete programme channel made use of uniselecter switches controlled by keys, the design of the switching circuit being particularly directed towards the reduction of fault liability by eliminating cords and plugs. Facilities were also provided for the instantaneous reversal and limited pre-setting of programmes.

This method of programme switching proved very satisfactory, and was still in use in 1946, when it became necessary to remove the programme equipment, in common with the trunk test positions and long line equipment, from its location in the G.P.O. to new premises provided for the Engineering Branch in 42-46 Franklin Street, City. As the transfer would necessarily involve the replacement of at least portion of the programme equipment, the time was considered opportune to re-examine the switching circuits and introduce any improvement thought worthwhile.

General Description

Although some consideration was given to the use of relay switching, and various other methods under the control of keys, these were discarded, for the following principal reasons:—

(a) The large number of relays necessary for full flexibility required far more mounting space than uniselectors.
(b) The circuits were more complex.
(c) The uniselector method had been proved over a period of five years to be absolutely dependable in operation.

Other important features considered were the further simplification of the manual switching required to operate the system, provision for switching more simultaneous programmes, and an increase in the number of channel outlets or splits to meet future development.

With regard to the former, it was necessary, in the original circuit, to operate a minimum of two keys to extend a programme incoming on one channel to one other outgoing channel. One key would arrange the connection of the incoming programme to a line equipment unit comprising a transformer, equalizer and line amplifier, while the second key would connect the channel requiring this programme to the output of the line amplifier. All of the connections were arranged by uniselectors and relays operating under the control of the two set-up keys. The keys were mounted in two separate key fields; one for the input and one for the outlet group. For every additional outlet or split required from the incoming programme channel, one key must be operated in the output key field.

While in practice the switching was found to be reasonably straightforward, it was possible for operators to confuse the input and output groups. In the new circuit the keys have, therefore, been merged into one group, and only one key operation is required for the simple extension of one programme to one outlet, instead of two keys, as previously. The grouping of the keys has also been arranged so that the operator can easily visualise the routing of each programme and a permanent indication of the splits from a received programme is given by lamps which glow for the duration of the set-up.

In the original installation, sufficient line equipment units were provided to connect the maximum number of simultaneous programmes likely to be required. To provide the simplified switching, it was necessary to abandon the separate line equipment group and to equip each programme line with its own line amplifier, equalizer and gain control. This has the added advantage of increased flexibility in switching, and provides for more simultaneous programmes. The circuit arrangement also permits the expansion of the channel amplifier outlet group to any desired number, the only limiting factor being the size and, therefore, the accessibility of the controlling key field.

The number of lines which can be included in a switching group of this kind depends largely on the number of switching keys which can be mounted in a reasonably compact group within easy reach of the operator. With this end in view, the new switching circuit was based on a non-locking key with one make and one break contact. It was therefore possible to use the standard order wire-type key with the spring sets suitably re-arranged. Twenty-two such keys may be mounted in one row on a standard carrier rack, in addition to a radio type potentiometer which is used for small adjustments in the gain of the line amplifier associated with each row.

For the convenience of the maintenance staff, each horizontal row of 22 keys has been mounted in a separate panel, $1\frac{3}{4}''$ wide, and allows individual strips to be partly withdrawn from the front of the rack to attend to spring set adjustments, etc. It was found that 18 such strips was the maximum number which could be kept within a reasonable height on the control rack, and it was therefore decided that the switching group should be limited to 18 switchable programme lines, thus forming a compact key field, which is shown in Fig. 1. A general view of the equipment racks in the programme room is shown in Fig. 2.

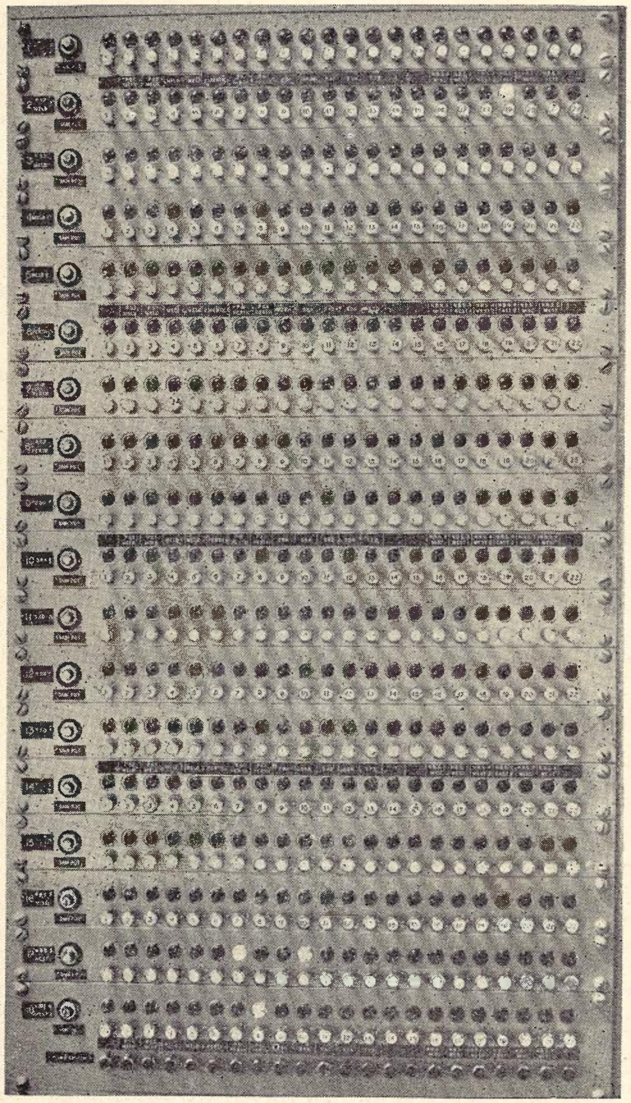

Fig. 1.—Setup key field showing volume controls and indicating lamps.

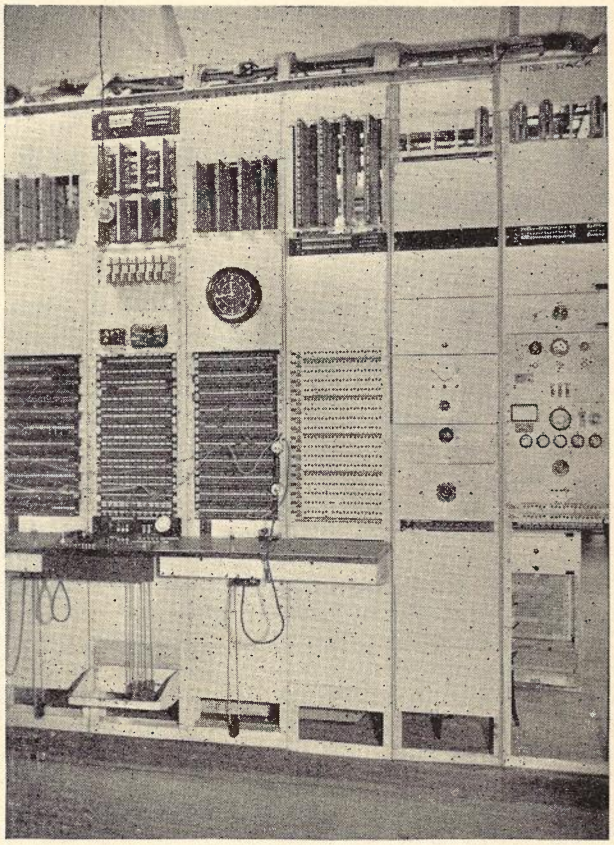

Fig. 2.—General view of control and test racks.

The switching circuits are designed to arrange any desired combination of the 18 programme channels in the group. The switching is performed by uniselectors controlled by the "set-up" keys mounted on the control rack. The method of mounting the uniselectors and associated relays is shown in Fig. 3. Each of the 18 circuits in the group may be selected for use as a programme channel, from which a number of splits may be taken, or, alternatively, as a channel taking a split from another programme channel in the group. In the majority of cases, it is not necessary to split a programme into more than two outlets. The 18 circuits therefore provide for 6 simultaneous relays, but if fewer than two splits are required, the number of simultaneous relays may be increased. With the object of providing for unforeseen events, however, 4 additional channel amplifiers (Nos. 19-22), complete with switching equipment, but with no line amplifier, are provided. These are common to the whole group, and may be used individually or collectively, to provide outlets from any of the 18 line amplifiers. Should it be necessary to provide more outlets in the future, it is proposed to increase the number of such outlet circuits. For example, this will be done by limiting the first four to lines circuits 1-9, and providing four more for circuits 10-18. Should it be necessary, this idea can be extended until, ultimately, each line circuit has four individual outlets of this type, in addition to the choice of the 18 common switching circuits, thus giving a maximum number of, approximately, 90 outlets or splits. Fig. 4 shows, in a simplified schematic form, the possible connections between programme sources and programme outlets.

Switching between the 18 programme lines referred to is completely automatic; no patching is required, as the programme lines are permanently wired to the switching equipment. Lines connected to these circuits are:—

(a) Permanent interstate and intrastate programme channels.

(b) Direct lines from the programme room to the studios of the various broadcasting stations, permanently used for programme relaying.

(c) Trunk lines frequently used for programme relaying but normally in use for trunk line service.

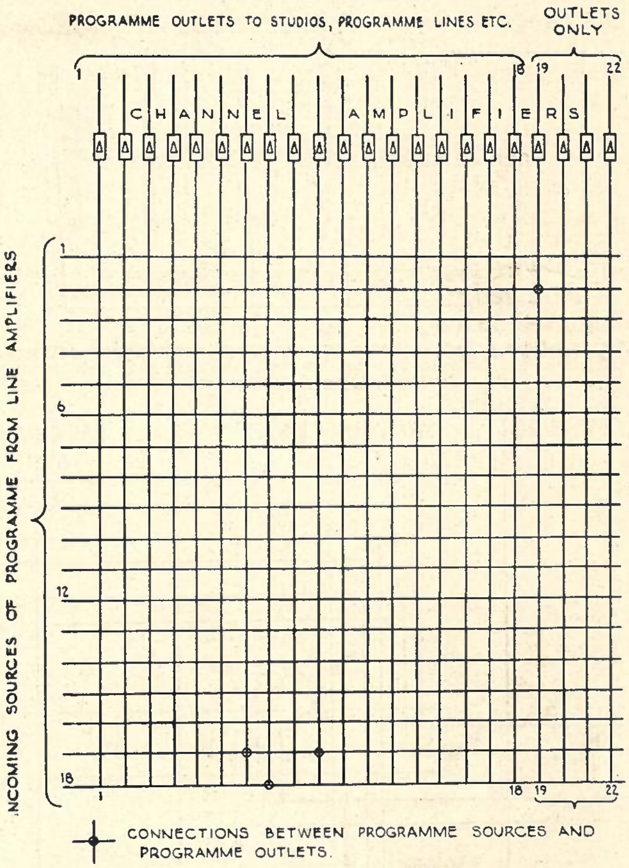

Fig. 4.—Showing possible connections between programme sources and programme outlets. The actual connections shown conform with those illustrated in Fig. 1.

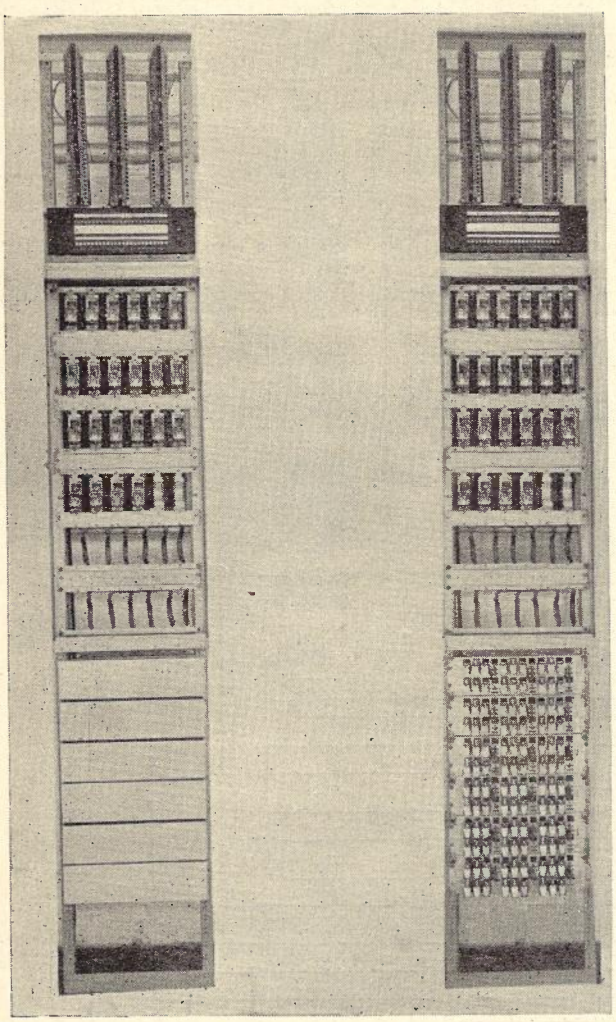

Fig. 3.—Uniselector and relay rack.

The latter are fed through the X and Y relay contacts, as shown in Figs. 5 and 6, to terminate on the trunk switchboard, or, in the case of V.F. dialling circuits, in the automatic exchange. When required for broadcasting, the line is disconnected from the switchboard and connected to the input of its line amplifier, if it is to relay the programme to Adelaide, or to the output of the channel amplifier if required to relay a programme from Adelaide. This choice of connection is determined and effected entirely by the pushing of one non-locking set-up key.

The X and Y relays determine the direction of transmission for each channel. For example, the X relay associated with the channel from which a programme is to be split, will operate when any switch is driven to that bank position, but its associated Y relay does not operate under this condition. However, the Y relays of each outgoing channel will operate when their respective uniselectors have been driven to the desired bank

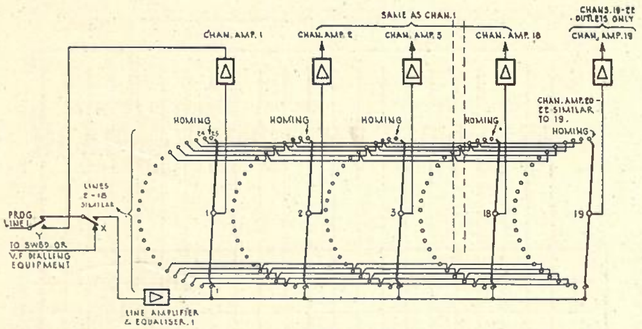

Fig. 5.—Simplified schematic showing multipling of programmes on uniselector banks and method of programme selection by uniselectors.

contacts, thus connecting the output of the channel amplifier to the outgoing line via the Y relay contacts. The X relays associated with each channel are wired to their respective bank contacts on bank number 3 of each switch. These are also multipled to each switch bank. Each X relay may, therefore, be operated from any uni-selector, or, in other words, the uni-selector of any channel automatically operates the X relay of the circuit to which it is driven, and thus prepares that circuit to carry the incoming programme. The Y relays, on the other hand, are individual to each vertical row of set-up keys for

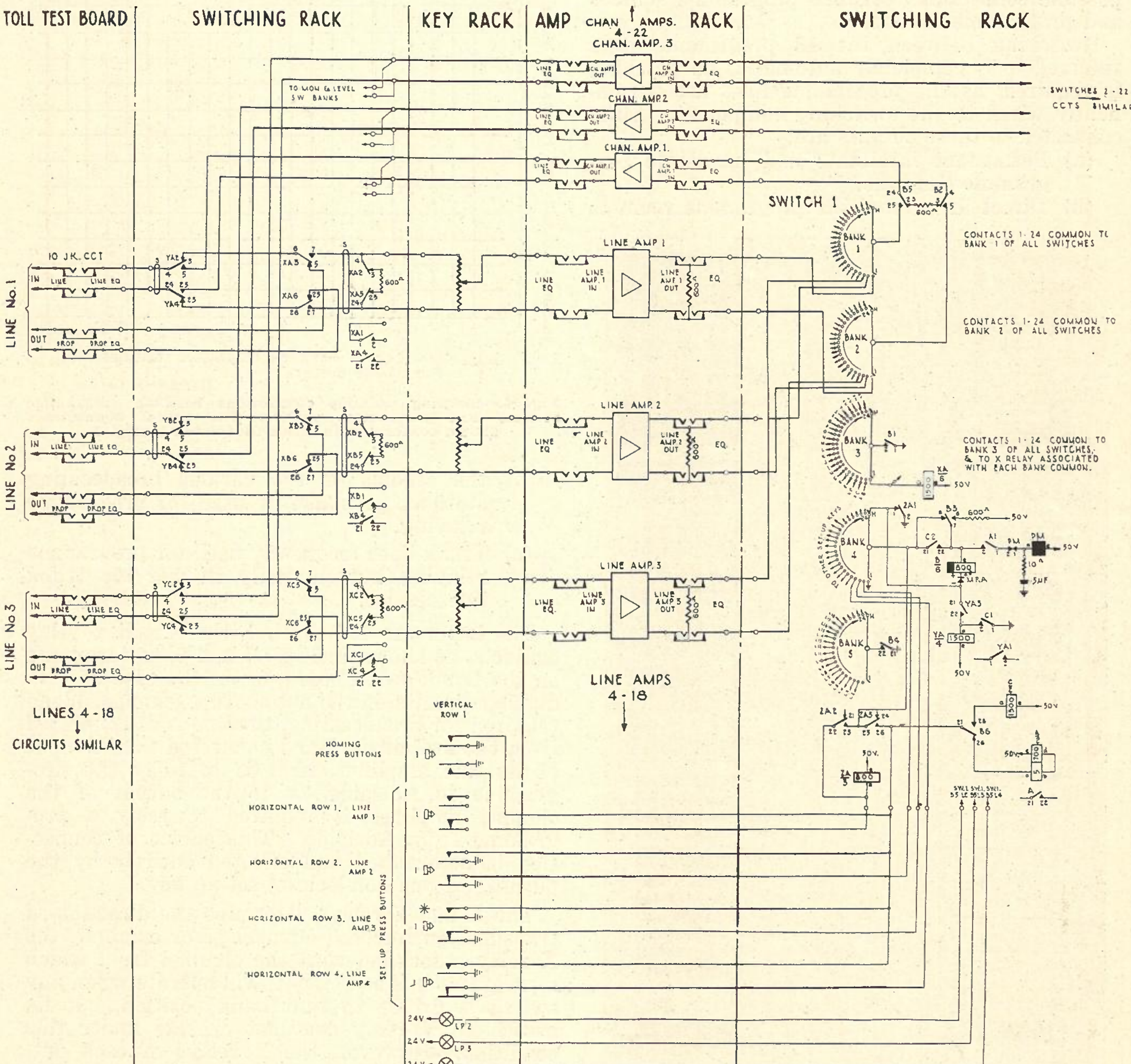

Fig. 6.—Programme switching circuit.

Note: Relays corresponding to XA, YA, ZA in switching circuits 2-22 are designated XB, YB, ZB for circuit 2; XC, YC, ZC for circuit 3; XJ, YJ, ZJ for circuit 10, etc., to simplify the circuit description.

each switching circuit, and operate immediately the uni-selector comes to rest on any one of the 24 bank contacts in bank 4. The operation of the Y relay thus prepares each programme channel to take a split via its channel amplifier and uni-selector.

Each of the 18 switching circuits includes the following equipment:—

One line amplifier equipped with variable equalizer and volume control.
One channel amplifier (zero gain).
One uniselector (five bank).
One relay set (six relays).
One group of 19 "set-up" keys.

The 19 keys associated with each programme switching circuit are mounted in a vertical row, and there are 22 such rows on the key field, which is shown in Fig. 1. Each vertical row of keys represents one switchable programme channel amplifier, and each key in the row, with the exception of the homing key (19th), represents a programme from which this channel amplifier could provide a split. This can readily be understood if it is remembered that the channel amplifier is connected to the wipers of the uni-selector, while the incoming programmes are connected to the banks, as shown in Fig. 5. Each channel amplifier can, therefore, be connected via its uniselector and set-up key to any one of the other 17 circuits or programmes. To take an extreme case, one programme may be split to all of the other 17 channels, but a more usual arrangement would be the splitting of several separate programmes to two or more outlets.

Referring to Fig. 1, the glowing lamps in the 2nd, 17th and 18th horizontal rows show the programme arrangement at the time the photograph was taken. The glowing of No. 19 lamp in row 2 indicates that a programme incoming from Melbourne on P.52 is connected to the National Broadcasting Service Studios (5CL). It will be noted that circuits 19-21 have been allotted permanently to the N.B.S. Studios for relaying programmes incoming to the studio only. These cannot be used as outgoing channels from the studios, as they are not equipped with line amplifiers.

Programmes relayed from the Adelaide Studios to Perth use circuits 17 and 18, while No. 16 is for other miscellaneous outgoing programmes. Most of the relays outgoing from Adelaide to the Eastern States are relayed on the reversible programme channel P.51. This channel is reserved for the exclusive use of the National Broadcasting Service Stations, and is switched direct from the N.B.S. switchrooms at Melbourne or Adelaide. P.51, therefore, does not appear on the key field. The glowing lamps in rows 17 and 18 show that programmes from the Adelaide Studios are being relayed to Perth. No. 17 (N.B.S.3) is relaying to Perth on P.61, and also feeds a split to local station 5KA, while No. 18 (N.B.S.4) relays to Perth on P.62.

Monitoring loudspeakers and level indicators are connected to any desired channel by uni-selectors, which have the output of each of the 22 channel amplifiers wired to their banks.

Circuit Operation

The following is the circuit operation required to split a programme incoming on line number 3 to two other channels, say, circuits 1 and 2. For simplicity, assume that all circuits are idle, the uniselectors being on their respective home contacts. As the channel amplifier of number 3 circuit will not be used in this particular instance, "set-up" keys in vertical row number 3 will not be operated. The operator will depress keys Nos. 1 and 2 in the 3rd horizontal row. These keys are non-locking and must be held operated while the uniselector rotates and until the lamp opposite the key lights. The lighting of this lamp indicates that the switching is complete, and the lamp will remain alight for the duration of the broadcast. For the sake of simplification the uni-selector, relays and set-up keys associated with circuit number 1 only are shown in Fig. 6. The arrangements are similar for all other circuits with sequential lettering for relays, and this should be borne in mind when following the circuit operation. It will be noted, also, from Fig. 1 and Fig. 6, that the "set-up" press-buttons particular to each circuit are installed for the sake of uniformity. They are not wired as, obviously, taking vertical row 1 as an example, it is not possible to switch line amplifier 1 to channel amplifier 1.

When key number 1 in horizontal row 3 (shown with an asterisk in Fig. 6) is pushed, earth is removed from bank contact number 3 of bank 4 of number 1 switch, thus marking this contact to stop the switch. At the same time relay A is operated from earth via the key contacts, B6, A relay winding to 50 volts battery. Contact A1 closes the drive magnet circuit from 50 volts, drive magnet winding, interrupter contacts, A1, B3, wiper on home (25th) contact to earth via ZA1. B relay is, therefore, shunted and prevented from operating via the earth applied at the ZA1 contacts. The drive magnet now operates, stepping the switch to number 1 contact, and the interrupter springs operate. Earth is again encountered on bank contact 1, and B relay remains unoperated. The drive magnet is again energised, as described above. The switch steps to the next contact, again finds earth on the second bank 4 contact, and steps on to number 3 contact, which has been marked by the removal of the earth at the "set-up" key. B relay now operates from 50 volts through the drive magnet winding, A1, B relay winding to earth via ZA1 and performs the following functions:—

(a) Locks itself, via B3, to 50 volts.

(b) Lights the warning lamp alongside the "set-up" key to indicate that the circuit is in use and that the switch has moved to the correct contact. The lamp circuit is completed from earth, via B4, wiper number 5, bank contact to 24 volts via lamp.

(c) Operates relay XC, i.e., X relay connected to C bank common, from earth via B1, wiper number 3, bank contact, relay XC winding to 50 volts.

(d) Closes the circuit of C relay momentarily while "set-up" key is still depressed, and C operates via earth from make contact of "set-up" key, B6, C relay winding to 50 volts. Contact C1 closes the circuit of YA relay, which operates and locks via YA3 and ZA1 to earth. C relay performs no other function at this stage, and releases when the "set-up" key is released at this juncture.

(e) Wipers of banks 1 and 2 which, up to this stage, have been disconnected, to prevent interference to working contacts over which the switch may have passed, are now connected, via B2 and B5, to the input of channel amplifier number 1.

(f) Removes 600 ohm termination from input of channel amplifier at B2 and B5.

Operating the "set-up" key has:—

Disconnected line number 3 from its normal termination and connected it, via contacts XC3 and XC6, to contact 3 on switch banks 1 and 2 of all switches, via its line amplifier, thus making the programme to be received on this channel available for splitting to as many channels as may be required.

Driven the uniselector associated with channel amplifier number 1, to the number 3 bank contact, and operated relay YA. Programme from this bank contact is, therefore, fed, via the switch and channel amplifier number 1, to programme channel number 1, via contacts YA2 and YA4. All circuit conditions necessary to relay programme from programme channel number 3 to programme channel number 1 are now complete.

A similar sequence is repeated when the "set-up" key associated with number 2 channel amplifier is depressed, with these exceptions:—

As relay XC in circuit 3 is already operated, the earth, fed via B1 of switch number 2, has no function at this stage.

Relay YB operates to connect the programme received from bank contacts 3 to programme channel number 2.

The circuit conditions are now complete to relay a programme, incoming on channel 3, to two outgoing channels (numbers 1 and 2). Should it be necessary, a number of additional outlets may be provided by operating the "set-up" keys of the channels required.

In the case of permanent programme lines, very few equalizing and volume adjustments are necessary prior to broadcast, as these have been permanently equalized in each repeater section. Should, however, any correction be needed, the facilities are available. For other lines, the equalizers and levels are adjusted at line-up prior to broadcast. The equalizer, which is incorporated in the cathode circuit of the first stage of each line amplifier, is mounted on the amplifier panel, together with the coarse volume control. A potentiometer, with a range of 10 db., is mounted on the "set-up" key panel on the left side of each of the horizontal rows of keys (see Fig. 1). This potentiometer is for the convenience of the controlling technician, who is able to make level adjustments at the control position, while lining up, without leaving his position. The coarse volume control on the amplifiers, which are mounted at the rear of the control panels, is used only on rare occasions, such as during the original line-up of a new channel, or to meet some emergency condition.

On the completion of a programme relay, a channel receiving programme may be switched to another, if so desired. If no longer required, the channel, with its equipment, should be removed from the network. This is done by operating the associated "homing" key, thus driving the uniselector to the 25th, or homing, contact. If, however, it is necessary to switch to another programme, this may be done by operating the "set-up" key common to both of the channels concerned (i.e., the channel supplying the programme and the channel taking the split). Instantaneous, or "on the clock," changeovers are possible with this equipment, as the only lost time would be that taken by the uniselector to move to the new bank contact.

The selection of the correct "set-up" key for a given connection is not difficult, the required key being found at the junction of the vertical row associated with the particular outlet and the horizontal row associated with the incoming programme channel. The operation of this key, which is a non-locking, push-button type, is the only action required by the operator to establish the connection.

The circuit operations concerned in the transfer of a channel from one programme to another are as follow:—

To take an example, assume that in the particular case referred to earlier, it is necessary to disconnect channel 1 from the programme on line 3, and to transfer it to a programme incoming on line 10. At the appropriate time, "set-up" key No. 1, in horizontal row 10, will be operated.

At this juncture, relays B and YA in channel 1 are locked up from the previous connection.

Earth is removed from contact 10, bank 4, at the inner spring of the "set-up" key, to mark the bank.

Earth from the "make" contact of the "set-up" key operates relay C, via B6.

Contact C2 shunts relay B, which releases and completes the circuit of A relay, which operates from 50V, A relay, B6, "set-up" key 10, to earth.

In releasing, relay B opens the circuit of relay C, which releases, while B3 shunts C2 to close the drive magnet circuit.

The drive magnet circuit is now complete, and operates from 50V, drive magnet winding, interrupter contacts, A1, B3, bank 4 wiper, to earth on contact 3.

The switch now steps to contact 10, which will be marked by the removal of earth at the "set-up" key. B relay again operates from 50V, drive magnet winding, A1, B relay winding to earth, via ZA1, and performs the functions described in (a) to (e), except that relay XJ will be operated to connect programme line 10 to its line amplifier and prepare it to supply programme to channel 1, amplifier 1.

Relay YA, which was previously operated, remains locked up for the duration of the broadcast. YA was not affected by the operation of relay C, as it remained operated to the earth at ZA1 contact.

Homing.—When programme is no longer required, the switch is returned to the home position. To do this the associated "homing" key is operated, and the following operations ensue:—

The "homing" key connects earth to relay ZA, which operates (and locks up over ZA2, to earth at bank 4). Relay C also operates, via B6, to earth at the "homing" key.

ZA1 opens the circuit of relay B, which releases and completes the circuit of A relay, which operates to earth (at bank 4), via ZA3. Relay C releases and B3 prepares drive magnet circuit.

Relay YA releases and unlocks.

The drive magnet circuit is now complete, and the switch steps to the 25th contact, which is marked by the removal of earth at the ZA relay contact; this prevents further movement.

It is only necessary to operate the "homing" key momentarily to start the switch driving; the switch then rotates automatically to the home position, where it will stop.

ZA relay, which had been held operated by earth over the contacts of bank 4, now releases, breaking the circuit of relay A at ZA3, which also releases.

The rotary switch associated with channel 1 is now at the home position, and all relays are normal.

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MR. R. W. TURNBULL

In the previous issue of the Journal, reference was made to the resignation of Mr. J. A. Kline as a member of the Board of Editors. The Postal Electrical Society has much pleasure in recording in this issue the appointment of Mr. R. W. Turnbull to the position on the Board of Editors vacated by Mr. Kline. The co-Editors join with the Society in welcoming Mr. Turnbull to the Board. After seven years' experience in the Telephone Equipment Section in N.S.W., Mr. Turnbull was appointed Divisional Engineer in 1944 and was transferred in 1945 to the Telephone Equipment Section Central Office, where he is at present Acting Assistant Supervising Engineer. Mr. Turnbull's wide and detailed knowledge in the communication field will be of considerable value to the Journal.

THE RECRUITMENT AND TRAINING OF STAFF, ENGINEERING BRANCH, N.S.W. - PART 1

G. Buckland, B.Sc.

This article briefly surveys the various aspects of staff recruitment and training in the Engineering Branch in New South Wales. The organisation and procedures adopted in the training schools will be covered in Part II.

General Organisation of Department: The Postmaster-General's Department has been divided, essentially on a functional basis, into a number of Branches, under the control of Branch Heads, who are responsible to a Deputy-Director in each State. The activities of the States are co-ordinated by central Branch Heads under the control of the Director-General, who is directly responsible to the Minister.

The Engineering Branch in each State is controlled by a Superintending Engineer, who is responsible for the planning, installation and maintenance of telecommunication plant. The control also includes the planning, installation and maintenance of station and studio equipment for the National Broadcasting System. The functional organisation of the Branch is indicated in Fig. 1.

The staff strength of the various Branches in New South Wales, as at June 30, 1947, was as follows:—

Engineering	7,994
Postal Services	4,924
Telephone	3,006
Mail	1,739
Telegraph	1,230
Accounts	727
Stores and Transport	415
Personnel	371
Buildings	186
Wireless	93
	20,685

The Engineering Branch contains approximately 39 per cent. of the total staff, which includes all grades, from labourer and office assistant to the professional and administrative ranks.

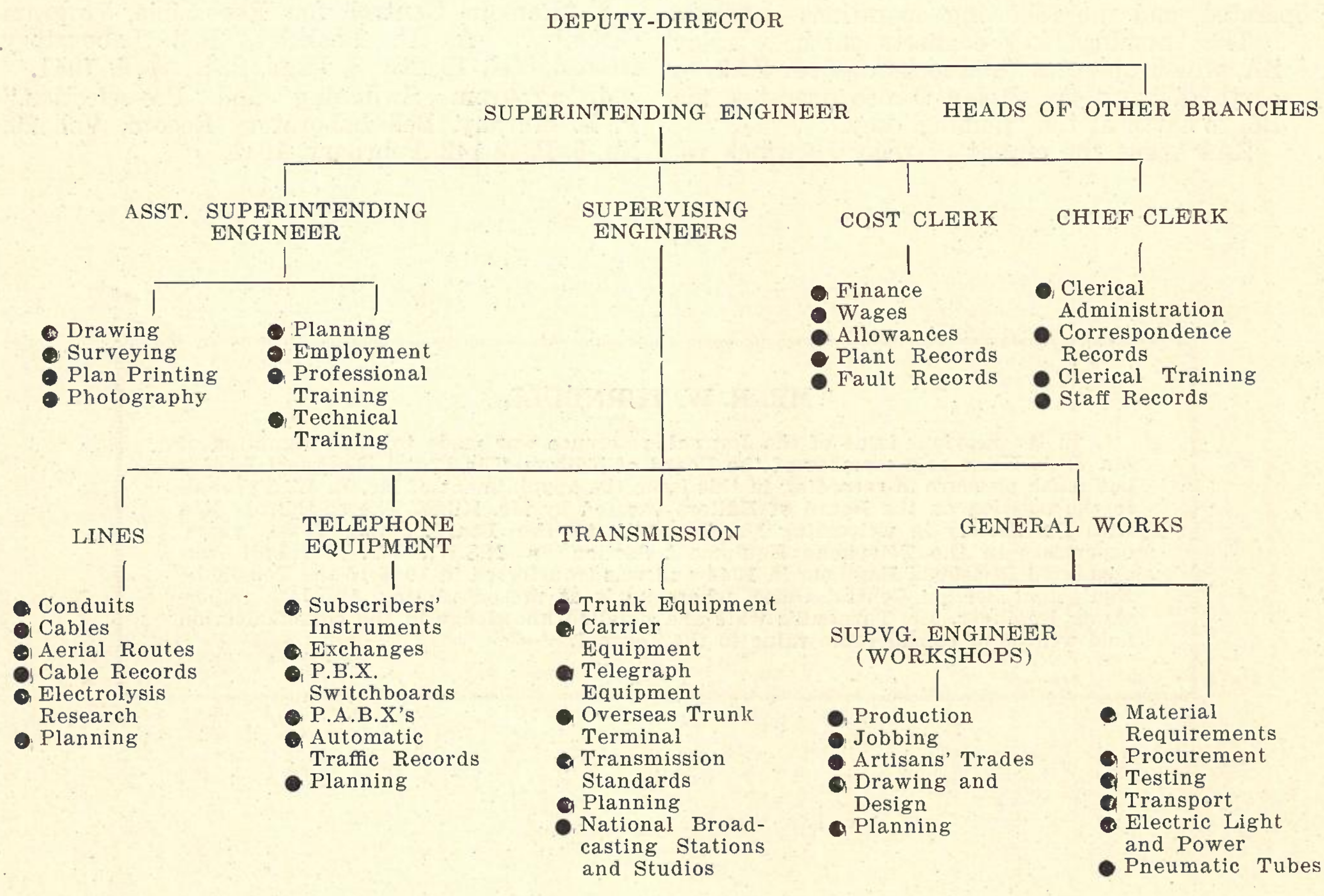


Fig. 1.

Staff Recruitment

General: Staff is recruited into the Service in a permanent or temporary capacity. The former is appointed, normally, by competitive examination, to fill positions of a permanent character. Temporary employees are engaged for a specific position, or type of work, without the need to qualify by a written examination, and are usually selected by interview.

All promotion and recruitment of staff is subject to the approval of the Public Service Board. However, in the case of certain positions in the Fourth Division, such as Artisans, Technician and Line Staff, the Chief Officer of the State Department, namely, the Deputy-Director, may approve or delegate authority for the engagement of suitable temporary labour. In such cases, the temporary employees are referred to as Exempt Staff, and the provisions of the Commonwealth Public Service Act do not apply, as they are engaged under agreement or Arbitration Determination. The ratio between permanent, temporary and exempt staff in the Engineering Branch has varied considerably over the years, and the variation since 1929 is indicated in Fig. 2. The Table below shows the position just prior to the war as compared with the position last year.

Year	Total Staff	Permanent	Exempt	Temporary
1938	4918	60%	33%	7%
1947	7994	46%	50%	4%

The abnormal increase in the Works Programme, and the urgency attached to its execution, have required a heavy rate of intake of exempt employees, which has exceeded the rate of recruitment of permanently trained staff, but the percentage of the latter should increase considerably during the next two years.

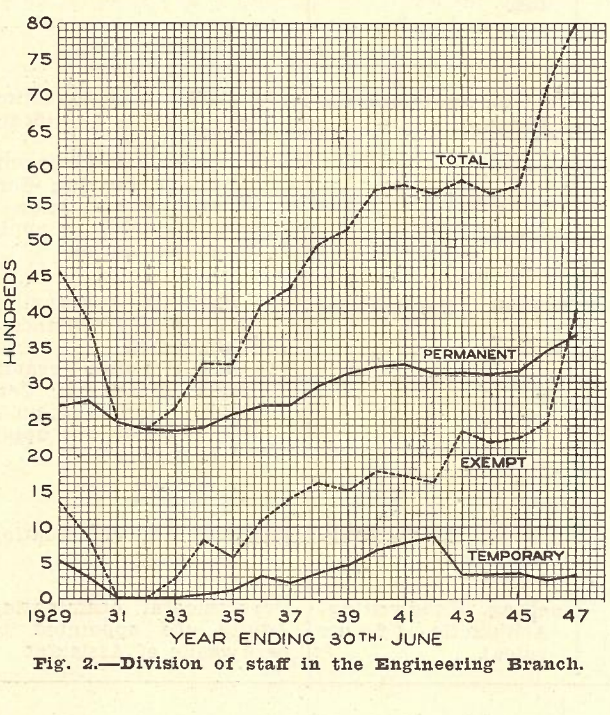


Fig. 2.—Division of staff in the Engineering Branch.

The Staff in the State is divided into three Divisions, as follow:—

(a) Second Division—Head of State Organisation. i.e., the Deputy Director.

(b) Third Division—Administrative, Professional and Clerical Staffs.

(c) Fourth Division—Supervisory, Manipulative and Assistant Staff.

(The Head of the Department as a whole—the Director-General—is in the First Division.)

The Staff of the Engineering Branch is composed of Third and Fourth Division officers only, and, of a total of 7994, in 1947, 5.8 per cent. were included in the Third Division.

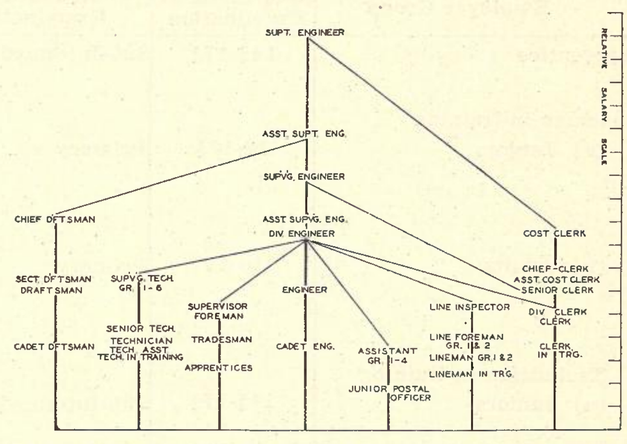


Fig. 3.—Staff lines of relative advancement and control.
Advancement lines shown thus ————
Control lines shown thus ————
Note:—A trainee in one group may qualify for appointment as a trainee in another group.

The organisation of staff in the Branch is simplified by the use of common titles for employees carrying out work of a similar grade, although of a widely different character; thus Technician, Broadcasting, in the same grade as Technician, Telephone Equipment, and a similar arrangement applies in the case of other titles. Salary gradings for similar titles are the same,

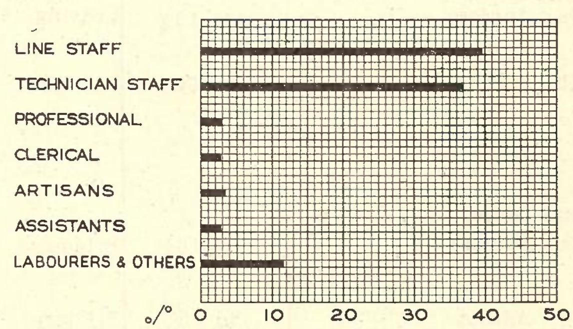


Fig. 4.—Distribution of staff into various groups as at 30th June, 1947. (Includes all types of staff within various groups.)

except at the Supervising Engineer level or in a few cases where specialist knowledge is required. A number of positions in the Fourth Division are sub-divided into grades covering different degrees of responsibility. The relative level of responsibility and control held by each individual in the Professional, Trade, Clerical and other groups is shown in Fig. 3. The distribution of the Staff among the various groups, including temporary positions, is indicated in Fig. 4.

Permanent Staff

Details of Examinations: Notices regarding examinations are advertised in the Commonwealth Gazette and the more important newspapers throughout the Commonwealth. Other advertising media are used where a large number of positions are involved or the position requires special aptitudes and abilities, or where there is some difficulty in obtaining sufficient and suitable applicants. General details of examination requirements for staff employed in the Branch are shown in Table No. 1. All applicants are required to complete a form of application, giving personal details, such as date of birth, marital state, nationality, educational standard, etc.

Examination Standard: The standard of the examination for appointment to the permanent

TABLE No. 1

DETAILS OF REGULAR METHODS OF RECRUITMENT OF DIFFERENT GRADES OF PERMANENT STAFF

Employee Group	Age Limit at Examination	Standard of Examination	Essential Subjects	Remarks
Apprentice	14¾-17¼	Sub-Intermediate	English, Mathematics, Science	Departmental examination
Lineman-in-training				
(a) Juniors	18-19½	Primary	(a) Spelling, Handwriting, Arithmetic (four rules) (b) Trade Test	Departmental examination Trade test requires ability to use wood and metal tools, blow-lamp, knowledge of knots
(b) Adults	to 50	Primary	(a) Spelling, Handwriting, Arithmetic (four rules) (b) Trade Test	Trade test requires ability to use wood and metal tools, blow-lamp, knowledge of knots
Technician-in-training				
(a) Juniors	14¾-17¼	Sub-Intermediate	English, Mathematics, Science	Departmental examination
(b) Adults	to 50	Sub-Intermediate	(a) English, Mathematics, Science (b) Trade experience test	Departmental examination
Cadet Engineer and Cadet Draftsman				
(a) Juniors	15¼-19¼	Leaving Certificate	English, Mathematics, Physics	(a) Held in conjunction with Leaving Certificate Examination
(b) Permanent Officers	to 24			(b) Departmental examination or Leaving Certificate Examination—Special conditions apply for ex-servicemen
Clerk				
(a) Juniors	15¼-19¼	Leaving Certificate	English, Mathematics	(a) Held in conjunction with Leaving Certificate Examination
(b) Adults	to 50			(b) Departmental examination or Leaving Certificate Examination—Special conditions apply for ex-servicemen
Postal Officer				
(a) Juniors	14½-16¼	Primary	Spelling, Handwriting, Arithmetic (four rules)	Departmental examination
(b) Adults	to 50	Primary	Spelling, Handwriting, Arithmetic (four rules)	Departmental examination Adults are appointed to base grade of Assistant

staff varies with the type of employment. Special examinations are conducted throughout the Commonwealth by the Public Service Board, for entrance to particular trainee positions. For some other positions, competitive tests for entrance to the Service at Leaving Certificate standard are conducted in conjunction with the Public examination of the State concerned.

Age of Recruitment: This varies with the type of work, but the limiting age is 51 years for appointment for any position on the permanent staff. Normally, juniors only have been recruited for trainee positions in the Branch, but, since the Re-establishment and Employment Act of 1945, adults have been appointed to trainee positions.

Final Selection: All provisionally selected applicants are given a medical examination to determine their physical fitness for the particular position concerned. In addition, an investigation is made to ensure the applicant does not possess a record which debars him from employment. Selection, in some cases, such as professional staff, is also subject to interview by a Selection Board. All staff is required to take the Oath of Allegiance to the Crown, and undergo a period of 6 months' probation, before appointments are confirmed.

Promotion to Higher Positions: Selection for promotion to higher positions in the Service is usually made from Departmental Officers. However, in the case of a position of a specialist nature, requiring particular qualifications, and when there is no suitable applicant from among the permanent staff, the Public Service Board will issue a certificate to this effect, and an appointment may then be made direct to the position from outside the Service, without examination.

Exempt Staff

Methods of Employment: There is a close liaison between the Employment Officer of the Personnel Branch and the Placement Officer in the Engineering Branch. The former arranges for advertisement of positions and investigation into previous history, and makes the final recommendation for approval for employment. The Placement Officer interviews the applicant, and advises the Employment Officer whether he is suitable for employment in the Branch.

Method of Selection: All applicants for a position in the Branch must complete an application form, which records:—

(a) General personal details.

(b) Educational standard.

(c) Previous training and experience in industry.

(d) Training and experience in defence forces.

(e) Details of physical standards.

(f) Agreement to accept conditions peculiar to employment in the Branch.

The primary purpose of the application form is to facilitate exclusion of those applicants who are obviously unsuitable, to act as a grading medium for order of call-up, and to assist in directing the line of discussion at the interview.

The Placement Officer, in association with the Technical Training Division, is required to determine whether an applicant:—

(a) Possesses suitable educational and trade knowledge for the position.

(b) Is suitable to undertake a course of training.

(c) Is likely to be a labour turn-over problem.

(d) Has obvious physical disabilities which would prevent him carrying out the work efficiently.

He is then required to act as follows:—

(a) Arrange trade tests, if necessary.

(b) Advise applicant of conditions of employment.

(c) Make recommendation for employment or otherwise.

(d) Make a recommendation for placement of applicant in a position suitable to his aptitude and ability.

(e) Arrange for medical test.

(f) Arrange for locality of employment.

Commencement of Employment: New employees selected for work on the Line or Technician Staff are given a short period of training at special Departmental schools, immediately on, or soon after, commencement. During this time the new employee is required to demonstrate his ability at practical and theoretical tests. The training course acts as a further selection ground before the employee finally takes up his position.

STAFF TRAINING

General: The staff of the Engineering Branch requires, for many of its activities, a specialised knowledge which is not available in outside industry. A course of training is given to all staff required to fill base grade positions in order to provide for efficient employee performance. In addition to the normal courses for permanent staff, refresher courses have been conducted in some sections for those resuming from the Services. Since 1945, short training courses have been given to Line and Technician Staff, covering particular sections of the work in which they are engaged. The schedule of training for the various grades of permanent staff is indicated in Table No. 2. The general details of the training for each group are as follow:—

TABLE No. 2

SUMMARY OF TRAINING FOR PERMANENT STAFF

Trainee Group	Period of Training	General Method of Training	Training Details			
			Deptl. Schools	Technical College	University	Field
Apprentice	5 years	On the job and assoc. Tech. College Trade Course.		4-5 years part-time		4-5 years part-time
Cadet Draftsman	5 years	On the job and spec. Tech. College and Deptl. Training School Course.	2 years part-time	4 years part-time		5 years part-time
Cadet Engineer	4 years	Experience in various Sections of the Branch, University and Deptl. Trng. School Course.	2 years part-time		2 years part-time	2 years part-time 2 years full-time
Clerk	1 year	Experience on job and special Deptl. lecture and practical courses.	1 month			11 months
Lineman-in-Training	1½ years	Part-time in School and on the job.	1 year part-time	1 year part-time		1½ years part-time
Technician-in-Trng.	5 years	1st year wholly in School, 2nd-5th part-time School and on the job.	1 year full-time 4 years part-time	3 years part-time		4 years part-time

Regular Training Courses—Permanent Staff

Apprentices are employed in various Artisan Trades, and qualify as Tradesmen on completion of the normal five years of training on the job, coupled with the appropriate trade course at the Technical College, which is of four or five years' duration.

Cadet Draftsmen: The drafting work covers an extensive field, including design, layout and drawing of the various circuits associated with telecommunication, mechanical engineering drawing and design, surveying and general office procedures. The cadet spends five years on practical training, covering each section of the work. A four-year course is undertaken at the Technical College in conjunction with the practical work, and this includes Mathematics, Physics, Engineering Drawing, Descriptive Geometry, Materials and Structures, Mechanical and Electrical Engineering, Engineering Design and Surveying. The Cadet also completes at the Technicians' Training School the lecture course in Telephony, which is given to technicians-in-training during the first two years. However, more recently, the special lecture courses, which are undertaken by the Cadet Engineers, have also been attended by Cadet Draftsmen.

Cadet Engineers: The control and direction of these trainees (also Cadet Draftsmen) is under the guidance of a Divisional Engineer specially allotted to this work. The Cadets are given four years' training and experience in all the engineering activities of the Branch.

The first two years of the training provide for satisfactory completion, at the University, of courses in Mathematics and Physics. In addition, practical and theoretical studies, related to the field training, are carried out at Departmental Training Schools. Supplementary lectures appropriate to the year of training and the sections in which the Cadets work, are given by Engineering Officers attached to these sections. The field training for the first three years includes on-the-job experience in workshop and drawing practices, sub-station equipment, magneto and trunk switchboard operation, line construction, and the principles of automatic exchange working and office procedure. At the end of the three years the Cadet is required to sit for written final examinations in Line Construction and that portion of Telephony and Transmission covered during the training. The fourth year provides for training in telegraph equipment, radio, long line equipment, and organisation, while automatic exchange systems and transmission theory are studied in more detail. At the end of the fourth year, final examinations are conducted in automatic telephony, transmission and telegraphy. A review of the training schedule is being considered, and interesting suggestions are supplementary courses in industrial management.

Clerks: Training, for a period of approximately 12 months, of newly-appointed clerical staff for the Engineering Branch, commenced this year. The group is handled in three stages, by different sections of the Service.

(a) **Public Service Board**—General principles and broad organisation of the Service.
(b) **Personnel Branch**—Induction and tentative allotment to a Branch for job experience. Lectures on the functions and organisation of the Department. Preparation of official correspondence. Elementary principles of stores and accountancy procedure.
(c) **Engineering Branch**—Allotment and completion of training within the Branch.

The Trainee will be under the control of a special training officer attached to the Engineering Branch. The training in various Branches will be co-ordinated by a Training Officer attached to the Personnel Branch of the Department.

The training schedule includes a short period at special schools, lectures by various officers on Service, Departmental and Branch methods and procedures, visits of inspection, practical exercises and on-the-job experience in various phases of Branch activity.

Linemen-in-Training are given eighteen months' training, including, approximately, one year at the Departmental Training School. This period, however, is interspersed with training in the field at the conclusion of each specific course. Full training is undertaken on the installation and maintenance of aerial and underground construction, including cable jointing and plumbing; less extensive training is given in telephone equipment, mobile excavation plant, store work, estimating and transport. In addition, the trainees are given tuition to a lower secondary standard in mathematics and physics, including electricity and magnetism.

Technicians-in-Training: This designation includes all trainees who will be engaged in the electro-mechanical side of telecommunication equipment and allied activities, such as fitting and machining, and electric light and power work, which are associated with repair and production of equipment and energy supply, respectively. The Trainees are divided into five groups, for employment in the following types of work:—

(a) Telephone and long line equipment.
(b) Telegraph equipment.
(c) Radio equipment.
(d) Fitting and machining.
(e) Electric light and power work.

All Trainees are given a five-year course, with final examinations at the end of each year. Groups (a), (b) and (c) receive a common course of training during the first three years, which includes attendance at the Departmental Training Schools and the Technical College. The first year is spent wholly in the Training School, and is devoted to the fundamentals of communication, the elements of fitting and machining and substation equipment. During each of the remaining years of the training, the trainees receive a minimum of two hours per week in lectures on the theory of communication, coupled with approximately 4-8 weeks' practical work in the School, which is interspersed with different sections of the field training. The course is gradually built up from fundamentals to magneto, common battery and the various automatic telephone systems and high frequency transmission. During the last two years of the course the trainees specialise in a particular section of the work, which is covered in much more detail. The field training is supervised by field training officers, who ensure that each trainee receives the necessary experience in the various phases of the work.

Groups (d) and (e) receive only a short, initial period of training of up to six months at the Training School, essentially on the elements of fitting and machining. The remaining section of the technical training is undertaken at the Technical College in the appropriate Trades Courses. The field training is similar to that for trainees in the other groups.

This year, adult ex-servicemen technicians-in-training have been appointed by special examination, which not only includes the normal entrance examination taken by the juniors but, in addition, a further paper on the fundamentals of electricity and communication practices. It is anticipated that the period of training for the adults will be reduced considerably under these circumstances. (Similar appointments of adult trainees are to be made in other trainee groups.)

Junior Postal Officers: These officers receive a short, introductory training of a few weeks, under the guidance of officers in the Personnel Branch. This course includes lectures on Departmental activities and organisation, and includes visits of inspection. The trainees are encouraged to qualify, by examination, to transfer to other trainee positions in the Service, but may pe promoted directly to Assistant, Grades I-IV, in any of the various Branches of the Department. More recently, adults have been appointed as Postal Officers. These officers, after a short training period, will advance through the normal grades of Assistant, or, if already employed in the Branch, may continue, if they so desire, in their present positions in an acting capacity.

Other Courses

Short-Term Training — Exempt Staff: The rehabilitation programme, required to overtake the arrears of work which have accumulated during the war years, and maintain current development, has necessitated the employment of large numbers of men untrained in Departmental procedures and telecommunication work. In order that these employees may be brought to a stage of efficiency where they become effective units as quickly as possible, special training courses have been introduced at the various Departmental Training Schools. The men are engaged in the base grade of line labourer or technicians' assistant, and are selected for the position for which they appear most suited.

The training is divided into primary and secondary courses, the primary courses covering the particular field of work in which the men will be engaged. These courses are sub-divided, as follows, one month being spent in each sub-section:—

Line Construction—
(a) Underground conduits and cables.
(b) Aerial construction.

Internal Equipment—
(a) Sub-station installation.
(b) Exchange and carrier installation.
(c) Exchange maintenance.

Examinations are given in both theory and practice during the course, and if the trainee fails to attain a satisfactory grade of pass he is transferred to work more appropriate to his ability.

The secondary courses are undertaken by the senior, untrained exempt staff, and selected new employees who have demonstrated their ability during the primary training. The course is designed to enable the men to undertake the higher grade of work on particular types of equipment on which they are employed. Such specialisation does not allow much flexibility in the movement of staff, as between different sub-sections, but

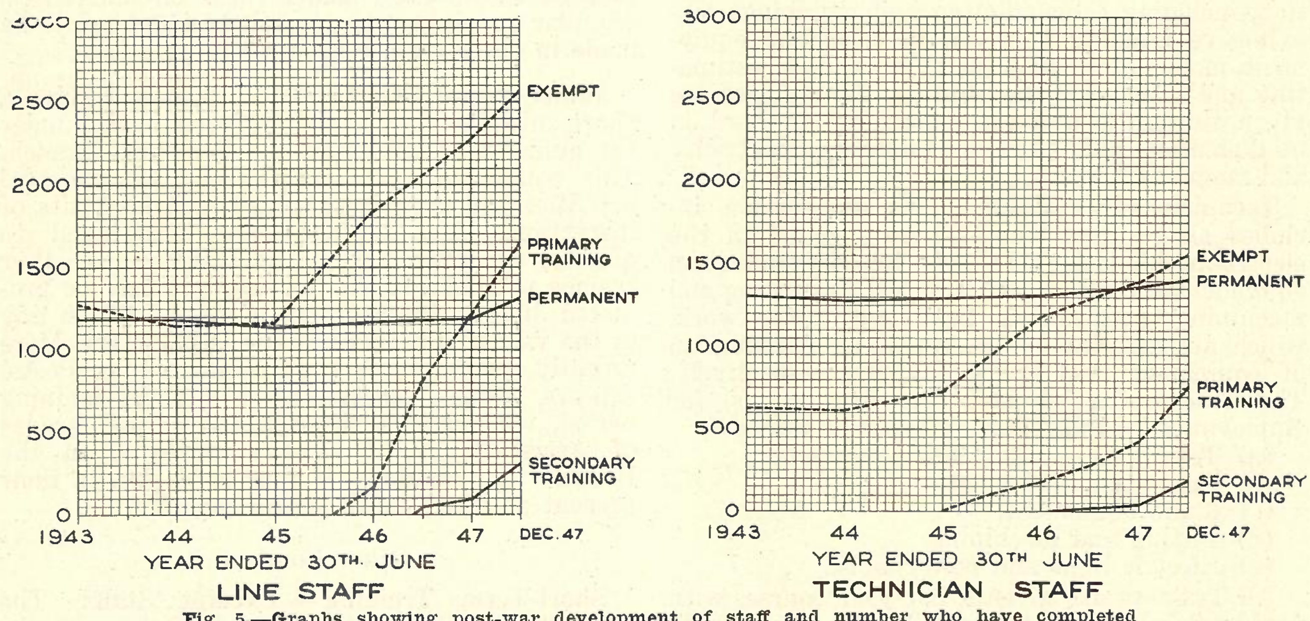


Fig. 5.—Graphs showing post-war development of staff and number who have completed special training courses.

enables efficient staff to be obtained at a fast rate. The courses provide for training in the following sections of the work:—

Line Construction—
(a) Cable jointing—1-3 months.
(b) Party leader courses—1 month.

Internal Equipment—
(a) Sub-station equipment—6 months (approx.)
(b) Pre-2000 type exchange equipment—6 months (approx.)
(c) 2000 type exchange equipment—6 months (approx.)
(d) Sub-station and magneto exchange equipment—2 months (approx.).

The line construction courses are carried out in a short, continuous period of 1 to 3 months, the length of the course in the case of cable jointing depending upon the previous experience of the employee. The courses in equipment, except course (d), which is designed for country staff, are extended over a longer period, and include weekly lectures and short periods of practical training in the School. All employees attending the classes are engaged on work appropriate to the training, and are required to demonstrate satisfactory progress, and pass a final test at the end of the course.

The longer courses enable the staff to be properly trained, and large numbers, up to 200, have been dealt with at one time without serious interruption to the normal working schedule. It is anticipated that a large number of the staff receiving such courses will qualify by examination for appointment to the permanent staff, and that it will not be necessary to repeat this section of the training. The relationship between the exempt and permanent staff and the number who have received special primary and/or secondary courses is indicated in Fig. 5, for the technician and line sections, respectively. The graphs for the primary and secondary training include permanent staff who have undergone similar training in refresher courses. The number of trainees qualifying through the normal training channels is not included in the graphs, as the numbers were small, owing to restricted recruitment. The deficiency of regular trainees has emphasised the need for an accelerated output of new men, suitably trained to undertake particular phases of telecommunication work.

Commonwealth Reconstruction Training Scheme—Ex-Servicemen Trainees: Since the Re-establishment and Employment Act of 1945, the artisan group has been supplemented by ex-servicemen trainees included as:—

(a) Commonwealth Reconstruction Trainees.
(b) Probationary Trainees.

The first group has attended special Commonwealth Reconstruction Training Schools, provided for ex-servicemen, covering the various trades. The trainees there attend a full-time training course for a period of up to six months and, on attaining 40 per cent. efficiency, they are placed in employment in the particular trade in which they have studied. Trainees are expected to show, at the end of every three months, a 5 per cent. progress in efficiency up to 70 per cent. of the trade standard, and, thereafter, 10 per cent. increase each three months. Thus, these men may qualify as tradesmen after a maximum period of $2\frac{3}{4}$ years of intensified training.

Probationary trainees are men who have been occupied in a particular trade for some time, and are assessed as 75 per cent. efficient in that trade and, with guided instruction, can complete their training in 12 months. The training of both Reconstruction and Probationary Trainees is supervised closely by Inspectors associated with the ex-servicemen's training scheme.

Refresher Courses—Permanent Staff: The syllabus designed for the training of exempt staff has been utilised as the basis of refresher courses for permanent staff. These courses were undertaken by the line staff, more particularly owing to the number of changes in the types of plant and methods of operation introduced during the war years. Ex-servicemen recently appointed to the permanent line staff have received a period of secondary training which varied from $4\frac{1}{2}$ to 9 months, depending upon the previous experience of each individual appointee. This training included all the short-term courses given to the exempt staff and, in addition, sections of the normal linemen-in-training syllabus, and some instruction on telephone equipment.

Supervision Courses—Supervisory Staff: A very important factor in the development of greater efficiency is the spirit of co-operation existing between the supervisory staff and those under their charge. The necessity for training in supervision is looming large on the horizon of modern industrial affairs, and, to meet this need, a short series of lectures, spread over a period of 3 months, is proposed for approximately 500 supervisory staff. Other courses covering recent developments in line construction are to be presented to the supervisory staff engaged on this work, in order that they may keep abreast of current trends. It is anticipated that the introduction of such courses, besides giving the supervisors more confidence in themselves, will develop a better understanding of that increasingly important factor, human relationships.

Methods of Training: The efficiency of the Department depends upon the standards and methods adopted in the recruitment and training of staff. In order to obtain the maximum degree of efficiency, training schools have been established to ensure that the staff is trained in specialised Departmental knowledge and procedure as well as in normal educational fields. Their organisation will be described in Part II of this article.

ENGINEERING ASPECTS OF THE NATIONAL BROADCASTING SERVICE*

R. J. Boyle, M.I.R.E.(Aust.)

Introduction

The National Broadcasting Service is something we all tend to take for granted as one of the commonplaces of everyday life. Few of us, therefore, give any thought to the complex engineering efforts which lay behind such feats as, for example, the instantaneous switching of an Australia-wide programme network from one source to another some thousands of miles away—yet this is going on every day so smoothly that most of us are not conscious of it. Indeed, too little credit is given in any broadcast set-up to those silent workers on the engineering staff without whose brains and toil the most lavishly-publicised extravaganza would be a dismal failure.

In some respects, therefore, this article may be regarded as a tribute to those "silent workers," without whose efforts the subject matter would not be in existence. It is proposed to convey this tribute by an outline of the establishment of the National Broadcasting Service in Australia; the problems involved in this establishment; and the methods by which these problems have been overcome.

Constitution of the National Broadcasting Service

The National Broadcasting Service was established in Australia during 1929 by a Federal Act of Parliament called the "Australian Broadcasting Act." It is quite evident that those who drafted this Act realised that within the framework of Australia's national communications organisation —the Postmaster-General's Department—there existed the resources necessary to provide for a broadcasting system on a national basis.

Research, planning, construction, operation and maintenance, all could be provided for from the existing Australia-wide organisation. The natural move, therefore, was to establish a cultural body to provide programme material which would be disseminated through facilities provided by the Postmaster-General's Department. This body was called the Australian Broadcasting Commission, but was not established immediately, and, during the first years of National broadcasting, the programmes were provided by the Australian Broadcasting Company.

The present Act delineates the functions of the two parallel organisations which, joined by law under one common Ministerial head (the Postmaster-General), constitute the National Broadcasting Service. Section 22 of the Act requires the A.B.C. to provide the studios and "such accommodation in relation to the studios as the Minister requires for the proper carrying-out of the technical services to be provided by the Minister." Section 36 requires the Postmaster-General "to provide and operate all technical services associated with the transmission of programmes provided by the Commission."

The National Broadcasting Service as a whole is, of course, Commonwealth-wide, but this article has been written around the State of New South Wales and the Australian Capital Territory, and it should be understood that the particular applications referred to are, generally speaking, State details of a Commonwealth generalisation.

Planning the Transmitter Locations

The coverage of the N.B.S. transmitters is a designed service to the people of Australia. It is not the haphazard result of individual achievements, nor is it the outcome of localised resources. It has grown, and is still further expanding, in accordance with a deliberately conceived plan. The development of this plan was, in common with most other peacetime works, retarded by the advent of war. Now that the war is over, the work of completing the plan is once more proceeding as smoothly as material and labour shortages will permit.

(a) **Existing Transmitters:** There are at present 8 National transmitters in N.S.W., and 3 more either under construction or in an advanced stage of design.

Fig. 1 illustrates the primary service area of the major existing and designed stations in N.S.W. The boundary lines are either the 0.5 millivolt per metre contour or the contour of 50% fading.

Two important points immediately arise from a study of this map, viz.:—

(a) The inland stations have a far greater coverage than the coastal stations. This is principally due to the mountainous nature of our coastal areas; and

(b) there is apparently a large area of the State that receives no service. This is partly true, because the general plan has not yet been fully executed.

It obviously is impossible to cover every portion of the State with a primary service—not only are there insufficient frequencies available for the purpose, but the question of economics must be considered. It costs something in the vicinity of £50,000 to establish a major National station, and sometimes £20,000 more to provide its associated programme line. Add to this an amount of about £5,000 per annum for operation of the station and it becomes immediately evident that very serious consideration, indeed, must go into the selection of areas to be served. The population density of

* Lecture presented before Sydney Division of the Institution of Radio Engineers, Australia, on Monday, July 30th, 1947, by Mr. R. J. Boyle, M.I.R.E. (Aust.), and published in "Proceedings," November, 1947, Vol. 8, No. 11.

N.S.W. is heaviest in the coastal regions, falling off to the westward. This factor results in the location of the major stations approximately along two imaginary lines—one along the coast, and another, paralleling the first, to the west of the Great Dividing Range. Service to the Far West is provided by the two National shortwave transmitters VLR and VLH in Melbourne.

(b) **High-Frequency Coverage:** Whilst considering the question of service, it is of interest to note the coverage of the National high-frequency transmitters, also shown in Fig. 1.

An effective service to quite a large section of the State is provided by VLR, which operates on 9,540 kc/s by day and as VLR2 on 6,150 kc/s at night and in the early mornings. It will be seen that this transmitter closes a gap which economic factors leave in the medium-frequency coverage. An alternative service is provided by VLH, which radiates the Interstate programme as VLH5 on 15,230 kc/s. by day; as VLH3 on 9,580 kc/s. by night; and as VLH4 on 11,880 kc/s. in the mornings until 9 a.m. These services are commended especially to those who are associated with radio in the country, because personal observation has satisfied the author that the HF transmitters—particularly VLR—provide much-needed entertainment in the Far West, especially during those lengthy periods when atmospheric interference makes medium-frequency reception impossible.

While considering the subject of HF broadcasting, the following notes are of interest. They are a direct extract from a Departmental report concerning Field Strength surveys covering the Mid-North coastal area of N.S.W.

"Field Strength measurements showed that the strongest signals received at night in Port Macquarie peaked to about 2 mV/metre, these signals being received from stations 3AR and 2FC. On the afternoon of September 25, a thunderstorm passed over Port Macquarie at

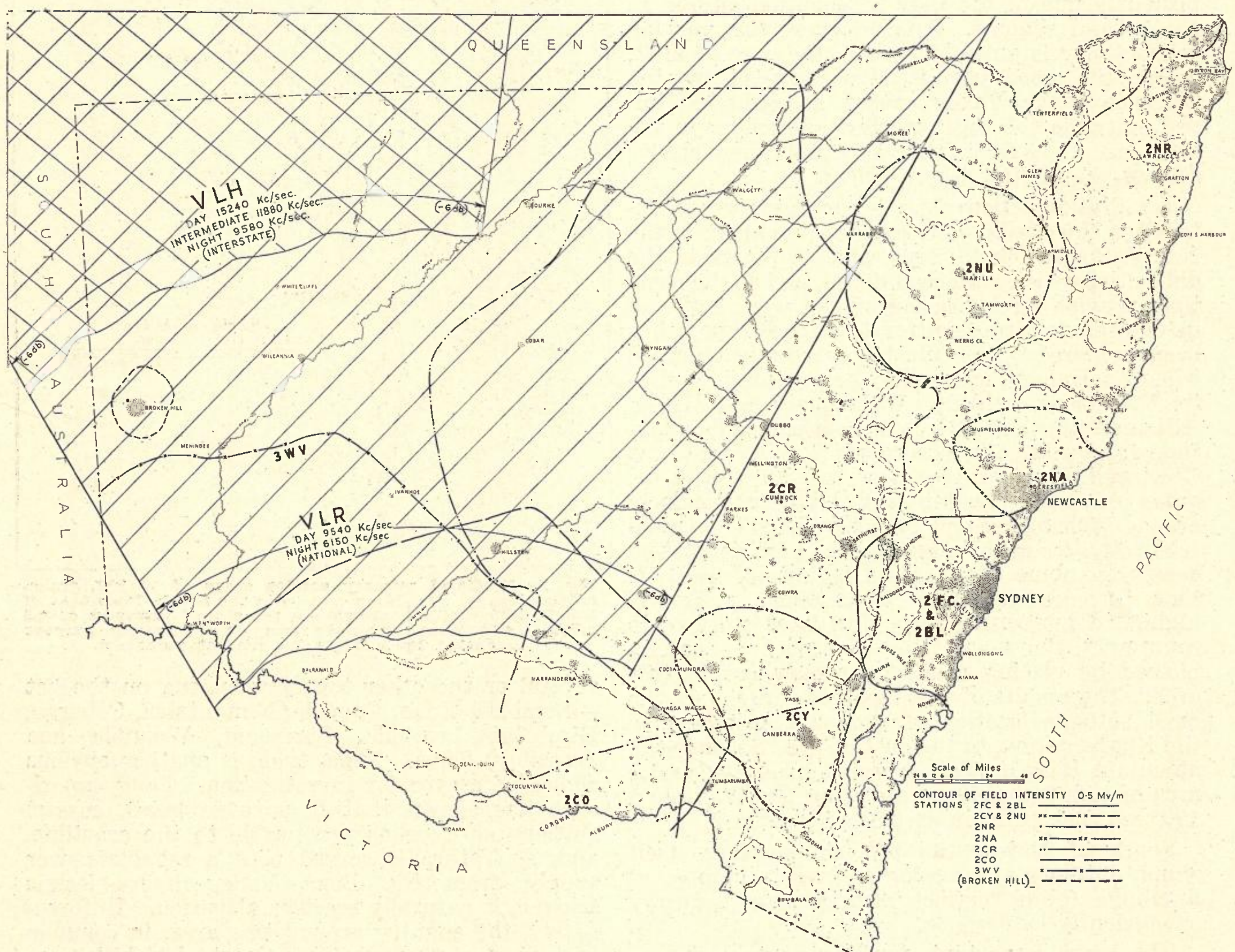


Fig. 1.—Primary service areas of major National broadcasting stations in New South Wales, including general coverage of high-frequency transmitters VLR and VLH and also projected stations at Manila and Broken Hill.

about 3 p.m. From mid-day on this day until about 6 p.m. **on the following day,** reception of any station on the broadcast band was quite impossible. On the night of the 25th, notwithstanding the signals of up to 2mV/metre that measurements had shown to exist each night, it was not possible even to determine whether stations were transmitting in the medium-frequency band—so intense was the barrage of atmospherics. At 9 p.m. on the night of the 26th (the day following the storm), the measured intensity of the atmospherics at 560 kc/s. showed a peak of 1 mV/metre once every 10 seconds. It is of interest to note that on the night of the storm, reception of the Melbourne high-frequency transmitters was not merely good, but practically free of atmospheric interference."

The inland medium-frequency stations possess much greater service areas than do the coastal stations. This is partly due to the different frequencies on which the stations operate, but it is primarily due to the high attenuation offered in the coastal regions. The effect of the varying conductivity is quite marked in the case of 2NR, where the good conductivity provided by the Clarence River Valley causes a noticeable improvement in the south-westerly direction. In the case of 2NA-2NC, the superior conductivity follows the Hunter River Valley.

(c) **Site Selection:** The generally-poor conductivity in the coastal zone reaches its climax in the N.S.W. South Coastal area, and, to illustrate the difficulties which are encountered, and at the same time provide an indication of the work involved in determining transmitter locations, Fig. 2 has been prepared. This illustrates results obtained when analysing the problem of providing service to the areas between Wollongong and Eden. Although 2FC and 2BL provide a reasonable daytime rural service to coastal areas as far south as Greenwell Point, there exist, within this zone, areas of high population density, particularly around Wollongong and Port Kembla. The industrial activities in this area and the high population density combine to provide a high noise field. It thus becomes necessary to establish relatively high field intensities from broadcast stations to counteract the noise, and this may be accomplished by placing a station somewhere in this area. The results of five separate surveys fix the most suitable location of such a transmitter in the Kiama region, to the east of the "Saddleback" Mountain Range. The expected primary service area of this transmitter, radiating 10 kW. from a 190° vertical radiator, is plotted in Fig. 2.

South of Nowra the problem resolves itself simply into one of covering as great a number of dwellings (quite distinct from area of country) as efficiently as possible.

The more important dwelling centres, in descending order of population, are: Bega, Ulladulla (including Milton), Bombala, Moruya, Narooma, Eden, Candelo, Bateman's Bay, Nimmitabel, Cobargo, Bemboka, Pambula, Bermagui, Central Tilba, Wolumla, Bodalla.

It will be noted that the first three are Bega, Ulladulla (Milton) and Bombala. Looking first at Bega, it is seen that this centre is surrounded by

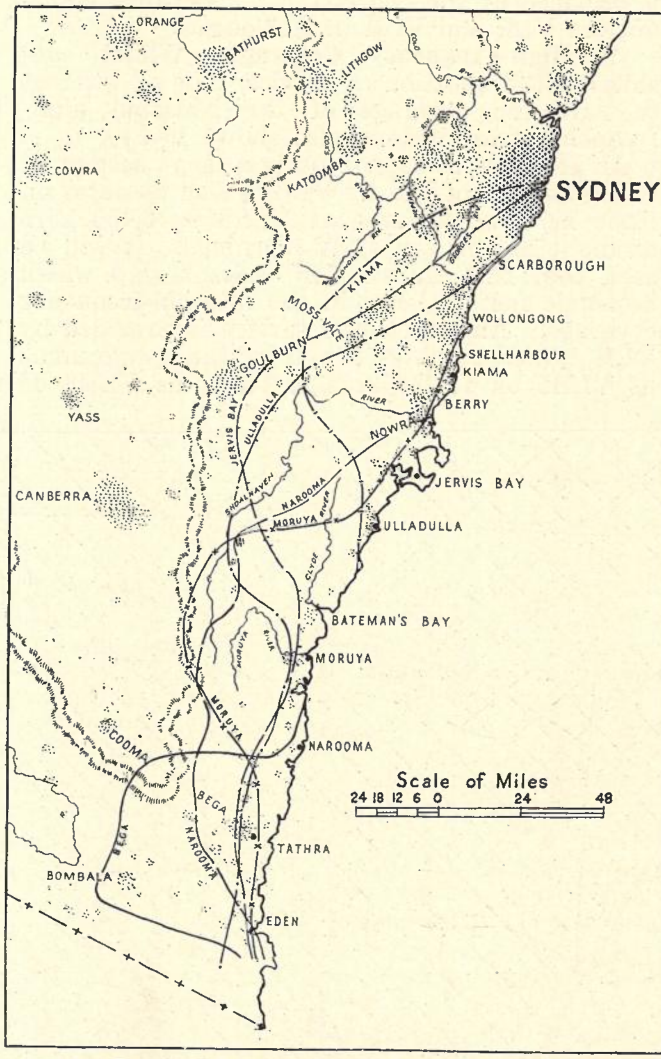


Fig. 2.—Predicted primary service areas of 10 kW. transmitters located at various centres in the South Coast area of N.S.W. The contours shown are for a field intensity of 0.5 mV/m., and were obtained from field intensity surveys conducted by P.M.G.'s Department personnel.

several of the other towns appearing on the list —Bombala, Eden, Candelo, Nimmitabel, Cobargo, Bemboka, Pambula, Bermagui, Wolumla and (possibly) Tilba. Bega, then, is another obvious choice of centre for investigation. Long experience has shown that it pays to locate coastal stations as close as practicable to the coastline, and, as Tathra is served with a reliable power supply from the Bega Valley hydro-electric scheme, it naturally receives attention. Unfortunately, the country around this area, in common with most of the far South Coast of N.S.W., consists primarily of ironstone and granite, resulting in very poor conductivity. Tathra is in a very bad spot in this regard, and it is necessary to move back towards Bega. The results of a field strength survey from a location about half-way between Bega and Tathra are included in Fig. 2 in the form of an expected primary service area contour for 10 kW. radiated from a 190° vertical radiator. It is interesting to note that the installation near Bega will provide a markedly different service area from that given by the same type of installation near Kiama.

Assuming 10 kW. stations to be located at Kiama and Bega, there still remain Moruya and Bateman's Bay to be served, with the possibility of Milton, Narooma and Tilba, as well.

In order to examine the available alternatives, and to provide soil conductivity information about the areas concerned, further surveys were made from Narooma, Moruya, Ulladulla and Jervis Bay. The results of these surveys also are shown in the standard form in Fig. 2. The manner in which coastal transmitters give extended service areas is amply demonstrated in comparing the Bega tests with those from (in particular) Jervis Bay. The manner in which the whole area is to be served is now under consideration. The results of the surveys show how effectively Nature has complicated this consideration.

The general subject of station site selection and field intensity surveys was the subject of a recent lecture by R. Gill (1) before the Institution of Radio Engineers, Australia. It may be of interest to discuss, in some detail, the methods and equipment used by the Postmaster-General's Department in making these surveys.

(d) **Site Selection and Field Intensity Surveys:** Fig. 3 depicts schematically the set-up used on locations under investigation. The transmitter is housed in a 2-ton truck, with its power supply derived from an engine-alternator unit contained in a trailer. Both vehicles are of the enclosed type. The transmitter delivers 500 watts of unmodulated carrier into an aerial coupling unit capable of providing a correct match into a wide variety of aerials. The aerial generally used on survey work is a "T" type, 60 ft. high, with a 100 ft. single-wire horizontal top. The earth system consists of 48 radials, each 100 ft. long, laid and pegged on top of the ground. The aerial is supported by 60 ft. high demountable octagonal-section oregon masts. Each mast consists of six 10 ft. lengths with socketed joints, and stayed from three levels with four rope guys from each level.

The transmitter is capable of operation from 550 to 1,600 kc/s., and measurements are usually carried out on the frequency allotted to a proposed transmitter.

A crew of three erects, operates, maintains and dismantles the entire equipment, which may be away from Sydney for months at a time.

Once the transmitter has been set up, the aerial and earth system rigged, and the transmitter correctly coupled to the aerial, the important task at that end is to ensure that the signal radiated is maintained constant as to frequency and power. The use of a petrol engine-alternator set fitted with a centrifugal governor ensures constancy of primary power voltage and frequency. A crystal ensures stability of carrier frequency, so that the most important variable remaining is radiated power. The stable power supply helps greatly in this direction, but we find that variables in the radiating system require the close supervision of an attendant. It is desirable to use rope guys and halyards in a transportable installation of this type, and, despite precautions, rain and wind cause unwanted variations of the vertical portion of the aerial. It has been found that these variations can have marked results on the coupling of such a highly reactive aerial as this, and the transmitter operator spends much of his time ensuring that the aerial is kept taut and the aerial current correspondingly constant.

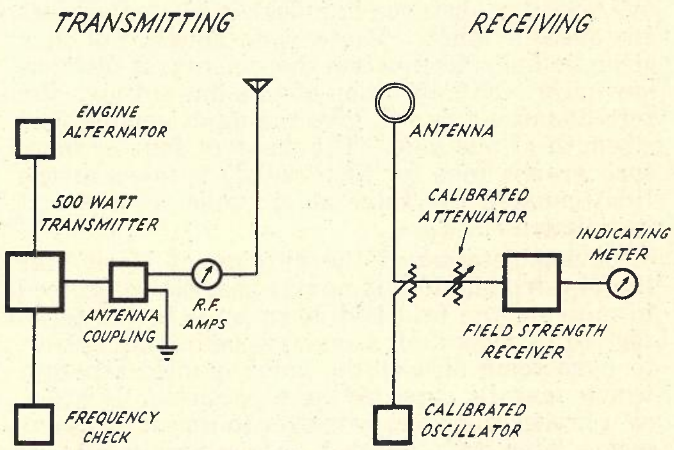


Fig. 3.—General schematic arrangement of the equipment employed by the P.M.G.'s Department for site-testing and field-intensity surveys.

The field strength laid down by this test transmitter may be measured, usually in millivolts per metre, at any desired location, by means of a Field Strength Meter, of which several types are available. The meter usually is carried in a vehicle with a wooden body, so that measurements may be made without having to remove the equipment from the vehicle. On occasion, of course, it is necessary to carry the set into a paddock, or to the top of a building, or to other inaccessible places, but such occasions are rare.

In order that we may relate the field strength received from the test transmitter to that which may be expected from the final installation, an expression, called the "Figure of Merit," is used.

Figure of Merit is a value which is designed to permit direct comparison of radiators and earth systems. It is defined as the unattenuated field strength of the system at a radial distance of one mile from the aerial. It is determined by extrapolation of a graph of measured values of field strength when these measurements have been made at radii sufficiently close to the transmitter to eliminate the factor of attenuation due to soil conductivity. Measurements made at radii between about 1 mile and 3 miles generally avoid errors due to the induction field, on the one hand, and attenuation on the other.

As the errors caused by inaccurate map-reading at short distances could produce misleading results, it is customary to use large-scale maps in carrying out Figure-of-Merit measurements. Either the 1-mile to the inch (1: 63360) Military survey maps or Parish maps are generally employed for this purpose. It is essential that measuring points are accurately located on the map, so that the radial distance to the aerial can be established. At least four radials are chosen, at 90° intervals or thereabouts, so that each radial cuts roads or fences or some other marked and clearly identifiable points on the map.

Several measurements are made along each radial, and the ED value (field strength in mV/metre × distance in miles) is plotted against Distance in Miles. These plots should fall in a straight line (attenuation due to inverse-distance law only). Extrapolation of this line through the zero distance axis will give the unattenuated field strength at one mile. The mean of four or more such graphs (one for each radial) is taken as the Unattenuated ED value at one mile for the test installation.

Having determined the "Figure of Merit" for the test installation, it now is possible to proceed to measure the field laid down by it in the territory to be served. It is as well, before doing this, to have some idea of the value of field strength which may be expected in a particular location, as it may not be an easy matter to repeat measurements later on. It is not always practical to be assured that the transmitter is radiating the correct power at the instant of measuring the field strength; sometimes, too, local conditions may cause variations from the mean district value of the field. The author has even experienced cases where power lines were hidden by trees, but were sufficiently close to cause errors.

One method of guarding against erroneous measurements is to take a large number of measurements. Another is to measure continuously from a moving vehicle. The first of these can be uneconomical, while the second may not be practical. In the author's opinion, it is best to know beforehand the approximate value to be expected. This can be predicted within reasonable limits from soil conductivity values, and comprehensive surveys of this factor have been made by the Department.

A useful reference to this work has been provided by D. McDonald (2). In continuation of this work, a large number of recent measurements made by the author indicate that two standard values of soil conductivity suffice to cover most of N.S.W. These are: 1×10^{-13} e.m.u. for "good land," such as loamy plains and slightly undulating country, and 2×10^{-14} e.m.u. for mountainous regions and residential areas. If these figures are assumed to be reasonably accurate, then all that remains is to prepare a table or a graph indicating the field strength at any given distance from the transmitting station of defined unattenuated ED value for soil conductivities of the values stated.

By this means, it is possible to check the field measurements as they are carried out, thus ensuring that local conditions are fully taken care of in evaluating the results. Measurements are taken over the whole of the area which is likely to come within the primary service boundary of the proposed installation (the contour of field strength: 0.5 mV/metre).

Since the Unattenuated ED value of the test installation is accurately determined in each case, it merely remains to multiply the measured field strength figures by a factor,

$$ED \div ED_0,$$

where ED = Unattenuated ED value of the final installation.

ED_0 = Unattenuated ED value of the test installation.

Fig. 4 shows the figure of merit for uniform cross-section vertical radiators of varying heights, for a radiated power of 1 kilowatt. Curve "A" is the theoretical no-loss curve; curve "B" shows average measured values when a good earth system is used. Some measured values for Australian

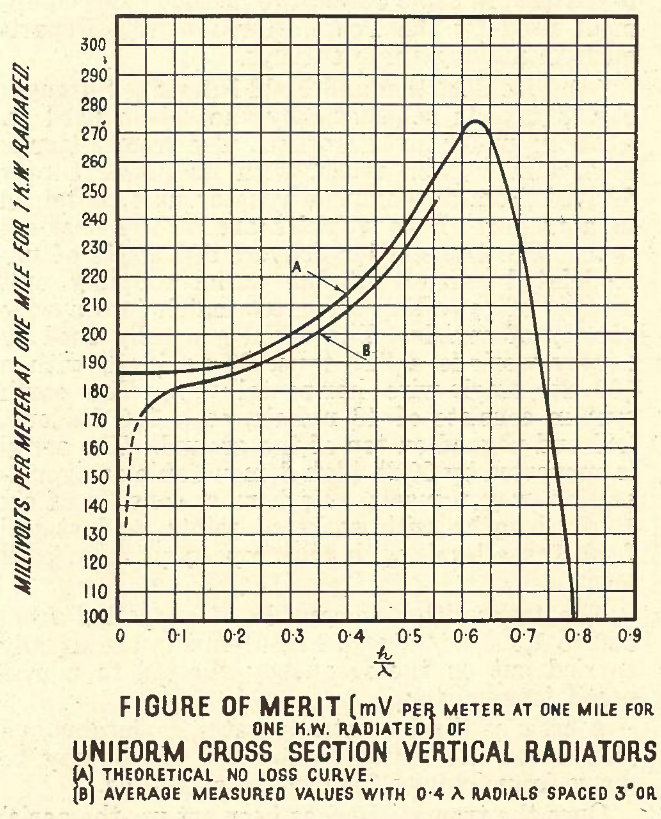


Fig. 4.—Figure-of-merit for grounded vertical antennae of constant cross-section.

National transmitters are 2CR—251, 2NR—242, 3WV—249, 4QS—243, 3LO—240. These compare with the curves in Fig. 4 which were compiled in the U.S.A. by Chamberlain and Lodge(3).

If we take the figure which measurement has shown to be 240 mV/metre at one mile unattenuated per kilowatt in the case of 3LO and multiply it by the square root of 10, we get 760 mV/metre at one mile unattenuated for 10 kilowatts. This is a typically representative figure for a 10-kilowatt station of the type used in the National Broadcasting Service, and is, therefore, chosen as a basis for estimating the service to be expected from a typical 10 kW. installation. At 720 kc/s. the Unattenuated ED value of the test installation is 64 mV/m/mile, so that the multiplying factor in such cases is $760 \div 64 = 11.88$; and, if all the field strengths measured from the test transmitter are multiplied by 11.88, the result will be the field strengths (to a very reasonable approximation) which may be expected from a 10 kW. standard installation. In the case of a 2 kW. transmitter and a 0.125 wave-length radiator, the multiplying factor would be $(180 \times \sqrt{2})/64 = 2.54$.

To indicate the degree of accuracy which can be achieved with this method of approach, the following figures, relative to 2NR, are quoted from P.M.G. Research Laboratory Report No. 88(4). The measured values were taken after the transmitter had been placed into service, while the predicted values were derived from a preliminary survey carried out some two years previously with a low-power transmitter operating on 650 kc/s. (2NR operates on 700 kc/s.) :—

Town	Predicted	Measured
Mullumbimby	0.81 mV/m	0.78 mV/m
Casino	2.3	2.5
Tenterfield	0.32	0.24—0.37
Dorrigo	0.69	0.64
Bellingen	0.48	0.49

Provision and Operation of Transmitting Stations

The general location for a transmitter having been determined by the broad requirements and by soil conductivity measurements, the next step is to fix the actual site. The transmitter power and type of antenna are usually determined by the service area requirements.

(a) **Aerial Systems:** Taking first the question of the aerial. This is a vital part of the system which must receive detailed consideration. There is no doubt that the best form of aerial for use in broadcasting stations operating on medium frequencies is the grounded vertical type. If this statement is accepted, then the only questions to be decided are the height of the mast and the physical form that it is to take.

Vertical polar diagrams of radiation from the types of aerial under consideration have been widely published (1,4), and it can be shown that best performance is achieved when, for a given transmitter, the ground wave is strongest—provided that this condition coincides with the weakest sky wave. Sky waves represent waste power in the daytime and interference, either in the form of fading or with other stations, in the night-time.

Referring again to Fig. 4, it is seen that the ground wave field intensity at a standard distance (1 mile) increases with the height of the radiator until this reaches 0.625 wavelength. Beyond this it falls rapidly. It is usual to refer to the field strength at one mile radius, expressed in millivolts per metre, per kilowatt radiated, as the "figure of merit" of the antenna.

Consideration of the polar radiation characteristics of vertical radiators in conjunction with the information contained in Fig. 4, and bearing in mind the ionospheric reflection which occurs at night-time, shows that the 0.625 wavelength radiator (the one which produces the greatest field along the ground) is not the best that can be used. The half-wave radiator produces least sky wave, while the 0.625 wavelength radiator projects a not inconsiderable signal into the sky. The best compromise lies between these two heights, and varies with soil conductivity and frequency of operation. It usually lies somewhere between 0.53 and 0.56 wavelength, and represents that value which gives the greatest fading-free coverage.

The foregoing comments apply to a radiator intended for use with a high-power transmitter (radiating 5kW. or more).

Circumstances are not likely to arise in the National Broadcasting Service which would warrant the expense of an anti-fading radiator for a small transmitter, as the large radiators are provided only to establish as great a non-fading area as possible. Low-powered transmitters cannot establish a satisfactory ground wave at the extremity of the sky wave skip distance of a 190° radiator, so that the question of fading at such distances does not assume great importance.

It is, of course, quite conceivable that in other broadcasting services factors (such as power limitation) might arise to warrant the maximum possible gain from an antenna system. In such cases, an entirely different set of circumstances would exist, and the above remarks would not apply.

For transmitters of outputs up to 2 kW., low aerials are used. As among these, there is little difference in high-angle radiation for aerials between 0 and 0.25 wavelength. Therefore, as far as fading is concerned, aerials in this range have similar properties. The field intensity of the ground wave from a 0.125 wavelength aerial is only about 0.5 db. below that from one of 0.25 wavelength, for the same earth system. For these reasons, provided low-loss inductances are used in the aerial coupling unit and a good earth system is laid down, the results from a 0.125 wavelength radiator are practically identical with one a quarter-wavelength high.

Tall masts are quite a problem, and, in 1937, A. J. McKenzie (P.M.G.'s Department Research Laboratories) evolved a design for a top-loaded radiator of physical height 0.357 of a wavelength which was electrically equivalent to one of height 0.56 of a wavelength (4). Fig. 5 illustrates the type of construction used.

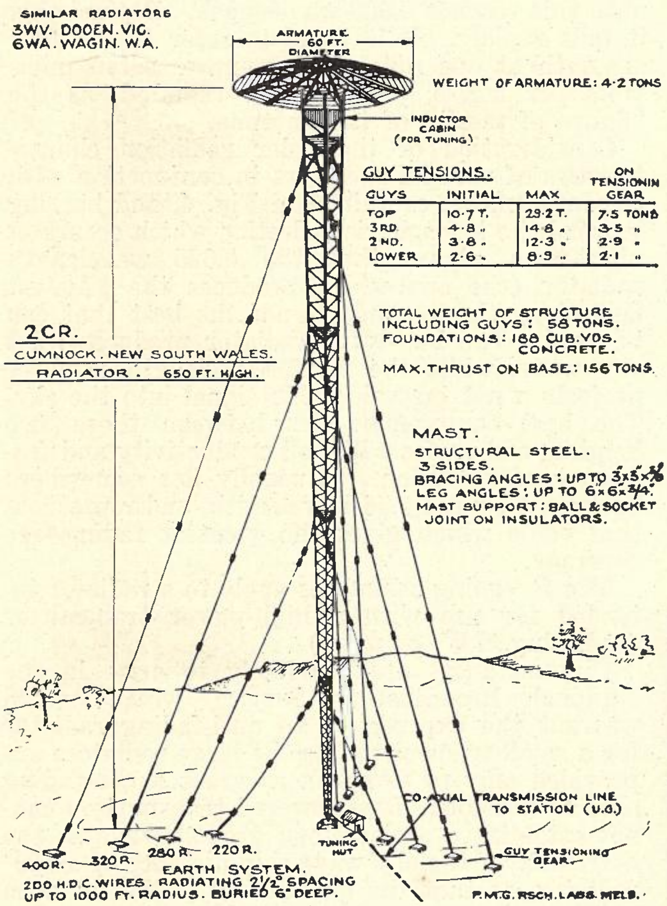


Fig. 5.—General constructional arrangement of a vertical radiator with top loading. The structure shown is that used at 2CR, Cumnock, N.S.W. Similar antenna systems are in use at 3WV, Dooen, Victoria, and 6WA, Wagin, Western Australia.

These radiators, despite their comparatively low physical height, have performances quite comparable with vertical unloaded radiators of optimum dimensions. The armature is 60 feet in diameter, and coupled to the top of the mast through an inductance. Such a radiator is used at 2CR, and is 650 ft. high. Were a loaded radiator not used, a mast no less than 950 ft. high would be necessary to achieve a similar result. The effectiveness of the armature is such that 300 ft. of mast is saved with but little variation in performance.

A departure from the loaded type of radiator is employed in Sydney, where the two 10 kW. transmitters 2FC and 2BL are both operating from the one radiator. This mast is of the constant section, unloaded type, and is 730 ft. high, thus operating at 0.46 wavelength for 2FC, and at 0.55 wavelength for 2BL.

Figs. 6, 7 and 8 illustrate some of the features of the 2FC-2BL mast structure, which, in these respects, is comparable with other tall radiators used in the National Broadcasting Service.

It is one of the requirements of the Department's specification that transmitters supplied to it must automatically trip and reset themselves in the event of an arc forming after lightning striking the radiating system. The radiator itself, also, of course, must withstand lightning.

(b) **Transmitter Equipment:** Transmitters supplied to the Department must comply with a specification which covers all details of both transmitters and ancillary equipment. The following are some typical extracts from the relevant specification:—

(a) The transmitter must be capable of operation continuously for 18 hours daily, every day.

(b) One operator must be able to bring the transmitter from the cold to the fully working condition, in complete safety and certainty, without moving away from the front of the transmitter.

(c) Complete protection to be given to personnel by means of interlocks and gate

Fig. 6.—View looking down from the top platform of the 730 ft. vertical radiator used for 2FC and 2BL at Liverpool, N.S.W. Included in the photograph are portions of the bonding system, the protected internal ladder, and the guys, coupling hut and the coaxial transmission lines.

switches which shall remove all dangerous voltages, including those due to charges on condensers, when the enclosure gate is opened.

(d) The overall frequency response to be within 1 db. from 30 to 10,000 c/s.

(e) The harmonic content to be not worse than 30 db. below the fundamental (about 3%) at 80% modulation, and 26 db. (about 5%) at 96% modulation. This is measured at 400 c/s.

(f) The noise content of demodulated output below 250 c/s. to be not worse than —60 db. below 100% modulation, and above 250 c/s. it is to be not worse than —70 db. below 100% modulation.

(g) The voltage of the predominant harmonic of the unmodulated R.F. output at full power to be not more than 0.2% of the fundamental.

(h) The stray radiated field from the transmitter when delivering full power into the artificial aerial shall not exceed 95 μV/metre at 1 kM. from a 10 kW. transmitter.

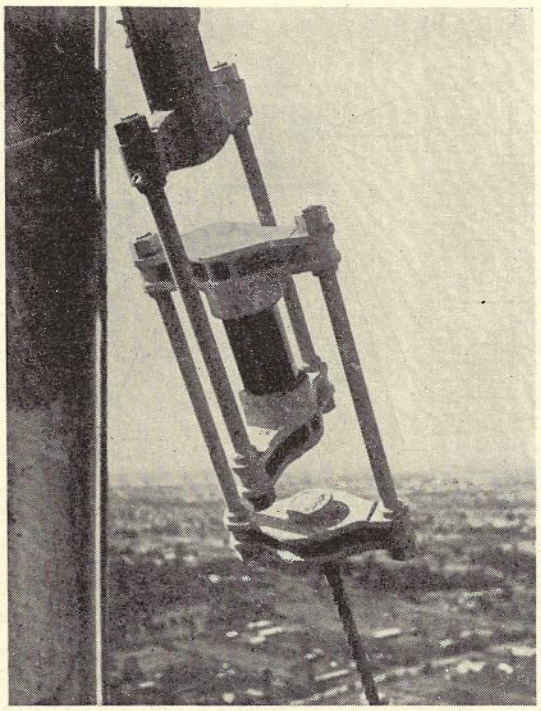


Fig. 7.—One of the guy insulators on the 2FC-2BL radiator. The upper guys on this structure are attached at the 600 ft. level—130 ft. from the top.

Daily and weekly routine checks show that the above limits are not exceeded by N.B.S. transmitters unless fault conditions develop. The routine measurements are an insurance against interruptions due to breakdown during transmissions.

Records of transmitter interruptions during the months of June and July, 1947, show that 2FC suffered a total of 29 interruptions. Of these, 25 were due to commercial power failure, the remaining 4 being all due to mercury-vapour rectifier failure. The duration of the longest interruption was 90 seconds.

As standard equipment, all transmitting stations are supplied with a beat frequency oscillator, Noise and Distortion meter, and Modulation

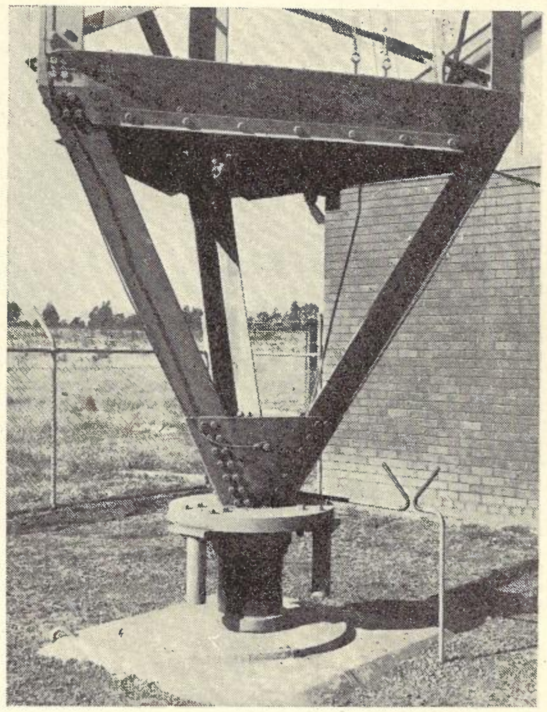


Fig. 8.—Base of 2FC-2BL radiator, showing base insulator and safety pegs, bonding cables, lightning discharge horn-gaps, and feeder to coupling hut.

Monitor. All stations also have stand-by power plant.

As an example of the grade of service maintained, measurements made during July, 1947, give the following frequency response:—

	35	50	100	1000	3000	5000	7000	10,000 c/s.
2BL	0.8	0.7	0.4	0	0.1	0.1	0.6	—1.7 db.
2FC	0	—0.6	—1.3	0	—0.1	0	0.5	3.4 db.

The above measurements were made overall from the studio amplifier input to the demodulated output of the transmitter, and include the programme line in each case. The frequency checks are broadcast on Thursday evenings after the normal programme has concluded, and could be used as a check of any receiver. It is suggested that those able to do so measure the output of a normal radio receiver during one of these tests—the results, in most cases, will be rather surprising.

All the high-power transmitters in use to date employ water-cooling of the final amplifier anodes, and Fig. 9 illustrates the main and stand-by water pumps at 2FC, Liverpool. Fig. 9 also illustrates the induction-type voltage regulator at 2FC. This carries the total load of the transmitter and compensates for a large percentage of the power supply variations.

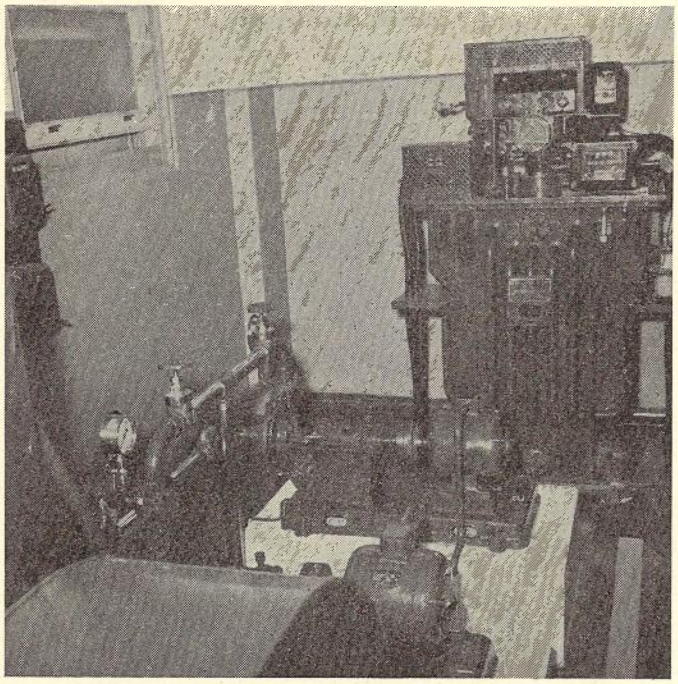


Fig. 9.—Main and stand-by water-circulating pumps at 2FC. At right rear of the illustration is the induction-type voltage regulator which controls the three-phase AC input to the transmitter.

Anode supply for the final amplifiers is provided at 12,000 volts by a 3-phase, full-wave rectifier utilising hot-cathode mercury vapour tubes.

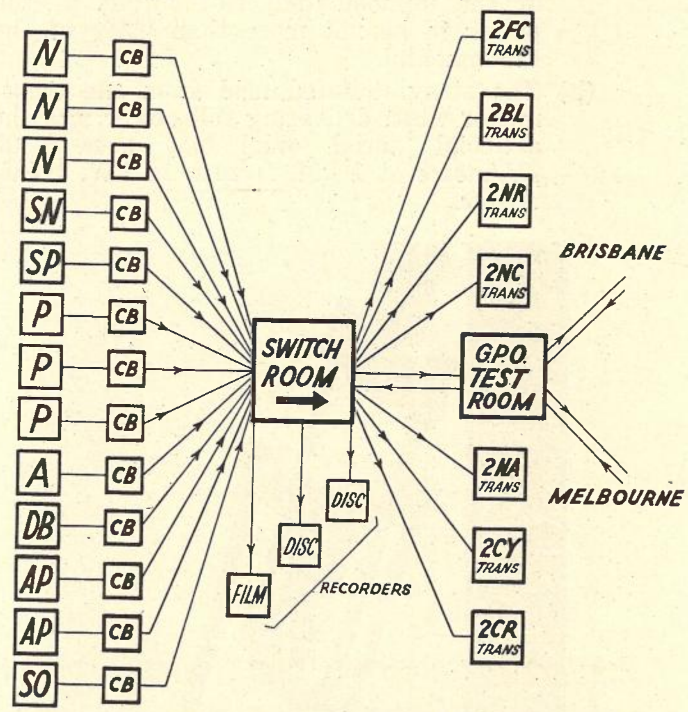
Transmitters are delivered from the manufacturer in more or less unit form. They are installed by Departmental staff skilled in fitting, cable-laying and similar trades associated with this type of work. Aerial masts are provided and installed by the contractor, and the associated earth system and transmission line for each is installed by Departmental staff. Most of the older installations used a co-axial transmission line coupling the transmitter to the radiator, but, following on the successful application of the 6-wire line to 2BL in 1942, the present tendency is to use this form of line in all new installations.

The N.B.S. Studios

Practically all the programme material broadcast over National stations originates in (or is routed through) the capital city studios. There are studios associated with each regional station, but these, in general principle, are very similar to the Sydney studios. For this reason, it is not proposed to deal with them in detail.

It was pointed out earlier in this article that, under the Act, the ABC is responsible for providing the programmes and studio buildings, including acoustic treatment. The Postmaster-General's Department, as the provider of technical services, provides, instals, operates and maintains all the technical facilities associated with the studios, as well as the remainder of the service.

(a) **General Arrangement:** There are thirteen studios in Sydney, not all in the one building. Fig. 10 illustrates in block schematic form the general electrical arrangement by means of which the output of all studios is routed through what might be called the "nerve centre" of the National System in the State. Through this room pass programmes from outside broadcast points to studios, from studios to transmitters, from State to State, or from any of these sources to any of three separate recording systems.



Legend: N—Network studio; SN—Sporting and News studio; SP—Sporting and Production studio; P—Production studio; A—Announcing studio; DB—Dance Band studio; AP—Audience Participation type production studio; SO—special studio for Sydney Symphony Orchestra; CB—Control Booth.

Fig. 10.—Block diagram showing general programme routing arrangements at the Sydney studios of the National Broadcasting Service and the Sydney G.P.O. Test Room.

Fig. 11 shows, also in block schematic form, a typical studio-control booth combination. Every studio has a control booth attached to it. This follows American practice and was adopted by the Department as a standard arrangement for National Studios in 1937. In the Studio proper, the announcer has available to him two microphones, with keys to switch them on or off; two gramophone turntables and reproducers, with both keys and faders, together with facilities for listening to records on headphones without necessarily broadcasting them; headphones for moni-

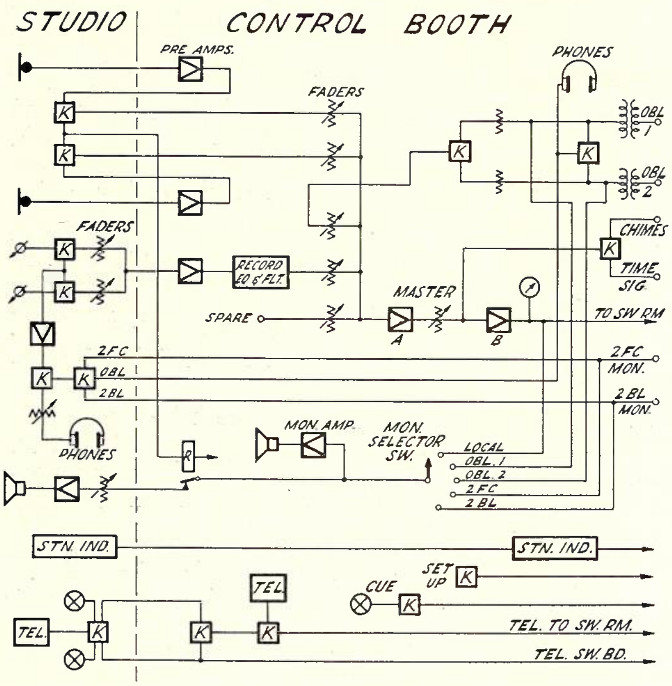


Fig. 11.—Block schematic diagram of programme circuit arrangements at an N.B.S. Network studio.

toring outside broadcast lines or the National or Interstate programmes; and a high-quality loudspeaker for normal listening. He also has a bank of indicator lamps to show which transmitters are radiating his programme, and a telephone fitted with lamp-calling indicators.

In the control booth is a standard rack fitted with all the necessary amplifiers and associated equipment, including gramophone equalisers and filters. The control operator sits at a desk which mounts microphone and phonograph mixers, a master level control, volume indicator, and control keys. He also has a bank of indicator lamps similar to those in the studios, together with an additional bank which indicates those transmitters he may be about to take on or drop off his outlet. Fig. 12 shows a typical lamp indicator bank of this type. The control operator, who sits in a position giving him full vision of the studio, also intercepts all telephone calls to the announcer, thus relieving the latter of the embarrassing decision of whether to talk on the telephone or into the microphone.

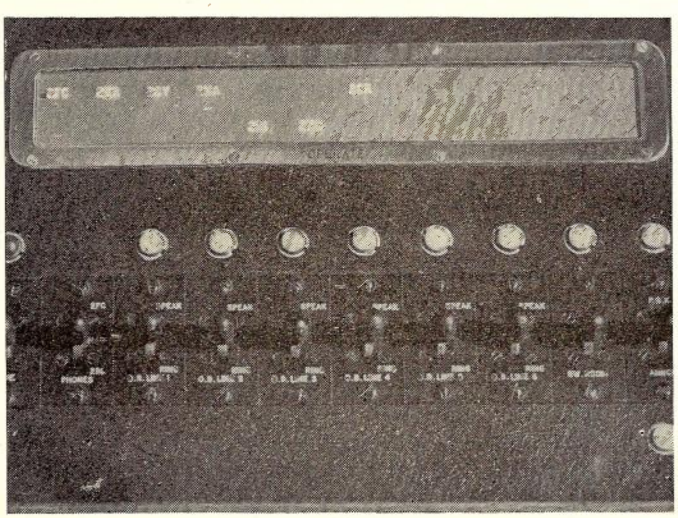


Fig. 12.—Illuminated station indicator and key panel in an N.B.S. Sporting studio control booth. Transmitters radiating programme from this studio are shown in the lower group, while the upper group indicates transmitters about to take the programme.

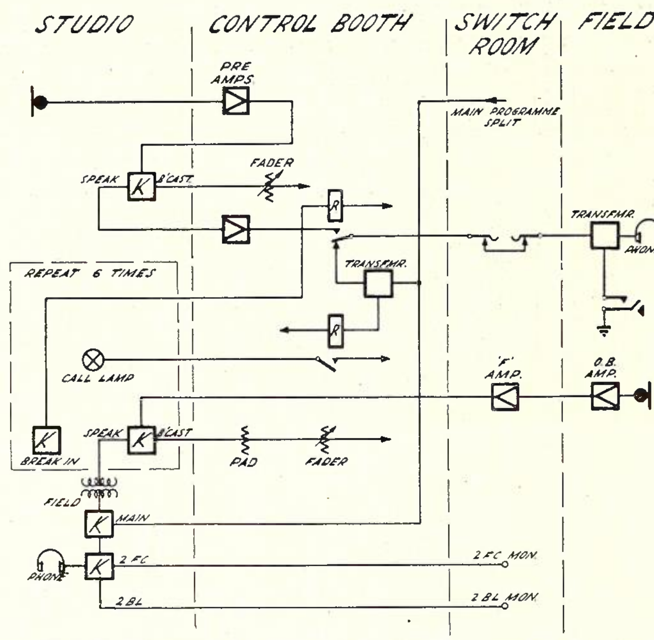


Fig. 13.—Simplified block schematic diagram of circuit arrangements at an N.B.S. Sporting studio.

(b) **Outside Broadcasts:** Fig. 13 depicts the arrangement of equipment installed in the two sporting studios. This has been specially devised for good presentation of sporting programmes, but lends itself admirably to any other type of outside broadcast in which a multiplicity of announcers participate.

Provision is made in this equipment to handle up to six outside points. Main features are:—

(a) Broadcasting from the studio or any of six points—either individually or simultaneously or in any combination.

(b) The control announcer (at the studio) can converse with any or all of the outside operators at will—the conversation being broadcast or not, as desired.

(c) The studio announcer also can break in on an outside commentary—either by superimposing his voice over that of the commentator, or by speaking to him via his headphones and requesting that he terminate his commentary.

The operation of the above facilities is as follows:—

In the case of (a), either the control announcer or any of the outside announcers is put on the air by the operation of the associated "Broadcast" keys and faders.

When wishing to avail himself of facility (b), the control announcer operates his own key to "speak" and the chosen OB keys to "Speak" and "Break In." This permits conversation on a 4-wire basis. Should it be desired to broadcast the conversation, then both keys are operated to "Broadcast" and the "Break-In" key restored. This permits both announcers to monitor the programme with headphones.

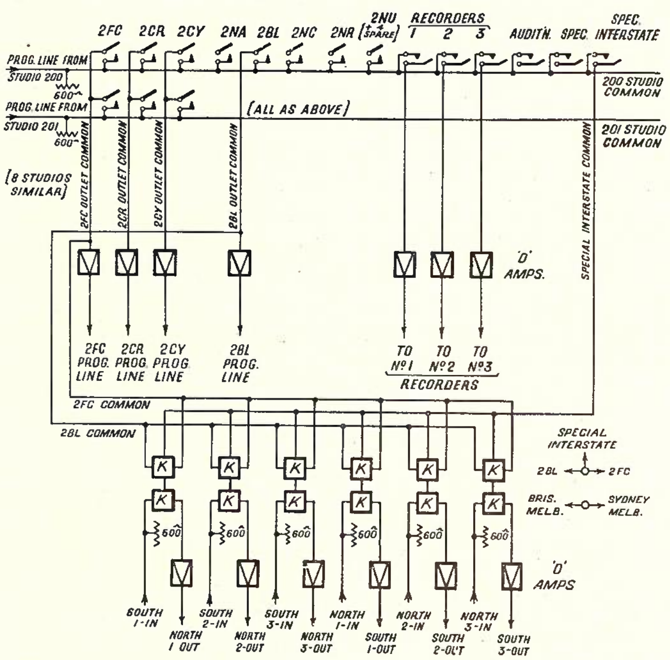


Fig. 14.—Simplified schematic diagram of the programme switching facilities at the Sydney studios of the National Broadcasting Service. This equipment is installed in the Switch Room (Fig. 16). The relay contacts in the outlet circuits are those associated with relay "BA" in Fig. 15.

The two studio arrangements just discussed may be regarded as typical of the whole set-up. The studios themselves, however, vary in size and facilities, depending on their use.

(c) **Programme Switching Facilities:** Fig 10 indicated that all studio outputs were routed through the switch room. Reference to Figs. 14 and 15 will show, in simplified form, the circuit arrangement used. This system has been in use since 1938, and gives very flexible operation with low fault liability.

Fig. 16 illustrates the main control panel in the Sydney Switch Room. An important feature of this installation is the use of a unit power supply for high tension requirements of all amplifiers. Experience has shown that in such a large installation a multiplicity of power converters tends to render the room excessively hot—even to the point of discomfort. The use of a spare power converter with automatic change-over facilities takes care of component failures.

The switch room may be regarded as the nerve centre (in perhaps more senses than one!) of the whole set-up. All outside broadcast lines terminate here and are tested for any possible type of fault (short circuit, open circuit, loss to ground or between conductors, or noise induction). Through the "F" amplifier rack these lines are extended to the various control booths after equalisation and amplification to provide a standard input level to each control booth. Some of these lines are permanent (such as the Town Hall, certain Churches, etc.), while others are extended through the underground cable network to whatever points may be required for outside broadcasts.

Other lines feeding programme into the switch room for passing on to studio control booths originate from the Test Room (G.P.O.) for Interstate programmes or broadcasts from country centres, and from the Sydney Observatory for time signals. A line also was provided from the G.P.O. tower in pre-war days for broadcasts of the clock chimes.

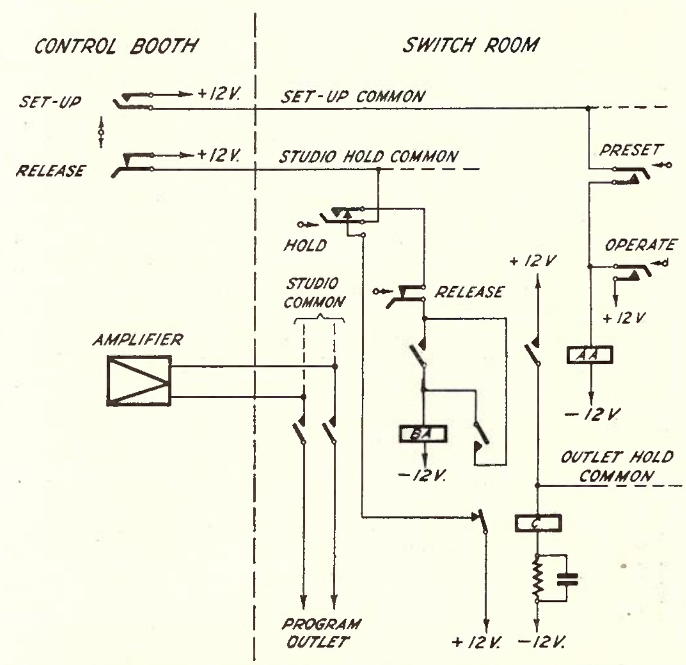


Fig. 15.—Simplified block schematic diagram of the switching relay circuit used in the N.B.S. Sydney studios.

Facilities exist also for splits (or "samples") of the various programmes to be divided and wired to monitoring points in various parts of the city. By a system of key switching, instantaneous monitoring facilities exist which enable the senior technician in the Switch Room rapidly to check the programmes at the first point of arrival in the Switch Room and the last point of departure. In addition, the extensive use of strapped jacks enables quick checking for fault location and rapid replacement of faulty equipment.

Before leaving the Switch Room, it will be of interest to mention the monitoring receivers used

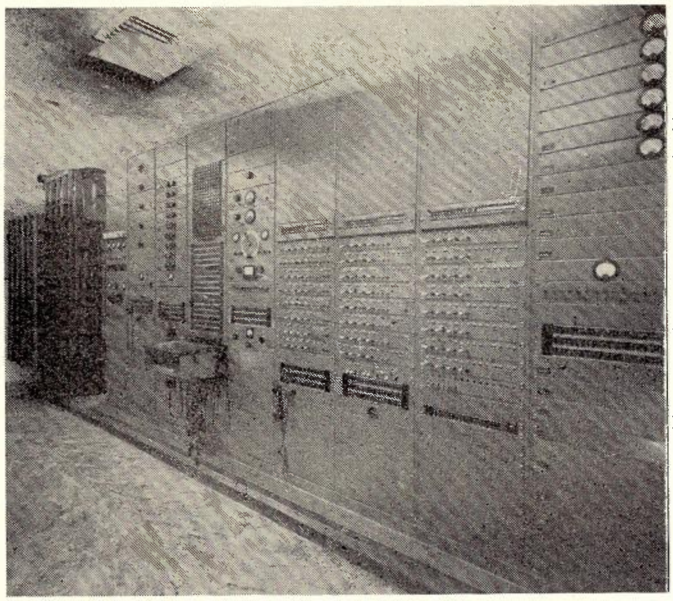


Fig. 16.—General view of the main control panel in the Sydney Switch Room of the N.B.S. Included in the illustration, from left to right, are the main distributing frame; power supply; monitoring amplifiers and receivers; "F" amplifiers; OB lines rack; test rack; and two bays of studio switching equipment.

by the Department for many years, and which contain two features of great importance. The first is quality—a MUST in any broadcasting system worthy of the name. This is achieved by using a broadly-tuned two-stage TRF amplifier and a cathode-follower fed diode detector. A great deal of research has proved this to be the best combination for the purpose. The second feature is the use of the DC component of the demodulated carrier to operate a relay which sounds an alarm and automatically changes over all the studio monitoring circuits in the event of transmitter carrier failure.

The broadcasting of Federal Parliament is perhaps worthy of mention in passing. The arrangement is such that one may regard the House of Representatives and the Senate Chamber as two studios. Each is fitted with microphones on stands, and there is a built-in control booth in both cases.

The microphone layouts have been designed to give the best coverage without disturbing Parliamentary procedure. The associated equipment is very similar to a standard studio set-up, with two major exceptions. The first is the use of a limiting amplifier to take care of violent level fluctuations. The second is a specially-arranged microphone mixing panel. This is in the form of a plan of the House with the mixer for each microphone located on this plan in the same relative position as the associated microphone in the House. The plan is engraved to indicate the acoustic coverage of each microphone to make the operator's work as simple as possible. Associated with each mixer is a push-pull type of switch, by means of which a microphone may be brought into use with the mere flick of the finger.

(d) **Recording Facilities:** Before leaving the subject of the studios, perhaps a word or two about the electro-acoustic transducers might not be amiss. For some years crystal pickups have been used for gramophone reproduction, but lately these are in process of being replaced by Australian-made moving-coil units with greatly improved performance. These units have a response flat to 1 db. from about 20 c.p.s. to more than 8000 c.p.s. They have no resonant peaks within the audible range and introduce very little harmonic distortion into their output.

Associated with the general Studio arrangement, there are three stationary recording systems, as well as three portable disc recorders of high quality, one mobile recording van, two wire recorders, and two lightweight Portable Disc units for field work.

Features of the two disc recording installations at the Sydney Studios include the use of limiting amplifiers to drive the cutting heads; automatic equalisation for large (16 in.), $33\frac{1}{3}$ r.p.m. recordings; and diamond-point moving-coil reproducers for dubbing and checking acetate discs.

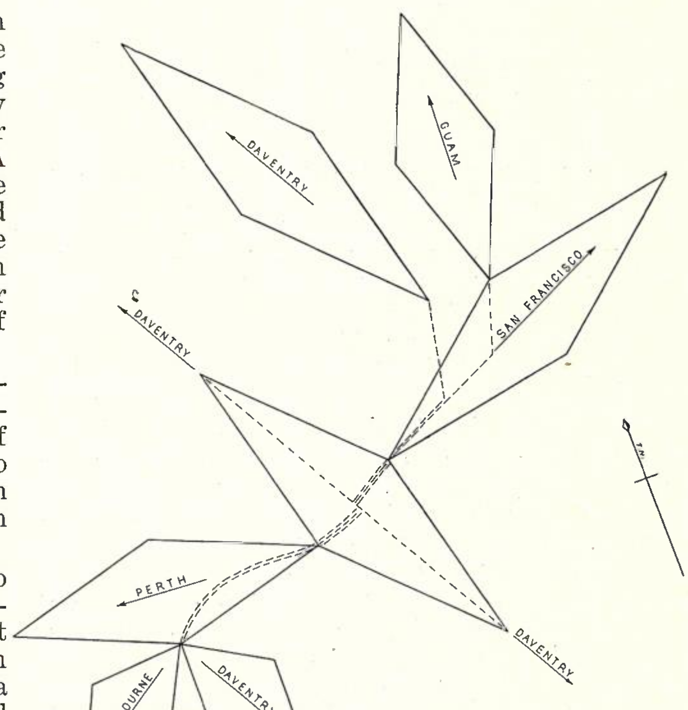


Fig. 17.—Plan of the aerial arrangement at the Postmaster-General's Department Radio Receiving Station at Liverpool, N.S.W.

Disc recording is very extensively used in the National Service. It represents a convenient method of storing programme material and is quick and comparatively inexpensive. The Department first installed disc recording equipment in Sydney in 1935.

A more expensive and more complex recording system is also used in the Sydney Studio set-up. This is the "Philips-Miller" system, which is capable of great fidelity of reproduction combined with low noise level, and incorporates a fool-proof cueing system, by means of which it is possible to record programmes of any length whatever, and reproduce them without any break in the continuity. This system of recording has been described fully in literature, and a particularly comprehensive review of its characteristics was given in a paper presented before the World Radio Convention by S. J. Rubinstein ([5]).

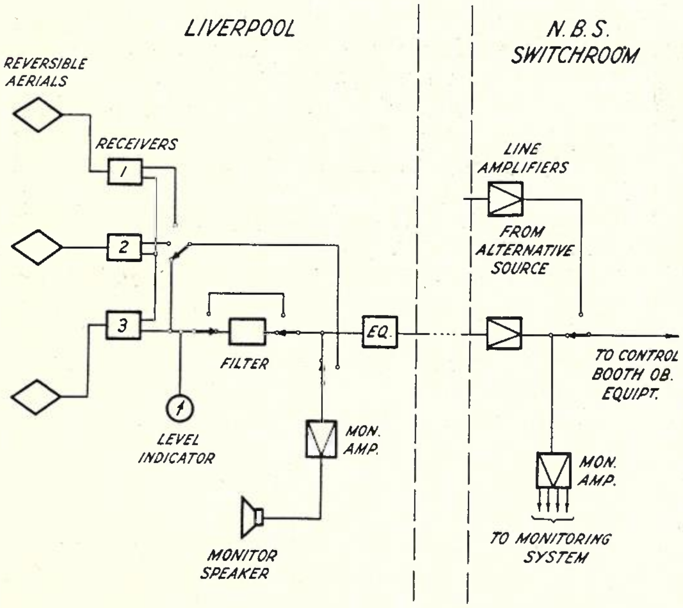


Fig. 18.—Simplified block schematic diagram of the circuit arrangement used for reception and re-broadcasting of overseas programmes.

The Receiving Station

A not unimportant source of programme input is that of international broadcasts. The BBC News is typical of these. In N.S.W., the source of rebroadcasts of this nature is the Departmental Receiving Station at Liverpool.

Fig. 17 shows the aerial and feeder systems at the Liverpool Receiving Station. Provision has been made for diversity reception from London over either the long or short route. Aerials also have been provided specifically for reception from Perth, Melbourne, Brisbane, Guam and San Francisco.

The station was designed to accommodate six receivers having access to eleven aerial systems. Each receiver input is cabled to an aerial selector switch, rotation of which provides the necessary choice of aerial. By means of key switching, each receiver's output may be switched to one of three programme lines to the studios. The receivers employed for rebroadcast purposes are fitted with internal coupling arrangements for diversity working. During the war, activities at this centre were increased by the handling of all inwards traffic for the British Pacific Fleet. Five groups of receivers were provided with access to the aerial systems by means of co-axial patch cords.

Fig. 18 illustrates the set-up employed when rebroadcasting overseas programmes. The filter passes frequencies between 250 and 3000 c/s.

Programme Lines

It is, of course, not practicable to operate a broadcasting service on a National basis without the aid of programme relay lines. This matter was very completely covered in a paper presented before the Institution of Radio Engineers, Australia, by R. Lawson ([6]), and it is proposed to deal but briefly with this important aspect of National broadcasting. Apart from the immense technical resources it is able to command, and from which it can draw to meet all contingencies of National broadcasting, the P.M.G.'s Department is able to make use of its widespread network of trunk lines to provide programme relay facilities of a high standard.

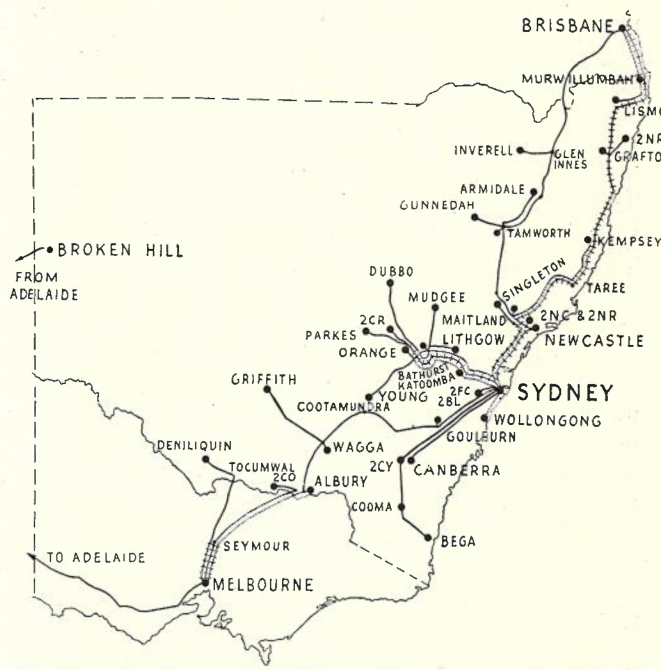


Fig. 19.—Circuit map of N.S.W., with connections to adjoining States, showing manner in which the trunk line network is brought into use for hook-ups involving both National and Commercial broadcasting stations.

Fig. 19 indicates how a network is provided for a hook-up of both National and Commercial stations. The full lines indicate physical programme circuits, while the broken lines show carrier circuits. It should be mentioned that certain country commercial stations rent permanent programme lines from Sydney, and these are not tapped for National relay.

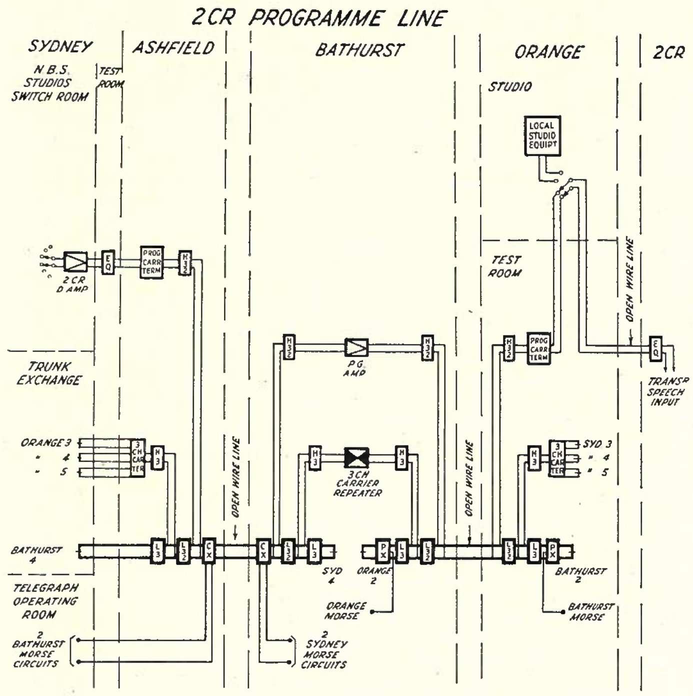


Fig. 20.—Block schematic diagram of the superposing system used to carry the 2CR programme over existing circuits. These circuits already carry two additional telegraph and three additional telephone channels.

It costs a considerable amount of money to provide and maintain pairs of wires over long distances, so that the maximum use must be made of such lines if the capital outlay is to be recouped within a reasonable time. In order to demonstrate one method of doing this, Fig. 20 has been prepared. This shows how a permanent programme relay line is provided to Cumnock for 2CR, while multi-channel telephone conversations and telegraph messages take place over the same line. 32 kc/s. filters separate the programme carrier system from the remainder of the circuits, while 3 kc/s. filters separate the physical circuit from a 3-channel carrier telephone system.

On interstate lines traffic requirements are much more severe, and Fig. 21 shows how broadcast programme channels are provided on lines which are bearer circuits for a comparatively enormous number of standard communication channels. In this case, 5.5 kc/s. filters separate the programme (which is carried on the physical line) from a 3-channel telephone carrier system. In turn, 32 kc/s. filters separate this 3-channel system from a type "J" 12-channel carrier telephone system. In the case shown, one of the 12 "J" telephone channels is used as a voice-frequency bearer circuit for a 24-channel VF telegraph system.

Although the examples shown are of circuits provided over physical (open-wire) lines, the modern tendency is to use underground trunk cables to an increasing degree. Such a cable is in use between Sydney and West Maitland, and carries all traffic north of Sydney. A second cable is at present being laid between Sydney and Bathurst, and it seems probable that we shall ultimately see one provided to link Sydney and Melbourne.

Tenders also have been called by the Department for the supply of V-H-F radio bearer circuits for multi-channel telephony and telegraphy, with provision for programme relay facilities. The future of this type of equipment seems assured, and trials with which the author has been associated indicate that it has some interesting possibilities.

Programme relaying is an important function of this section of the Engineering Branch, although it is small when compared with the provision of communication channels. As a matter of interest, there are 570 trunk telephone channels and about 800 telegraph channels radiating out from Sydney. Notwithstanding this, the Test Room in Sydney handles no less than 120 separate relays of programmes every Saturday, which is their busiest day. It readily may be imagined just what this means in terms of thought and organisation.

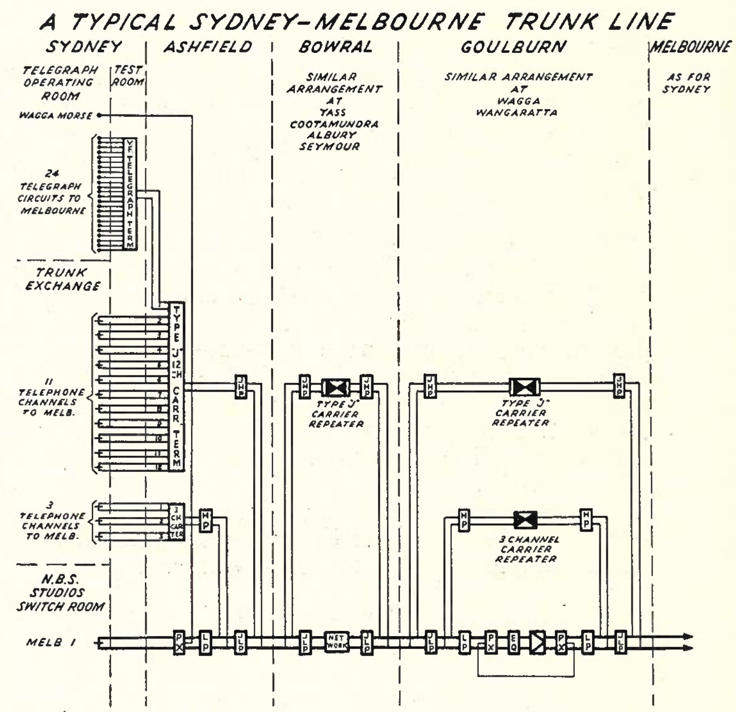


Fig. 21.—Block schematic diagram of a Sydney-Melbourne trunk circuit, in which the physical line is the actual programme line. A carrier system on this line provides an additional 25 telegraph and 14 telephone circuits over the same pair of wires.

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MATERIAL TESTING, SYDNEY LABORATORY

F. H. MacDonald

Introduction: The Material Testing Section in New South Wales is responsible for checking and testing engineering supplies and recommending their acceptance to the Superintendent, Stores. When it is realised how important are the communication services operated by the Department, and that the value of new material purchased annually amounts to millions of pounds, the need for taking all reasonable steps to ensure that no faulty or unsuitable material goes into service, does not need emphasising.

Historical: Prior to 1925, the material testing staff was located in the G.P.O., and consisted of an Engineer and Senior Mechanic only. With the introduction of collective schedules, the use of sealed patterns alone to indicate the material required by the Department was gradually abandoned in favour of the use of specifications and drawings, and this enabled a much higher degree of standardisation to be achieved. These changes in procedure resulted in a need for more staff and equipment to carry out the increasing number of tests. As additional floor space was required also,

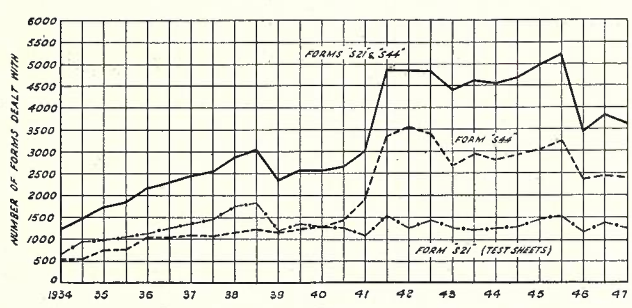

Fig. 1.—Graph showing growth in volume of testing.

the laboratory was removed to the then newly-erected City South exchange building in Castlereagh Street, Sydney. The quantity of material supplied by local manufacturers increased steadily in volume until 1939 and, during the period of World War II, the increase was very pronounced. Throughout the war years the Department's material testing organisation was used to check signal supplies for the Allied armed forces, and 12 testing officers were employed on this work, which included the initial stages of certain radar projects. Some idea of the growth that has taken place in the material testing organisation in New South Wales can be judged from the two graphs, Figs. 1 and 2. Fig. 1 shows the number of Forms S21 (test sheets) and Forms S44 dealt with over the period 1934-1947. The test sheet is issued on all deliveries of material purchased under contract and delivered into the local Stores, whilst the Form S44 covers the inspection of locally made material at the contractor's premises, including material destined for other States. Fig. 2 indicates the growth in testing staff.

Organisation: The testing laboratory and field inspection staff are controlled by an Engineer, under the supervision of the Divisional Engineer, Procurement and Material Testing. The testing staff consists, at present, of 1 Supervising Technician, 14 Senior Technicians, 5 Technicians, 1 Line Foreman and 1 Carpenter. Of this number, 3 Senior Technicians are stationed permanently at contractors' premises where the volume of in-

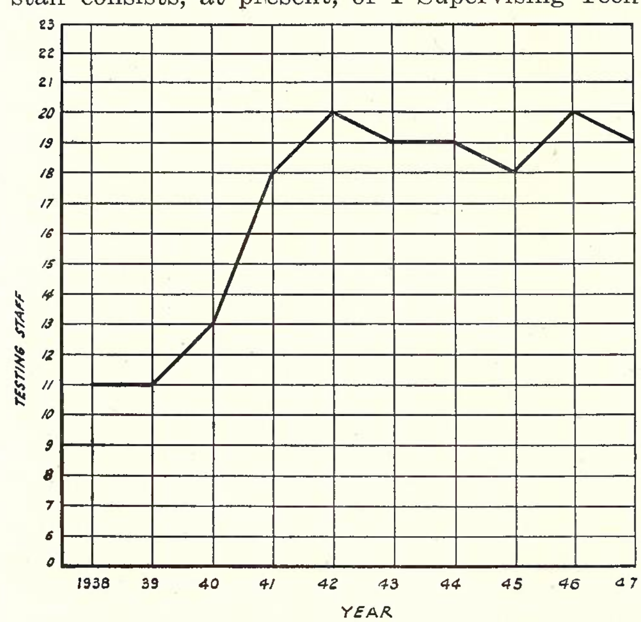

Fig. 2.—Graph showing growth of material testing staff.

spection is such as to warrant this arrangement. With the continued expansion of local production of engineering supplies, consideration may need to be given to locating staff in additional factories. As far as practicable, an endeavour is made to train each testing officer to become sufficiently versatile so that he can relieve any other testing officer as occasion arises. Apart from the relief consideration, staff flexibility is desirable, because of the wide range of material which is coming forward continuously for acceptance testing. Where working tests are required, reference is made to the Section with the most suitable facilities for carrying out such tests. For example, automatic exchange maintenance parts must,

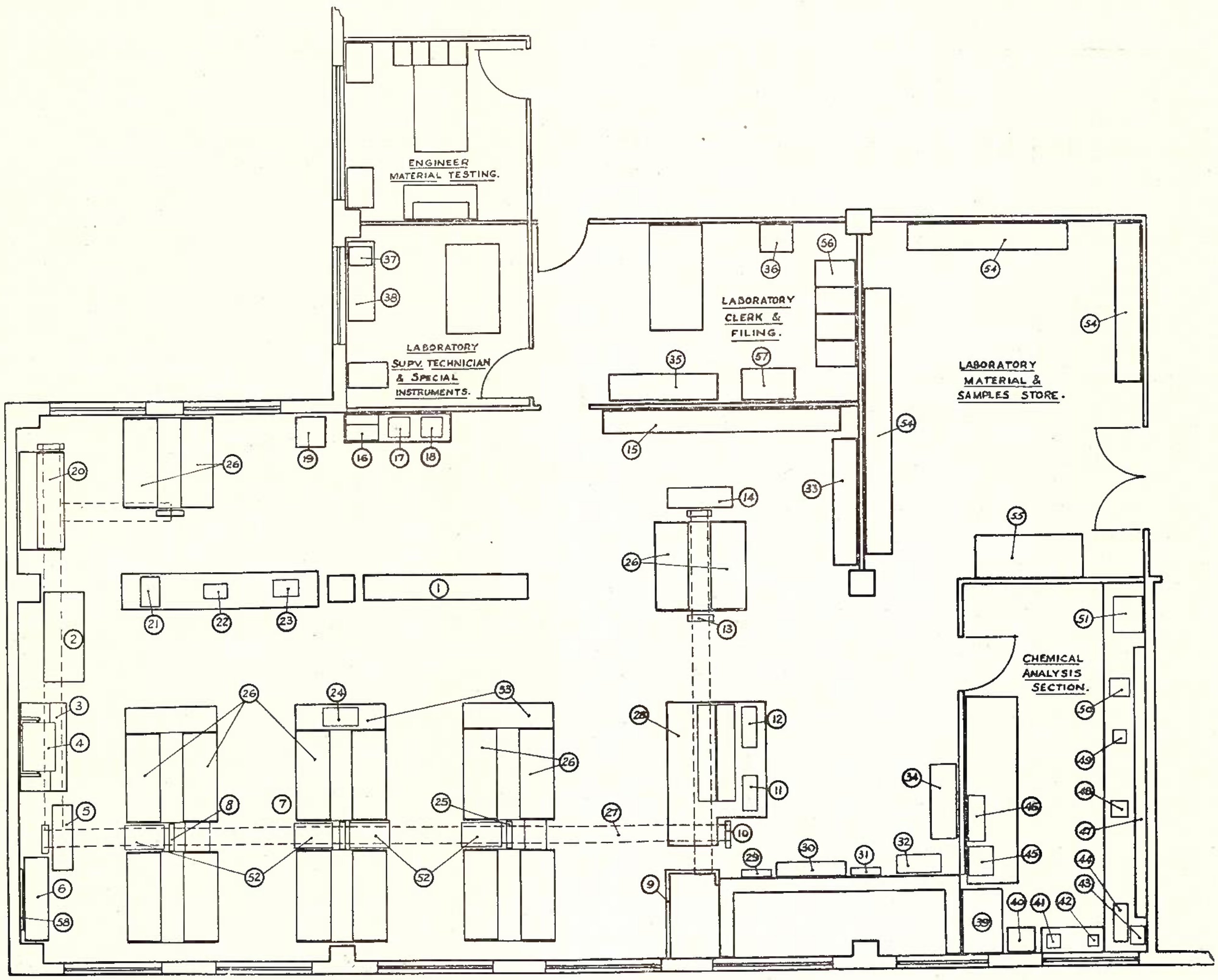

Fig. 3.—Layout of material testing laboratory, Sydney.

KEY TO PLAN

1. Tensile strength machine.
2. Wheatstone bridge (Silvertown).
3. Low resistance bridge (slide wire).
4. I.R. testing drum.
5. Telephone efficiency tester.
6. Torsion machine.
7. Heterodyne oscillator (0-15 kc/s.).
8. Valve testing panel.
9. Main power board.
10. Voice frequency repeater.
11. Ringing machine (16-2/3 c/s.).
12. Motor-driven megger (500V).
13. Lamp life testing apparatus.
14. Telephone dial tester.
15. Dry cell testing apparatus and storage shelves.
16. I.R. bridge (Leeds and Northrup).
17. Laboratory standard voltmeter.
18. Laboratory standard ammeter.
19. Immersion tank (for cables, etc.).
20. Transmission test desk includes amplifier, attenuator, cathode ray oscilloscope, cross-talk meters, capacity unbalance sets, etc.
21. Impedance bridge (General Radio).
22. Capacity bridge (General Radio).
23. Multiversal test set.
24. Scales and weights.
25. High tension (A.C.) testing panel.
26. Testing officers' test desks.
27. Power runway (overhead).
28. Equipment storage (resistances, etc.).
29. D.C. power board.
30. Accumulator charging cabinet.
31. A.C. power board.
32. Porosity tester (Massey).
33. Instrument press includes ammeters, voltmeters, wattmeters, etc.
34. Instrument press includes meggers, resistance boxes, etc.
35. Standards press includes all sub-standard meters, etc.
36. Precision gauges' cabinet (micrometers, verniers, etc.).
37. Hardness test (Firth Hardometer).
38. Cabinet containing special instruments and sample timbers.
39. Fume chamber.
40. Electric oven (Moffat, 600°F.).
41. Autoclave oven (358°F.).
42. Gas ring.
43. Electric water still (Elliotts).
44. Tiled acid resisting sink.
45. Viscometer (standard "U" tube type).
46. Chemical balance (Oertling).
47. Reagent cupboard.
48. Water turbine centrifuge.
49. Microscope (Voigtlander).
50. Pyrex desiccator.
51. Humidity chamber and control gear (Foxboro).
52. Filing cabinets (drawings).
53. Storage for material under test.
54. Storage shelves.
55. Packing bench.
56. Filing cabinets (contracts).
57. Filing cabinet (specifications).
58. Tool shadow board.

apart from other requirements, be checked for interchangeability with those in use.

Laboratory: Fig. 3 shows a floor plan and layout of the laboratory, and the key to the plan indicates many of the machines and instruments with which it is equipped. The area is approximately 2000 square feet, and the layout has been arranged so as to provide each man with good lighting and suitable power facilities close to his test table. Fluorescent type artificial lighting is installed. The disposition of the main instruments is such that, as far as possible, tests of similar nature may be made with ease and expedition; e.g., chemical and physical testing apparatus is grouped together, as is also equipment necessary to carry out life tests on switchboard lamps, batteries, etc. Test voltages are patched from a central power distribution board to each test table, the cabling being carried on overhead runways to patching panels fitted to standard 10′ 6″ racks. A range of voltages up to 480 DC and 415 AC, together with a 75 volt 33 c/s tone, are readily available.

Instruments and apparatus which are in almost daily use are rack-mounted, where practicable. These include the telephone efficiency tester, vacuum tube test set, Ryall Sullivan oscillator. high voltage breakdown set, and telephone dial tester. AC and DC bridges are mounted on tables for convenience in use. Laboratory "standard" instruments are normally kept in cupboards, and are only set up for use when required. A large number of testing instruments, of the ammeter and megger types, are stocked for use in the field and for loan to other Sections. Facilities are available for carrying out most chemical and physical tests required by the Departmental specifications, such as tests for quality of solders, sulphuric acid, creosote oil, lubricating oil, concrete, waxes, etc. Figs. 4 and 5 show views of the general testing and chemical sections, respectively.

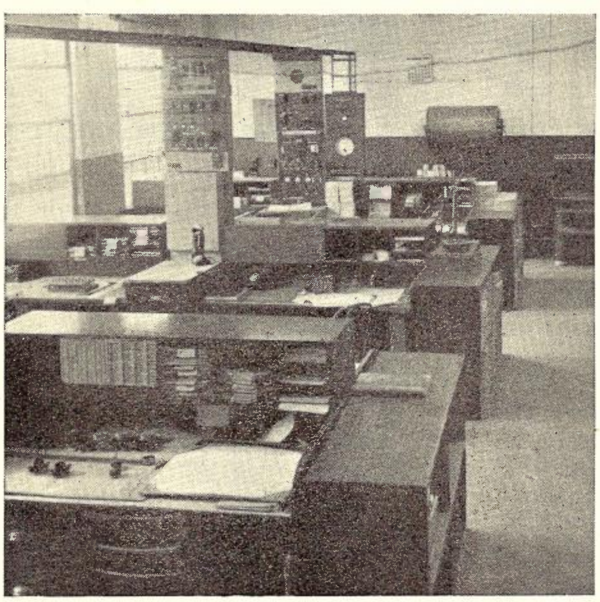

Fig. 4.—General testing section.

Sampling: One problem associated with the testing of supplies is in deciding the percentage of each delivery which should be tested. A few examples will help to clarify this point. Assume that a parcel of 1000 transposition spindles, valued at approximately 1/6 each, is to be accepted. The spindles are purchased to a specification and drawing which provides, amongst other requirements, for a galvanising test; an analysis of the lead head for antimony content; cantilever stress measurements, and, of course, a check on dimensions. It will be appreciated that it would be practicable to make these tests on a very limited number only, otherwise a condition may be reached where the cost of inspection approaches the cost of the article. These spindles, however, are a most important link in line construction, and are subject to conditions which could, if one or more failed, cause serious interruptions to trunk line services. It is apparent, therefore, that despite the low cost of the article a considerable amount of checking is justified, to ensure that the delivery will give satisfactory service when in position in the field. To meet cases such as these, "go" and "no go" gauges are employed, as much as possible, to reduce testing time, and a plate gauge is used to check the dimensions, position of lead head and thread formations. Providing all the samples are satisfactory in these respects a check of 5% of the delivery should normally suffice, as far as these matters are concerned. Usually, 10 samples would be sufficient to check the quality of the galvanising, antimony content of the lead head, and cantilever stress measurements. It might be mentioned here that samples are selected by the testing officer, the usual practice being to take them at random from the parcel submitted. In addition, a visual examination would be made of at least 50.

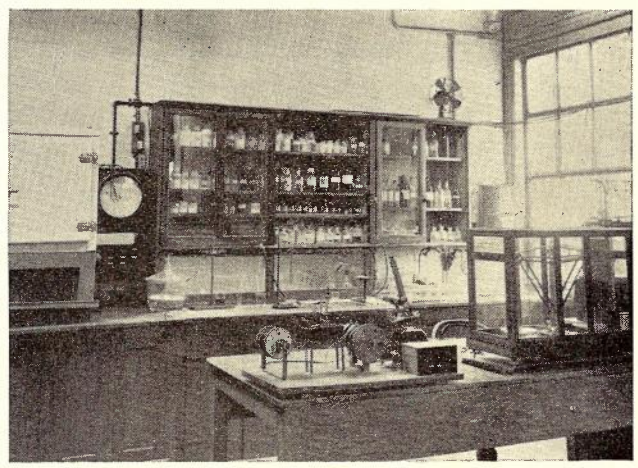

Fig. 5.—Chemical laboratory.

Each lineman's belt is tested separately for tensile strength, and 100% inspection is made for any defect whatsoever. (Fig. 6 shows a belt undergoing a tensile test.) The importance of testing and inspecting each belt will be appreciated, as the protection of life and limb is involved. A parcel of 150 electrical indicating meters (valued at, say, £10 each) submitted for test, would warrant a 100% check being made, whereas a parcel of 5000 bolts, ⅝" x 10", would not, except in extraordinary circumstances, warrant even 100 being fully checked. General cases are governed by one of the conditions appearing in "General Conditions of Contracts for the Supply of Material" (P.M.G. No. 1 and P.M.G. No. 1A), to which all tenderers must agree to comply when tendering. This condition reads as follows:—

> "17. Acceptance or rejection of the whole delivery may be decided by the Department, consequent on the examination of samples taken at random from the delivery. When samples are taken from the delivery they will be examined for compliance with the contract conditions. In general, not more than 5 per cent. from each delivery will be inspected, up to a maximum of 100, i.e., for a delivery in excess of 2,000 articles, not more than 100 will be tested. If the number tested complies with the contract conditions, the whole delivery may be accepted. If three-fifths of those tested fail, then, at the discretion of the Department, the whole delivery may be rejected, or additional samples, up to a maximum of 10 per cent. of the delivery, may be tested. The final decision of the Department in respect of complete or partial rejection of the delivery shall be binding on the contractor."

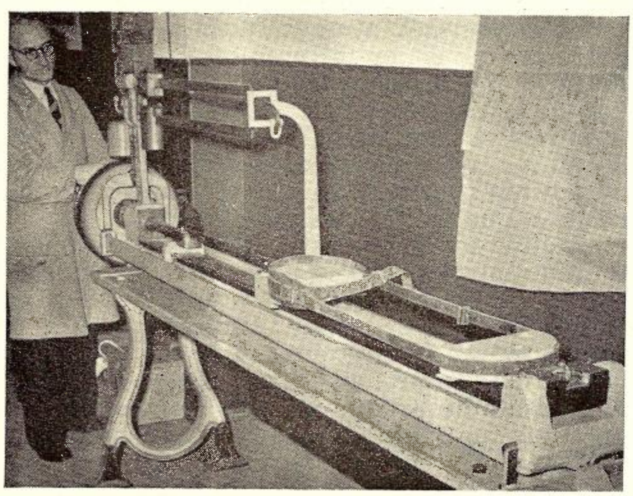

Fig. 6.—Tension test on lineman's belt.

Purchase of Supplies: The great bulk of the Department's engineering supplies is obtained by means of public tender. The tender schedule sets out, in addition to other provisions, the technical requirements to be met and special conditions to be observed in respect of inspection, delivery and packing, etc. A copy of each tender schedule is filed in the Material Testing laboratory and this, together with the letter of acceptance, forms the basis upon which the whole testing procedure hinges. A clause in the letter of acceptance invariably requires a local contractor to communicate with the Material Testing Section by telephone when the material is ready for acceptance. Every encouragement is given to the contractor to seek inspection during manufacture, apart from the obligatory and final inspection prior to delivery. In this way, defects in manufacture (sometimes due to wrong interpretation of specifications and/or drawings) are detected and remedied before the manufacture has proceeded very far. This minimises losses and saves time for all concerned. When a contractor manufactures an article for the first time, the usual procedure is for him to supply three samples to the Chief Engineer, before bulk manufacture proceeds. When the samples are approved, one is returned to the contractor, one to the Material Testing Section, and one is retained in the Chief Engineer's Office. An approved sample is particularly helpful to the inspecting officer as an indication of the standard of workmanship, quality and finish required, as it is difficult to specify these matters adequately in a specification.

Test Procedure: Material purchased by the Department may be classified under three main headings:—

(1) Material ordered under a collective schedule and manufactured locally;

(2) Material ordered under a collective schedule and manufactured overseas; and

(3) Material ordered on direct supply orders.

The testing procedure is generally the same in each case.

When the samples have been approved by the Chief Engineer, and the contractor has been advised that bulk manufacture may be commenced, the inspecting officer's sample is suitably tabbed and filed, ready for a request for inspection. Before visiting the contractor, the inspecting officer, allotted by the Supervising Technician, makes himself familiar with the terms of the contract, including any specifications and drawings mentioned. The first inspection during manufacture will usually be devoted to unassembled parts; for example, the wire to be used in the construction of a 3000 type relay may be checked, particularly for freedom from pin holes in the enamel insulation. The pin hole test is conducted in the laboratory on equipment designed to make the full tests provided for in the relative British Standard Specification. The method of testing is to pass a sample of wire, not less than 50 yards in length, through a bath containing mercury, while a potential difference of 50 volts DC is maintained across a circuit consisting of the enamelled wire under test (with the free end insulated), the mercury in the bath and a sensitive relay connected in series. A fault (pin hole) in the insulation of the wire will permit the passage of current, and so operate the relay. Freedom from acidity and alkalinity is an important requirement in connection with the coil coverings of relays, and is determined from the pH value of the material, measured with the aid of a Hellige Comparator. This apparatus consists chiefly of several standard colour discs, each disc covering a particular range in the pH scale. The discs are used in conjunction with standard indicator solutions covering the same ranges. Briefly, the method employed is to compare, through a viewing glass, the shade of colour obtained by two solutions each containing the same quantity of indicator in a measured quantity of distilled water. The solutions are identical, except that one has been in contact with the material it is desired to check. The introduction of the indicator will colour the solution, but the one which has been in contact with the material will (unless the material is neutral) assume a different shade to the other, and, by revolving the standard colour discs so that each standard colour is superimposed in turn over the unimpregnated sample, a match of colours is obtained. This assumes also that the material is within the pH range of the disc used. The pH value is read from the calibrated colour which formed the match.

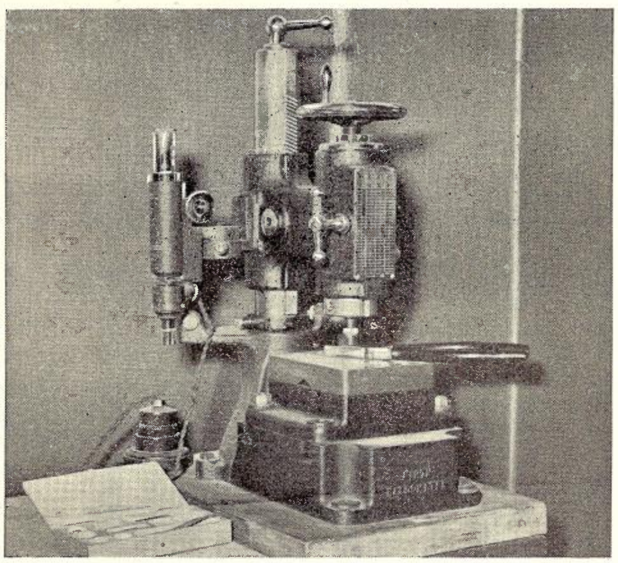

Fig. 7.—Brinell hardness tester.

At successive inspections in the contractor's premises, the testing officer's duty is largely to check dimensions and also to select parts for more complete laboratory tests, such as those described in the foregoing paragraph. The springs forming part of the relay are checked for dimensions, and selected samples sent in to the laboratory for hardness test. The hardness testing instrument is designed to apply a fixed spring tension load of 30 kilograms to the article under test, through the agency of a steel ball or a diamond indentor, the area of the indent being a measure of hardness. The instrument is calibrated in Brinell Hardness numbers, and is illustrated in Fig. 7. This instrument is very reliable for checking the hardness of steel articles, such as tools, but for non-ferrous metals, as used in the manufacture of relay springs, the Vicker's Machine, which permits of the application of varying loads, is more suitable. The testing officer furnishes a report after each inspection and, where necessary, submits samples for examination by the Engineer, who, at this stage, may desire to discuss with the manufacturer the suitability of material being used. In all cases where variation from the contract is desired, the matter is first represented to the Chief Engineer for approval and, usually, samples are then forwarded for examination. When the material is submitted for final inspection, the testing officer will select his percentage for test from the whole parcel, and the test at this stage is, generally speaking, of an overall character. For example, the testing officer will check 3000 type relays for mechanical adjustments, including spring tension and armature clearances, etc. Electrical properties, such as conductor resistance of windings, insulation resistance of parts not electrically connected, heating test of wire, operating test, inductance measurements, etc., will also be checked. Markings will be checked and the standard of workmanship judged. All the points to be covered have not been mentioned, as it is intended to give a general idea only of the scope of the tests. In all cases the testing officer is guided by the specification and drawing and other conditions of contract referred to in the letter of acceptance.

If the material complies with the conditions of contract, average samples are selected by the testing officer for each of the States concerned in the delivery. The object of this is to give the testing officer in the State of destination a representative sample of the articles which were passed as being acceptable, in order that the delivery, when it arrives, may be compared with the sample. Due to the weight and bulk of some articles it is not always practicable to select representative samples for despatch to the States concerned. In such cases the selected article is suitably branded or sealed to indicate that it is representative. After examination of the testing officer's final report, and after all the details of the contract have been carefully checked, to ensure that the material complies fully with the conditions of contract (apart from variations which may have been approved subsequently by the Chief Engineer), the contractor is advised, on Form S44, that the material is satisfactory and may be despatched. Where departures have been approved, such as the substitution of certain materials for those specified, details thereof are mentioned on the Form S44. It should be mentioned that the packing of the completed material is also checked by the testing officer, where practicable. The Department's interests are further safeguarded, in respect of deliveries, by the provision on the Form S44, which advises the contractor that "the material is satisfactory....... subject to it being delivered in full compliance with the Conditions of Contract." This form is made out in quintuplicate and copies distributed to the contractor, Superintendent of Stores in the State of destination, Superintendent of Stores in the State of origin, and Superintending Engineer in State of destination. One copy is retained by the Testing Section. On delivery into Store in the distant State, the material is not taken into stock until it has been submitted to a further check on Form S21 (Stores test sheet). The check at this stage is made only to ensure that the correct type of material has been delivered, that it is properly packed and branded and that it is in good order and condition. The

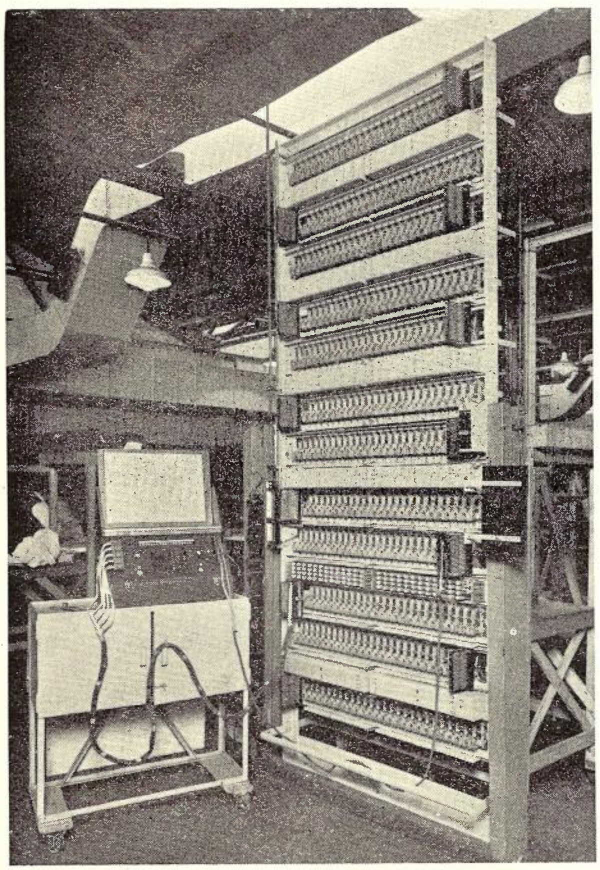

Fig. 8.—Uniselector rack undergoing final acceptance tests at contractor's works.

testing officer compares the material with the representative sample received from the State of origin and, if any doubt arises regarding the quality of the material, or where no advice has been received from the State of origin to indicate that it has been previously inspected, the material may be subjected to a full acceptance test, and the Superintendent of Stores is suitably advised on the Form S21.

Fig. 8 shows a uniselector rack at the works of a Sydney contractor, ready for final acceptance test. Until recently, this type of equipment was imported from overseas. It was subjected to a visual examination only, and to test under working conditions, and was accepted under a guarantee by the supplier to make good any defect in evi-

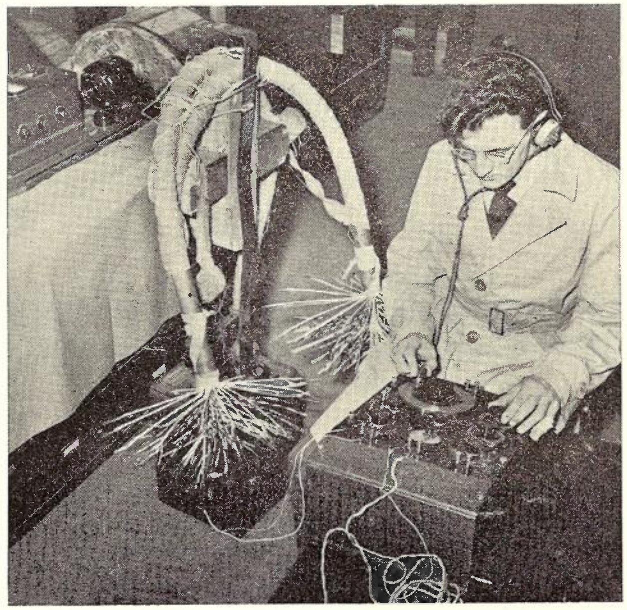

Fig. 9.—Check testing loading coils.

dence within two years, other than that due to fair wear and tear or due to the Department's negligence. With the locally manufactured article, however, the tests are extensive, as will be seen from the following list of specifications and drawings involved in checking a fully equipped uniselector rack:—

	Specification	Drawing
Uniselector	809A, 900	CE. 156
L & K Relays	807	CE. 110
B & S Relays	806	CE. 129
Ironwork	–	CE. 188

Articles made in England are, very frequently, the subject of preliminary inspections by British Post Office officials, but the acceptance of material is invariably subject to final inspection in Australia. On delivery into the Stores, the material is submitted, on Form S21, for acceptance tests, and these are made on selected samples. Fig. 9 shows a testing officer checking the inductance of an 88 milli-henry loading coil, received under contract from an overseas firm.

Tests other than for Acceptance Purposes: The laboratory is organised chiefly to carry out acceptance tests on ordinary supplies of material, but tests are also made on behalf of the other Sections of the Superintending Engineer's Branch. For example, tests are made to determine, by chemical analysis, the probable cause of cable sheath failures. Samples of the affected lead sheath, water from adjacent man-hole or pipe line, and soil from the surrounding ground, are submitted to the laboratory in connection with each cable failure. Microscopical examination of the lead sheath and chemical analyses of the water, soil and the corrosion product, are made and reported upon.

Samples of sulphuric acid electrolyte are also checked, to determine the quantities of impurities present, and an opinion is expressed as to whether these are considered excessive.

The calibration of electrical measuring instruments is another function of the laboratory, which is frequently made use of by other Sections.

Conclusion: There are in the order of 13,000 different standard items purchased by the Department, and a very large proportion of these is subjected to acceptance tests. To select typical examples for illustrating the tests applied is, in itself, not an easy task, as engineering material varies widely, from iron bolts and bakelised canvas, on the one hand, to motor generator sets and carrier systems on the other hand. It will be appreciated, therefore, that the author has been obliged to describe much of the procedure in general terms. An important point not to be overlooked is that the experience gained in the testing of supplies enables the Department to establish machinery whereby the material and plant purchased is always under notice for improvement in design, so that it may render the best possible service to the community.

STATISTICAL INVESTIGATION OF FAULTS ON OPEN-WIRE TELEPHONE LINES

*Z. Friedberg, Ingénieur I.T.N., M.I.E.E.**

Australia is one of the few countries where open-wire lines still offer the best solution for long-distance communications, and for this reason the writer feels that this article, containing details of a statistical investigation of line faults carried out on a number of open-wire lines, may be of interest to Australian telephone engineers.

Constructional Details: The Oil Company with which the writer is connected owns and operates its own telecommunication system consisting, inter alia, of a number of open-wire long-distance lines extending over a range of approximately 1000 miles. These lines carry D.C., V.F. and carrier telephone and telegraph channels. The lines are built in accordance with the British Post Office practice. The poles are of steel tubular type and consist of a steel taper and a cast-iron base of a special design to give extra strength against lateral pressure at ground level and to prevent water percolating down the base during rainy seasons. Where no saddle (cap) pair is used, the tip of the pole is provided with a finial cap and a lightning spike. The overall height of normal poles is 25 feet. Where other telephone routes, railway and roadway crossings have been encountered, longer poles of 28 feet and 32 feet were used. Where long spans exceeding 120 yards were required, i.e., across river beds, ravines, etc., standard poles were so placed as to form an "H" pole braced together with special braces. Apart from angle stays the route has only been line-stayed at every second mile. The length of normal spans is 211 feet, allowing 25 poles to the mile. The conductors consist of cadmium copper (c.c.) wires.

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The lines when constructed were calculated on the basis of a wind pressure of 15.67 lbs./sq. foot on $^2/_3$ diameter of the conductor (theoretically, the wind pressure is only 0.57 of the pressure which would exist on a plane surface of the diametrical cross-section). The factor of safety is $2\frac{1}{2}$ on the breaking stress of the conductor. Other line material, such as insulators, binders, tapes, etc., have been used in accordance with the British Post Office practice. The crossarms are creosoted Karri-wood arms.

Scope: The article gives a classification of the line faults and working time losses caused by these faults over one particular section of the route, 250 miles long, over a period of six years (1.1.1937-31.12.1942). The real fault distributions are compared with theoretical distributions based on the mathematical Probability Theory and, from the latter, probabilities of expected future line faults are derived.

The following are details of the lines on the section of pole route investigated:—

Line Nos.	Length miles	Type of wire lbs./mile-c.c.	Position on pole
1	250	300	1st crossarm from top
2	250	300	1st crossarm from top
3	200	200	2nd crossarm from top
4	200	200	2nd crossarm from top
5	40	70	Cap pair

Fault Distribution: The faults have been divided into two main groups:—

(a) Due to natural causes.

(b) Caused by malicious damage.

The former group covers eleven different types of faults from natural causes, and the latter, which has not been included in the Probability calculations, accounts for all faults caused by sabotage, malicious damage, etc.

Climatic Conditions: The test section passes through territories which differ in nature and in climatic conditions. Sandy deserts, terrains intercepted by wide "vadis" (dry river beds), marshy grounds, stony grounds, rocks, lava stretches, cultivated and semi-cultivated and rough, mountainous conditions, are traversed. The elevation of the country through which the route passes attains in certain places an altitude of 2700 feet.

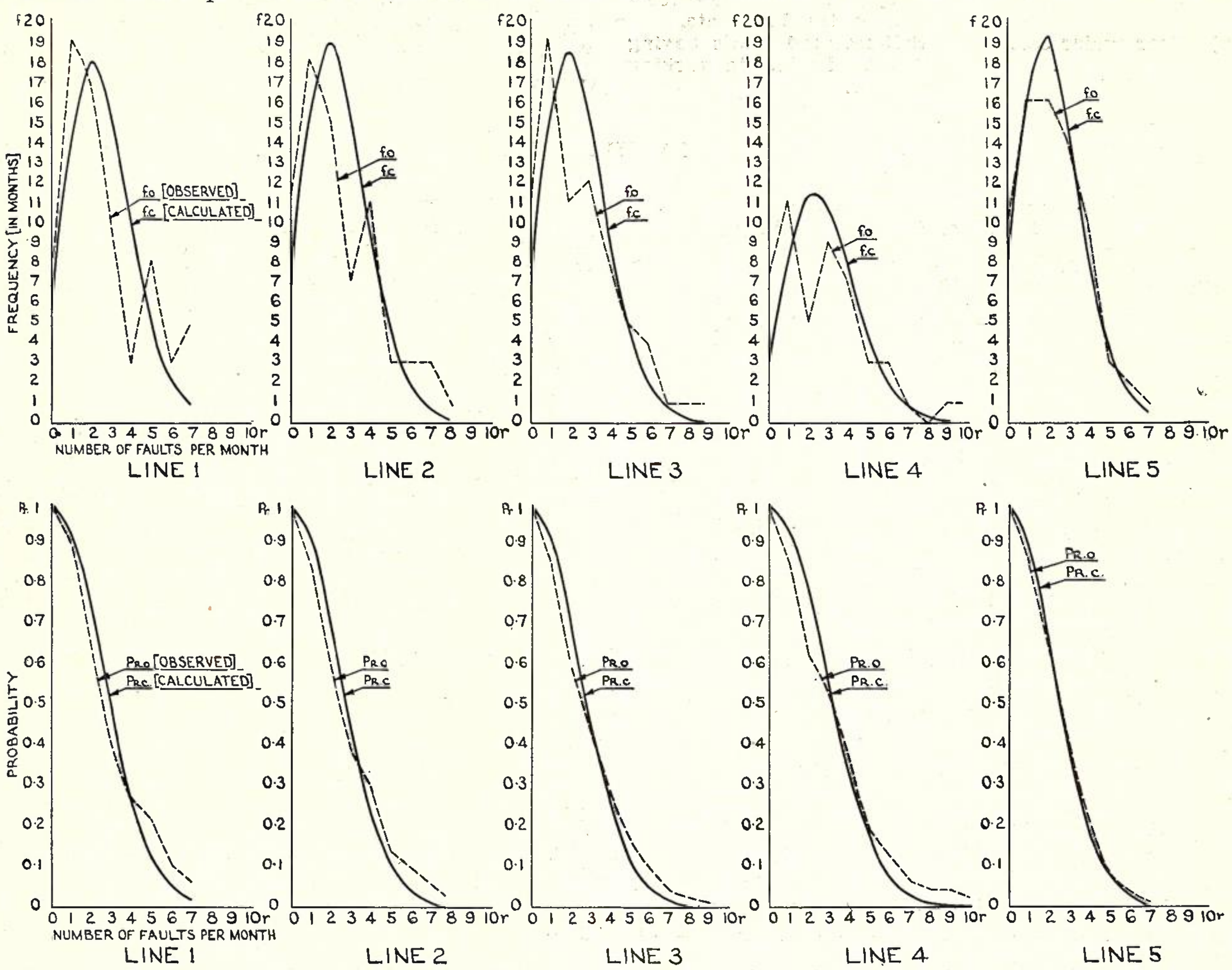

FIG. 1

Climatic conditions vary also to a considerable degree. The shade temperature varies from 20°F. to 120°F. Wind velocities attain sometimes 70 miles per hour. Severe sand-storms are frequent, and extremely heavy rains fall in the cultivated parts of the section, transforming sometimes dry water-courses into fast-flowing streams. In certain parts, too, heavy storms are experienced in winter, accompanied by lightning discharges. As a protection against these discharges, Telenduron insulators with vacuum dischargers are used. These insulators, fitted on leading-in poles (approximately every 50 miles) and at half-way points (approximately every 25 miles), also serve as testing points on the line.

Faults Distribution based on the Mathematical Probability Theory: The real distributions of faults obtained from actual observations have been compared with calculated Gaussian Distributions based on the Probability Theory. The results obtained are very gratifying. As it will be seen from the numerical results and the curves in Fig. 1, in practically all cases there is a very close correlation between the observed and calculated frequencies of faults, resulting in a very close fit between the two types of curves (observed and calculated). Furthermore, these results have been checked and corroborated by the "Test of Goodness of Fit," known as X^2 test (Ki square test). The check figures are included in the article.

The results of these calculations enable the future probabilities of any number of faults per month per circuit to be predicted. These probabilities have been calculated, and are referred to later.

The Distribution and Frequency of Faults from

Natural Causes: The faults in this group have been subdivided into the following types:—

(1) Disconnection in binder	Broken wires in binders near the insulators.
(2) Dis. in sleeve	Broken wires due to sleeves.
(3) Dis. in termination	Broken wires in termination.
(4) Dis. in bridge	Broken wires in bridges
(5) Dis. in span	Wires broken in span.
(6) Dis. in test insulator	Broken springs in test insulators, etc.
(7) Short circuit	Twisted in spans, by birds, by pieces of wire thrown over the lines, etc.
(8) Clear under test	Self-restored faults having caused a loss in working time.
(9) Accidental contact	Caused by foreign conductor bodies thrown over line and making contacts with wires, etc.
(10) Accidental breakdown	Caused by blasting operations, storms, floods, collisions, etc.
(11) Miscellaneous faults	Dry joints, disconnections in joints, intermittent faults, missing wires, noisy lines, etc.

Table No. 1 shows the distribution of the faults over the period of test, and Table No. 2 shows the number of faults for each line under the foregoing classifications.

TABLE NO. 1

Month \ Year	Line No. 1 -37	-38	-39	-40	-41	-42	Line No. 2 -37	-38	-39	-40	-41	-42
January	4	7	2	5	1	6	4	4	–	7	3	6
February	1	7	2	3	3	2	–	7	–	4	6	5
March	7	6	5	3	2	5	1	2	3	4	2	2
April	7	5	3	1	2	5	1	1	1	2	1	3
May	3	3	1	1	2	1	2	–	1	2	2	3
June	1	2	3	1	1	–	3	1	1	–	1	–
July	–	2	1	2	2	–	2	1	–	2	1	1
August	–	1	1	2	1	3	–	–	1	1	1	2
September	1	–	1	1	1	4	4	1	–	2	2	5
October	–	2	2	4	1	5	4	1	–	4	2	8
November	–	2	5	2	3	3	1	2	4	4	4	7
December	5	1	2	2	7	6	4	2	3	3	5	6
Total	29	38	28	27	26	40	26	22	14	35	30	48

Month \ Year	Line No. 3 -37	-38	-39	-40	-41	-42	Line No. 4 -39	-40	-41	-42	Line No. 5 -37	-38	-39	-40	-41	-42
January	3	4	2	8	1	5	4	4	3	3	4	2	1	2	4	2
February	1	5	2	3	2	4	5	5	4	5	1	3	1	3	2	3
March	4	–	2	6	3	5	10	2	6	1	1	1	3	3	1	3
April	4	7	–	1	3	6	–	1	3	3	3	3	2	4	3	4
May	3	2	4	–	3	6	3	–	3	4	1	2	2	4	2	–
June	1	1	2	1	1	–	3	2	–	–	1	2	1	6	–	–
July	3	1	1	1	3	1	–	2	1	1	2	5	–	2	1	5
August	1	–	–	2	1	1	1	1	1	1	–	–	2	4	1	1
September	2	–	3	–	1	2	3	3	–	1	–	3	1	–	1	3
October	1	2	5	4	1	4	4	7	1	4	4	–	6	7	4	3
November	–	3	9	3	1	–	–	3	1	6	2	1	4	2	2	5
December	3	5	4	2	6	1	4	2	9	5	3	2	1	3	–	4
Total	26	30	34	31	26	35	37	32	32	34	22	24	24	40	21	33

The record for line No. 4 covers only the period of four years, Jan., '39-Dec., '42, this line having been constructed at the end of 1938.

TABLE No. 2

Fault \ Line No.	1937 1	2	3	4	5	1938 1	2	3	4	5	1939 1	2	3	4	5
1. Dis. in binder	3	7	5	–	3	5	2	7	–	5	5	2	7	8	4
2. Dis. in sleeve	7	5	–	–	–	5	9	–	–	–	3	1	–	–	–
3. Dis. in termination	–	2	–	–	4	1	–	1	–	1	2	1	–	1	2
4. Dis. in bridge	3	3	–	–	5	3	–	–	–	4	2	2	4	7	9
5. Dis. in span ..	–	2	–	–	–	–	–	–	–	3	1	–	4	1	2
6. Dis. in test insulator	3	3	–	–	–	2	2	2	–	1	1	–	1	–	–
7. Short circuit	8	1	4	–	4	8	2	7	–	5	4	3	3	4	3
8. Clear under test	2	–	1	–	1	5	–	1	–	2	1	1	1	1	2
9. Accidental Contact	2	3	13	–	3	6	6	12	–	2	6	3	8	7	2
10. Accidental breakdown	–	–	–	–	–	–	–	–	–	–	1	1	5	7	–
11. Miscellaneous faults	1	–	3	–	2	3	1	–	–	1	2	–	1	1	–
TOTAL	29	26	26	–	22	38	22	30	–	24	28	14	34	37	24

Fault \ Line No.	1940 1	2	3	4	5	1941 1	2	3	4	5	1942 1	2	3	4	5	Total 1	2	3	4	5	Grand Total
1. Dis. in binder	4	7	4	4	6	7	5	7	6	3	3	11	9	2	12	27	34	39	20	33	153
2. Dis. in sleeve	8	8	–	–	–	6	8	–	–	–	9	9	–	–	–	38	40	–	–	–	78
3. Dis. in termination	2	–	–	2	1	2	2	1	2	–	3	–	1	–	2	10	5	3	5	10	33
4. Dis. in bridge	2	7	4	5	16	4	2	1	5	13	4	1	–	–	9	18	15	9	17	56	115
5. Dis. in span ..	1	1	–	1	1	–	–	2	–	–	1	2	2	1	–	3	5	8	3	6	25
6. Dis. in test insulator	–	–	–	–	–	1	1	1	–	–	1	1	–	–	–	8	7	4	–	1	20
7. Short circuit	–	2	2	4	11	1	5	2	4	–	3	8	4	3	5	24	21	22	15	28	110
8. Clear under test	–	2	–	2	–	2	–	–	1	2	3	3	–	1	1	13	6	3	5	8	35
9. Accidental Contact	8	6	20	11	4	–	3	8	8	3	9	9	14	24	1	31	30	75	50	15	201
10. Accidental breakdown	1	1	1	1	–	1	3	4	4	–	3	3	3	3	2	6	8	13	15	2	44
11. Miscellaneous faults	1	1	–	2	1	2	1	–	2	–	1	1	2	–	1	10	4	6	5	5	30
TOTAL	27	35	31	32	40	26	30	26	32	21	40	48	35	34	33	188	175	182	135	164	844

Sleeve faults are shown only for lines Nos. 1 and 2, as no sleeves were used on the other lines.

From these tables the distribution of faults shown in Table No. 3 is obtained.

TABLE No. 3

Line No.	Period in years	Total No. of faults	No. of faults per year	Length of line examined	Annual No. of faults per mile
				miles	
1	6	188	31.33	250	.125
2	6	175	29.16	250	.117
3	6	182	30.33	200	.121
4	4	135	33.75	200	.135
5	6	164	27.33	40	.685

Table No. 4 gives the average number of each type of fault per year per circuit.

TABLE No. 4

Type of Fault	Line No. 1		Line No. 2		Line No. 3		Line No. 4		Line No. 5	
	Tot.	Av.	Tot.	Av.	Tot.	Av.	Tot.	Av.	Tot.	Av.
1. Dis. in binder	27	4.5	34	5.65	39	6.5	20	5.0	33	5.5
2. Dis. in sleeve	38	6.32	40	6.68						
3. Dis. in termination	10	1.67	5	0.83	3	0.5	5	1.25	10	1.67
4. Dis. in bridge	18	3.0	15	2.5	9	1.5	17	4.25	56	9.3
5. Dis. in span	3	0.5	5	0.83	8	1.33	3	0.75	6	1.0
6. Dis. in test insulator	8	1.33	7	1.16	4	0.67	—	—	1	0.17
7. Short circuits	24	4.0	21	3.5	22	3.67	15	3.75	28	4.65
8. Clear under test	13	2.16	6	1.0	3	0.5	5	1.25	8	1.33
9. Accidental contact	31	5.15	30	5.0	75	12.5	50	12.5	15	2.5
10. Accidental breakdowns	6	1.0	8	1.33	13	2.16	15	3.75	2	0.33
11. Miscellaneous	10	1.67	4	0.67	6	1.0	5	1.25	5	0.83

Faults Distribution based on the Mathematical Probability Theory: In this section the problem of faults distribution over the different telephone circuits is discussed from the point of view of the Mathematical Probability Theory.

The theoretical frequency of faults is calculated according to this theory, and compared with the actual distribution to determine the various probabilities for any number of faults. In addition the real and the theoretical Gaussian distributions are checked by means of the X^2 (Ki square) test, known as the "Test of Goodness of Fit." It will be seen that there is, for practically all lines, an extremely close fit with the Gaussian distribution based on the mathematical theory.

The following principles are reviewed briefly at this stage to assist in the application of the Probability Theory to the problem under consideration.

The probability P expresses in a numerical form the degree of certainty of an event of which the limits are 0 and 1. 0 expresses the impossibility of the event to occur, and 1 the absolute certainty of occurrence.

For several events (several fault groups), of which two will never occur simultaneously, the probability of occurrence of any one of the events of the first K events will be:—

$$P = p_0 + p_1 + p_2 + \dots \dots \dots \dots \dots \dots p_k$$

Let N be the number of observations and P_1 the probability of occurrence of the event in one observation. By assuming N to be infinitely great and p_1 small,

$$Np_1 = m$$

where m is the arithmetic mean. The probability that the event will take place in each of the first r observations out of a total of N observations will therefore be:—

$$\left(\frac{m}{N}\right)^r . \left(1 - \frac{m}{N}\right)^{N-r}$$

The number of ways in which the event will happen exactly r times in N observations will then be:—

$$p_r = \frac{N(N-1).(N-r+1)}{r!} . \left(\frac{m}{N}\right)^r . \left(1 - \frac{m}{N}\right)^{N-r}$$
$$= {}^{N}C_r \left(\frac{m}{N}\right)^r . \left(1 - \frac{m}{N}\right)^{N-r}$$

This formula is known as **Bernoulli's formula.**

If we assume N to increase indefinitely:

$$\lim_{N=\infty} \left(1 - \frac{m}{N}\right)^{N-r} = e^{-m}$$

and

$$\lim_{N=\infty} {}^{N}C_r = \frac{N^r}{r!}$$

Bernoulli's formula then becomes:

$$\lim_{N=\infty} {}^{N}C_r \left(\frac{m}{N}\right)^r \left(1 - \frac{m}{N}\right)^{N-r}$$

whence

$$p_r = \frac{N^r}{r!}\left(\frac{m}{N}\right)^r e^{-m}$$
$$= m^r e^{-m}/r!$$

the latter formula is known as **Poisson's formula.**

Both formulæ have been applied to the first line (line No. 1) but, as it will be seen from numerical results (Table No. 5), the difference between the values obtained by the two formulæ is very small and of no practical importance. For all the other lines, therefore, the simpler Poisson's formula is used.

Applying the foregoing to the particular problem under review, if the different fault groups per month are:

0, 1, 2, 3, ...r,

the chance that there will be exactly r faults per month will be given by Poisson's formula:

$$p_r = m^r e^{-m}/r!$$

However, the chance that there will be at least r faults per month will be:

$$P_r = \sum_{n=r}^{n=\infty} p_n = p_r + p_{r+1} + p_{r+2} + \cdots + p_\alpha$$
$$= \sum_{n=r}^{n=\infty} m^n e^{-m}/n!$$

The chance that there will be 0, 1, 2, . . . n faults per month, i.e., none or any number of faults will naturally be an absolute certainty or $P_r = 1$.

$$\text{Thus} \sum_{n=0}^{n=\infty} m^n e^{-m}/n! = 1$$

$$\text{whence } P_r = \sum_{n=r}^{n=\infty} m^n e^{-m}/n!$$
$$= 1 - \sum_{n=0}^{n=r-1} m^n e^{-m}/n!$$

The foregoing Poisson's Exponential Summation formula has been used to determine the chances of exceeding a certain number of faults per month, and Tables Nos. 5-9 included in the Appendix show the results for the lines Nos. 1 to 5.

The curves shown in Fig. 1 have been derived from the calculations in Tables Nos. 5-9 and show the following:—

- f_o, f_c the degree of correlation (fit) between the observed and calculated frequencies.
- pr_o, pr_c the departures of the observed probabilities p_r from the calculated probabilities p_r.

It will be seen from these curves that there is a close agreement between the theory and practice and that the future probability of any number of faults on all the lines in the examined section may be estimated with accuracy. These results are further confirmed by the X^2 test (Ki square), known as the "Test of Goodness of Fit," referred to in more detail in the following paragraph. It may not be inappropriate to add that the results are very gratifying when it is remembered that there cannot be a perfect agreement between theory and practice, i.e., between the observed frequencies of faults and the Poisson distribution. Whereas the mathematical formula assumes an infinite universe (infinite number of faults), the case considered necessarily consists of a finite number of faults and, secondly, the faults considered are not absolutely independent as assumed in the theory but are physically linked by a certain degree of interdependence.

Test of Goodness of Fit: If a frequency distribution or table contains n' "cells" and the contents of the cells be m'_1 m'_2 . . . . . . m'_r in number while m_1, m_2, ... m_n be the numbers that would occur in these cells on any theory, then

$$X^2 = S\left\{\frac{(m'_r - m_r)^2}{m_r}\right\}$$
$$= \text{sum}\left\{\frac{\text{Square of difference of theoretical and observed frequencies}}{\text{theoretical frequency}}\right\}$$

and the probability that random sampling would lead to as large or larger deviation between theory and observation is given by:

$$P = e^{-1/2X^2}\left\{1 + \frac{X^2}{2} + \frac{X^4}{2.4} + \frac{X^6}{2.4.6} + \cdots \cdots \cdots \cdots + \frac{X^{n'-3}}{2.4.6 \ldots (n'-3)}\right\}$$

for n' odd, and

$$P = \sqrt{2/\pi}\int_X^\infty e^{-1/2X^2}dx + \sqrt{2/\pi}\, e^{-1/2X^2}\left\{\frac{X}{1} + \frac{X^3}{1.3} + \frac{X^5}{1.3.5} + \ldots + \frac{X^{n'-3}}{1.3.5 \ldots (n'-3)}\right\}$$

for n' even.

In the latter formula the integrated part may be obtained from Pearson's "Tables for Statisticians and Biometricians."

Values of X^2 have been calculated from figures given in columns 9 and 10 of the Tables Nos. 5-9, combining in each case all theoretical frequencies below the values of 5 into one group (empirical rule).

Detailed calculations for the foregoing formulæ are not included, but the probability P with the corresponding values of X^2 are as follows:—

Line No.	Table No.	n'	X^2	P
1	5	7	18.970	.00610
2	6	6	10.530	.06156
3	7	6	10.392	.06488
4	8	6	11.307	.04587
5	9	6	1.764	.6982

According to J. F. Donat and H. T. Josephs ("A Simple Introduction to the use of Statistics in Telecommunications Engineering," Post Office Electrical Engineers' Journal, January, 1942), if P is smaller than 0.05, the fit between the theoretical and practical frequencies of distribution is bad. If P lies between 0.1 and 0.9 there is no reason of suspicion. If P is smaller than 0.02, the hypothesis fails to account for the whole of facts. If P is smaller than 0.05, the chance of error is very small, and if P is larger than 0.95 the chance of error is very large.

From the foregoing and the final numerical results it will be seen that the above calculated values P (except for line No. 1) fully corroborate the previously calculated direct results of a close correlation between theory and practice.

Line Faults v. Wire Gauge: Considering the number of faults from natural causes in the first 40 miles route which also carries the 70 lbs./mile line, the following figures are obtained:—

Line No.	Conductor lbs./mile c.c.	No. of Faults	
		Total	Av./year
1	300	62	10.33
2	300	53	8.83
3	200	52	8.66
4	200	40	10
5	70	164	27.33

Deducting from the above those faults which have no direct bearing on the gauge of wire, i.e., short circuits, clear under test, accidental contacts and "Dis. in test insulator," we obtain the following number of faults for the five lines in this section:—

Line No.	No. of faults	
	Total	Av./year
1	32	5.33
2	27	4.5
3	22	3.66
4	20	5
5	112	18.66

The first two, being of same gauge (300 lbs./mile), give an average of 4.91, the third and fourth being of equal gauge (200 lbs./mile) give an average of 4.33 faults per year, against 18.66 on line 5, which is of a smaller gauge (70 lbs./mile).

From the first two figures we may assume that (a) the period considered was too short to produce a noticeable difference in strength between the two gauges, (b) the position on pole, first and second crossarm, may have an indirect bearing on the faults, or (c) the greater weight of 300 lbs./mile wire contributes to a greater number of faults. The latter assumption appears justified as, for the total length of 250 miles, the two types (300 lbs. and 200 lbs./mile) of lines give the following average per year (after deducting the same faults as given above which have no bearing on the gauge).

Line 1 = 18.66; Line 2 = 18.5; Line 3 = 13; Line 4 = 16.25. Of particular interest is the fact that, after the above deductions, the number of faults on line No. 1 over the six years (112) is almost identical to the number of faults on line No. 2 (111) over the same period.

Comparing the 200 lbs./mile lines and the 70 lbs./mile line, averages of 4.33 and 18.66 respectively are obtained for the section under consideration. Thus the annual excess for the 70 lbs./mile line is 15 faults. Assuming the centre of the section to be the resultant distance, this would represent a journey of approximately 60 miles per fault for the patrol vehicle, or a total of 900 miles per year.

Taking local pre-war rates and excluding the hypothetical loss in working time due to the greater number of faults, the difference in cost can be compensated after a period of approximately 12 years. For a public line where the loss in working time produces a direct marked loss of revenue this difference would be further greatly reduced and probably compensated after only a few years.

Conclusions: 1. During the period under review the maximum number of faults has never exceeded the following values:—

Line No.	Period (months)	Max. No. of faults	Frequency (months)
1	72	7	5
2	72	8	1
3	72	9	1
4	48	10	1
5	72	7	1

2. The probability of these numbers being reached again or exceeded is as follows:—

Line No.	Probability	Chance
1	.0228	1 to 44
2	.00255	1 to 393
3	.00457	1 to 219
4	.00188	1 to 532
5	.0061	1 to 164

3. Taking the lowest maximum number of faults (seven), the probability of this number being reached again or exceeded on all lines is as follows:—

Line No.	Probability	Chance
1	.0228	1 to 44
2	.0555	1 to 89
3	.0163	1 to 61
4	.0264	1 to 38
5	.0061	1 to 164

Excluding the last circuit line No. 5, which is of considerably shorter length and does not bear comparison with the others, the best record of these lines is in the order: (1) Line No. 2; (2) Line No. 3; (3) Line No. 1; and (4) Line No. 4.

4. The greatest number of faults from natural causes was due to "Dis. in sleeves" on line No. 2 and line No. 1 only, and to "Accidental Contacts" and "Dis. in binders" on all circuits.

5. For the same route and lengths the number of faults compare as follows (first 40 miles):—

Line No.	Conductor lbs./mile c.c.	Av. annual No. of faults
1	300	10.33
2	300	8.83
3	200	8.66
4	200	10
5	70	27.33

6. For the same route and lengths of the first four lines the number of faults compare as follows (250 miles):—

Line No.	Conductor lbs./mile c.c.	Av. annual No. of faults
1	300	18.66
2	300	18.5
3	200	13
4	200	16.25

giving an average for the 300 lbs./mile wire of 18.58 and for the 200 lbs./mile wire of 14.63 faults per annum.

7. From cost comparisons it would appear that the extra cost of a 200 lbs./mile line replacing the 70 lbs./mile line would equalize the cost of labour incurred in clearing the extra number of faults in approximately 12 years. This calculation does not take into consideration the loss of revenue due to faulty lines which, on the Company's private lines, can only be given a hypothetical value. On public lines this would probably be a factor of paramount importance.

Appendix

Included in this appendix are the tables Nos. 5-9, summarising the application of the data to Poisson's Exponential Summation formula. A brief description of the derivation of the details in the tables is given in the following:—

Column 1.—The maximum number of r is based on the highest number of faults per month obtained, as given by table No. 1 for the respective lines.

Column 2.—f_o is the observed frequency of faults in months as given by table No. 1 for the respective lines. Their total corresponds to the total number of monthly observations which for all but line No. 4 is 72 = (6 years). For the latter the total number of monthly observations N = 48 (4 years).

Column 2a gives the probability P'_r for a given number of faults calculated with the aid of Bernoulli's formula (given only for line No. 1).

Column 2b gives the hypothetical calculated frequency of faults f'_c derived from results obtained by means of Bernoulli's formula, where $f'_c = {}^N P'_r$.

Column 3 is the probability p_n for a given number of faults calculated with the aid of Poisson's formula where

$$m = \frac{\sum f_o . r}{N}$$

Column 4 gives the chances derived from the values p_n.

Column 5 gives the hypothetical calculated frequency of faults f_c derived from results obtained by means of Poisson's formula, where $f_c = {}^N P_r$.

Column 6 gives the probability P_r based on the actual really observed frequencies that there will be at least r faults per month where r = 0, 1, 2, etc., for the corresponding observed frequency values.

Column 7 gives the corresponding theoretical probability calculated by means of Poisson's Exponential Summation formula for the same values of r = 0, 1, 2, ... , etc.

Column 8 gives the chances derived from values P_r.

Columns 9, 10, are self-explanatory. They yield the necessary data required for the X^2 test (Test of "Goodness of Fit").

TABLE No. 5. LINE No. 1

$m = 175/72 = 2.61.$ $e^{-m} = 0.0735.$

1	2	2 (a)	2 (b)	3	4	5	6			7	8	9	10
							P_r (Observed)						
r Faults per month	f_o Obs. freq.	$P'_r = {}^NC_r \cdot (m/N)^r \cdot (1-m/N)^{N-r}$	$f'_c = NP_r$	$p_n = \frac{m^n e^{-m}}{n!}$	Chance (based on p_n)	$f_c = NP_r$	Values	No. of f'_os	P_r	$P_r = 1 - \sum_{n=0}^{n=r-1} \frac{m^n e^{-m}}{n!}$	Chance (based on P_r)	f_o-f_c	$\frac{(f_o-f_c)^2}{f_c}$
0	7	.06918	4.97	.0735	1/13.5	5.3	0 to 8	72	1	1	1/1	1.7	.545
1	19	.1865	13.4	.1915	1/5.22	13.8	1 to 8	65	.905	.9265	1/1.04	5.2	1.97
2	17	.261	18.8	.248	1/4.03	17.9	2 to 8	46	.64	.735	1/1.36	–0.9	.045
3	10	.22	15.8	.217	1/4.62	15.6	3 to 8	29	.404	.487	1/2.05	–5.6	2.02
4	3	.142	10.2	.141	1/7.1	10.15	4 to 8	19	.264	.27	1/3.7	-7.15	5.01
5	8	.0761	5.48	.074	1/13.58	5.33	5 to 8	16	.222	.129	1/7.75	2.67	1.33
6	3	.0308	2.22	.0322	1/31.2	2.31	6 to 8	8	.111	.055	1/18.2	)	
7	5	.0105	0.755	.012	1/83.5	.86	7 to 8	5	.0695	.0228	1/43.8	)4.83	7.15

$X^2 = 18.970$

TABLE No. 6. LINE No. 2

$m = 175/72 = 2.43.$ $e^{-m} = .0881$

1	2	3	4	5	6			7	8	9	10
					P_r (Observed)						
r Faults per month	f_o Obs. freq.	$p_n = \frac{m^n e^{-m}}{n!}$	Chance (based on p_n)	$f_c = NP_r$	Values	No. of f'_os	P_r	$P_r = 1 - \sum_{n=0}^{n=r-1} \frac{m^n e^{-m}}{n!}$	Chance (based on P_r)	f_o-f_c	$\frac{(f_o-f_c)^2}{f_c}$
0	11	.0881	1/11.35	6.35	0 to 8	72	1	1	1/1	4.65	3.4
1	18	.2141	1/4.67	15.4	1 to 8	61	.846	.9119	1/1.095	2.6	.44
2	15	.26	1/3.85	18.7	2 to 8	43	.597	.6978	1/1.435	–3.7	.732
3	7	.211	1/4.74	15.2	3 to 8	28	.389	.4378	1/2.28	–8.2	4.43
4	11	.128	1/7.82	9.8	4 to 8	21	.292	.2268	1/4.4	1.8	.353
5	3	.0623	1/16.05	4.48	5 to 8	10	.139	.0988	1/10.25	)	
6	3	.0252	1/39.7	1.81	6 to 8	7	.0973	.0365	1/27.5	)2.889	1.175
7	3	.00875	1/114.5	.63	7 to 8	4	.0555	.0113	1/88.5	)	
8	1	.00266	1/376	.191	8	1	.0139	.00255	1/393	)	

$X^2 = 10.530$

TABLE No. 7. LINE No. 3

$m = 182/72 = 2.53.$ $e^{-m} = 0.797.$

1	2	3	4	5	6			7	8	9	10
r Faults per month	f_o Obs. freq.	$p_n = \frac{m^n e^{-m}}{n!}$	Chance (based on p_n)	$f_c = NP_r$	P_r (Observed) Values	No. of f'_os	P_r	$P_r = 1 - \sum_{n=0}^{n=r-1} \frac{m^n e^{-m}}{n!}$	Chance (based on P_r)	$f_o - f_c$	$\frac{(f_o-f_c)^2}{f_c}$
0	10	.0797	1/12.53	5.73	0 to 9	72	1.000	1.000	1/1	4.27	3.18
1	19	.2015	1/4.97	14.5	1 to 9	62	.86	.9203	1/1.085	4.5	1.4
2	11	.255	1/3.93	18.35	2 to 9	43	.597	.7188	1/1.392	−7.35	2.94
3	12	.2145	1/4.67	15.45	3 to 9	32	.444	.4638	1/2.16	−3.45	.78
4	8	.136	1/7.35	9.8	4 to 9	20	.278	.2493	1/4.03	−1.8	.332
5	5	.0682	1/14.7	4.9)	5 to 9	12	.1665	.1133	1/8.83	)	
6	4	.0288	1/34.8	2.09)	6 to 9	7	.0972	.0451	1/22.2	)	
7	1	.0108	1/92.6	.78)	7 to 9	3	.0416	.0163	1/61.3	) 3.924	1.76
8	1	.00329	1/304	.239)	8 to 9	2	.0278	.0055	1/182	)	
9	1	.000926	1/1080	.067)	9	1	.01385	.004574	1/219	)	
											X^2=10.392

TABLE No. 8. LINE No. 4.

$m = 135/48 = 2.82.$ $e^{-m} = 0.0596.$

1	2	3	4	5	6			7	8	9	10
r Faults per month	f_o Obs. freq.	$p_n = \frac{m^n e^{-m}}{n!}$	Chance (based on p_n)	$f_c = NP_r$	P_r (Observed) Values	No. of f'_os	P_r	$P_r = 1 - \sum_{n=0}^{n=r-1} \frac{m^n e^{-m}}{n!}$	Chance (based on P_r)	$f_o - f_c$	$\frac{(f_o-f_c)^2}{f_c}$
0	7	.0596	1/16.8	2.86	0 to 10	48	1	1.0000	1/1	4.14	6.02
1	11	.168	1/5.95	8.06	1 to 10	41	.858	.9404	1/1.065	2.94	1.072
2	5	.2365	1/4.22	11.38	2 to 10	30	.627	.7724	1/1.3	−6.38	3.59
3	9	.2222	1/4.5	10.68	3 to 10	25	.522	.5359	1/1.865	−1.68	.265
4	7	.157	1/6.37	7.54	4 to 10	16	.334	.3137	1/3.19	−0.54	.0387
5	3	.0886	1/11.3	4.25	5 to 10	9	.1875	.1567	1/6.38	)	
6	3	.0417	1/24	2	6 to 10	6	.125	.0681	1/14.7	)	
7	1	.01675	1/59.8	.805	7 to 10	3	.0627	.0264	1/38	) 1.547	.321
8	0	.00592	1/169.5	.284	8 to 10	2	.042	.00965	1/103.8	)	
9	1	.001853	1/540	.089	9 to 10	2	.042	.00373	1/268.5	)	
10	1	.000523	1/1915	.025	10	1	.021	.00188	1/532	)	
											X^2=11.3067

TABLE No. 9. LINE No. 5.

$m = 164/72 = 2.28.$ $e^{-m} = .1023.$

1	2	3	4	5	6			7	8	9	10
r Faults per month	f_o Obs. freq.	$p_n = \frac{m^n e^{-m}}{n!}$	Chance (based on p_n)	$f_c = NP_r$	P_r (Observed) Values	No. of f'_os	P_r	$P_r = 1 - \sum_{n=0}^{n=r-1} \frac{m^n e^{-m}}{n!}$	Chance (based on P_r)	$f_o - f_c$	$\frac{(f_o-f_c)^2}{f_c}$
0	10	.1023	1/9.78	7.37	0 to 7	72	1.000	1.000	1/1	2.63	.94
1	16	.233	1/4.28	16.75	1 to 7	62	.863	.8977	1/1.115	− .75	.0336
2	16	.2665	1/3.76	19.2	2 to 7	46	.64	.6647	1/1.505	−3.2	.533
3	14	.203	1/4.92	14.6	3 to 7	30	.418	.3982	1/2.52	− .6	.0247
4	10	.1158	1/8.64	8.33	4 to 7	16	.2225	.1952	1/5.13	1.36	.222
5	3	.0528	1/18.9	3.8)	5 to 7	6	.0835	.0794	1/12.6	)	
6	2	.0205	1/48.8	1.48)	6 to 7	3	.0418	.0266	1/37.6	) .248	.0107
7	1	.00655	1/153	.472)	7	1	.0139	.0061	1/164	)	
											X^2=1.764

SOUND RECORDING AND REPRODUCING - PART 2

F. O. Viol

DISC REPRODUCTION

Probably no single event has had such a wide effect on the entertainment field as the development of the gramophone record. It was the medium by which the voices of the world's greatest artists were first brought into our homes and were preserved for the enjoyment of future generations. Without the record, it is safe to assume that broadcasting, which provides entertainment of such a high standard and so varied a character, would not have progressed as rapidly as it has, and one can hardly visualise the conditions which would exist today if broadcast stations were without their extensive record libraries.

The art of recording has made great advances since the days of the cylindrical records and the acoustic type of equipment originally used. It may not be realised that it was not until 1925 that records were first produced by electrical means, and even then it was not until some years later that complementary replay equipment was generally available. It is not the intention to discuss the early equipment but rather to consider the essential requirements of electro-magnetic devices suitable for use, primarily, in broadcast systems.

Gramophone reproducing equipment should be designed not only to translate the groove modulation of the disc with the minimum of distortion, but at the same time to cause least damage to the grooves of the record. Apart from certain fundamental causes directly associated with the disc, as discussed in Part 1, the major factors which tend to produce distortion and record wear are the imperfect design of the pick-up arm, the head, and the reproducing stylus. Consequently, careful design is required if the reproduction from a disc is to be satisfactory. Distortion here is used in the general sense to mean distortion introduced in the wave shape during the process of converting the groove modulation to electrical waves.

As a general basis for design, it will be assumed that the pick-up will be required to replay a record which has been laterally recorded with a constant amplitude characteristic, say, to 250 c/s, and thence with a constant velocity characteristic. The two reproducer types generally available are piezo-electric and electro-magnetic. The latter, which is a velocity-operated device and, hence, produces a voltage depending on the rate at which lines of force are cut, is the one which will, in the ideal case, reproduce, without equalisation, the constant velocity characteristic. On the other hand, the piezo-electric type is an amplitude-operated device and will, in the ideal case, reproduce the constant amplitude characteristic without equalisation. This type, which is more commonly termed the crystal pick-up, will be referred to more fully in later paragraphs.

Before proceeding further, it is desirable that the essential requirements of a pick-up suitable for use in a broadcast studio be listed for examination. The requirements are:—

(a) The pick-up should be robust and should not be damaged when it is dropped on the needle point.

(b) The electrical output should be satisfactory. The equalised output should not be less than microphone level, nominally accepted as −65 dbm.

(c) The electrical output should be relatively free of harmonic distortion, intermodulation and frequency modulation effects.

(d) The armature should have a low mechanical impedance with a low vertical force at the needle point.

(e) The construction of the arm and reproducer should be mechanically good, designed to have minimum tracking error.

(f) The pick-up should have sufficient mass to ensure that, with the existing armature compliance, the mechanical resonance is below 50 c/s.

(g) The method of needle changing should not be difficult.

(h) The performance of the reproducer should be independent of changes in temperature and humidity, and should not deteriorate with age.

(i) External electro-magnetic fields should not cause excessive electrical interference in the reproducer.

(j) The frequency response should be within close tolerances of the constant velocity characteristic.

Naturally, for use in the home, the requirements would not be quite so rigid as those specified for the broadcast studio, but the fact remains that the best reproduction cannot be obtained from a record unless the pick-up meets the majority of the requirements listed above.

Reproducing Stylii

The steel needle which is the most commonly used type of reproducing stylus has been produced in many forms, ranging from the easily recognised short, thick type, known as the "loud tone needle," to the long playing type, which has a tungsten tip fitted to a steel shank. Each has been designed to fulfil a special requirement, some to obtain a particular tonal effect and others to reduce needle wear. It can be shown, for instance, that because a long, thin needle attenuates the higher frequencies, a short, thick needle is to be preferred. With regard to record wear, records other than cellulose nitrate and certain plastics have an abrasive in the disc material, and it will be apparent that with these records the rate of wear will depend on the hardness of the needle and the vertical force at its point.

The abrasive is added to the disc material to shape the needle to fit the groove which, with an ordinary steel needle, is achieved in the first two or three grooves. This is necessary, as there is no universal standard for groove dimensions, and needle tips vary in size and shape, but it has been demonstrated recently that a needle to the following dimensions will play, with equal success, discs recorded over many years from many countries. This suggests that it may now be possible to use sapphire more generally.

Chromium-plated steel-tip, radius 0.0022″ to 0.0032″.

Sapphire-tip, radius 0.0025″ to 0.003″, angle 40° to 45°.

To obtain a satisfactory frequency response, extending, say, to 10,000 c/s, a limit which can now be achieved readily in records, it is necessary to reduce the mass of the needle to a minimum. If the needle and armature be considered as one rigid unit, then, so far as the middle frequencies are concerned, it can be represented by an equivalent mass "m" at the needle point. Now, this unit is not free to move about the armature axis, but is controlled by a stiffness "s," such that the resonant frequency of the movement "f" $= 2\pi\sqrt{s/m}$. In actual design, the mass of the steel needle is the limiting factor for, if it is desired to have the resonance above 10,000 c/s and have high compliance (1/stiffness), the design becomes impracticable. For instance, in a typical case of a moving coil pick-up, when a satisfactory compliance was obtained, the resonance occurred at 6000 c/s.

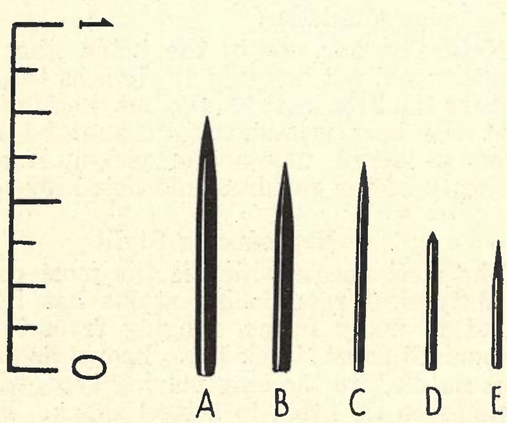

Fig. 1.—Comparative dimensions and mass of typical gramophone needles.

(A) Talkie, 0.230 grams.
(B) Loud tone, 0.177 grams.
(C) Soft tone, 0.065 grams.
(D) Sapphire with iron shank, 0.043 grams.
(E) Miniature steel, 0.036 grams.

The use of a sapphire as the stylus has been a major step in design and it is now possible to reduce the mass of the movement appreciably. If the sapphire is but a mere tip without a shank fastened directly to the armature, the resonance can be made to occur above 10,000 c/s. An intermediate step was the use of a miniature steel needle which permitted the production of a satisfactory type of pick-up with a frequency response to 9,000 c/s. Also available is an iron shank sapphire which has somewhat the same dimensions and mass as the miniature needle, and which can be used as a direct replacement for it. In Fig. 1 several needles are illustrated for purposes of comparison.

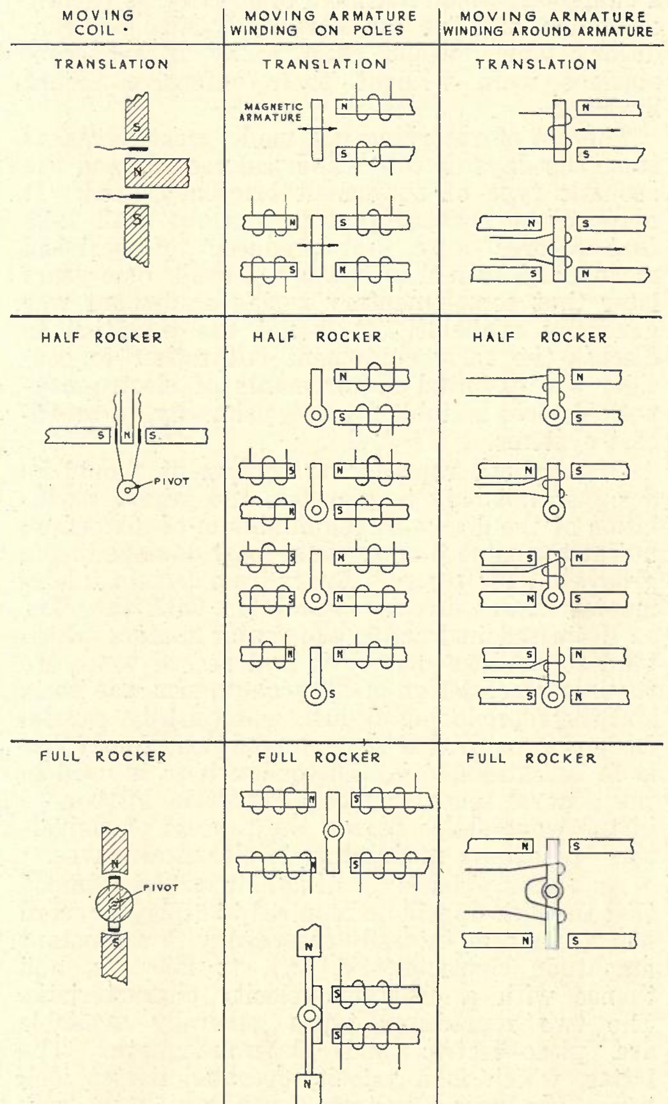

Fig. 2.—Gramophone reproducers basic magnetic types.

Some conflicting information has been published on the life of sapphire stylii, but it can be assumed that, with fair wear and tear, and provided the stylus is not removed from the pick-up, the life will depend on the compliance of the armature movement and the vertical force at its tip. On the other hand, carelessness or accidents may chip or even break the sapphire, while the removal and replacement of the needle in the pick-up may result in it being turned so as seriously to damage the grooves of the record. Sapphire is exceedingly hard and, once the grinding process has started, the turning of the stylus by even a few degrees would tend to cause damage to the grooves.

Reproducing Heads

There are many pick-ups of the electro-magnetic type available at present, but it is possible to determine their principle of operation from the basic types shown in Fig. 2. The most widely used is the half-rocker, but the tendency now is to use the moving coil or the modified half-rocker. The variations of these basic types, as used in practice, are many, and it is interesting to examine a range of pick-ups, if only to see the many attempts made to solve what would appear to be a simple problem, namely, converting mechanical movement to electrical waves.

As already stated, the armature should have a low mass and a satisfactory compliance, for this compliance has an important bearing on the vertical force at the needle point and the resulting record wear. If a relatively large stiffness could be used, there would be no difficulty in having the resonance of the armature with needle at a high frequency, but, ideally, the needle should follow the groove with just sufficient suspension stiffness to ensure its return to the centre line of the groove, a condition which requires a great deal of compliance. A vertical force is required to keep the needle point fitting tightly in the groove, consequently, as the stiffness of the suspension is increased, the vertical force and, hence, the wear on the record, is also increased. It is possible, by careful design, to obtain a frequency response to 10 or even 15 kc/s with a vertical force as low as $\frac{1}{2}$ oz. and sufficient compliance to prevent undue record wear, but designs of this nature are more suitable for laboratory use.

In the moving armature types it is necessary to have a good degree of mechanical balance of the armature movement in relation to the pole pieces, otherwise harmonic distortion will be produced. If the output voltage were not a consideration it would be possible to design the magnetic circuit so that the armature moved in a uniform field, even though out of centre, but a satisfactory output voltage is necessary and practical designs are a compromise resulting generally in a low voltage and low harmonic distortion. Fig. 3 shows a design which is satisfactory to 9,000 c/s, uses a miniature steel needle, has low harmonic distortion, a vertical force of $1\frac{1}{2}$ ozs. and an output of approximately –25 dbm when terminated in a matching load. It will be seen, however, that the magnetic circuit is inefficient in that there is no direct return path for the flux from the bottom of the armature and, likewise, the poles are spaced wide apart.

The moving coil type, Fig. 2, is now being produced in several forms and has the advantage that it can be of robust design. This type produces little distortion, but the electrical

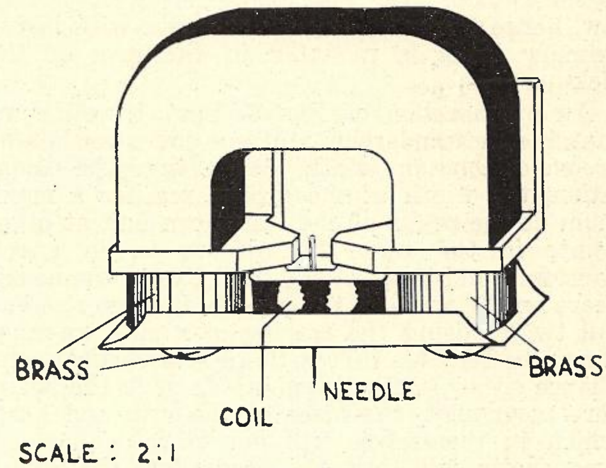

Fig. 3a.

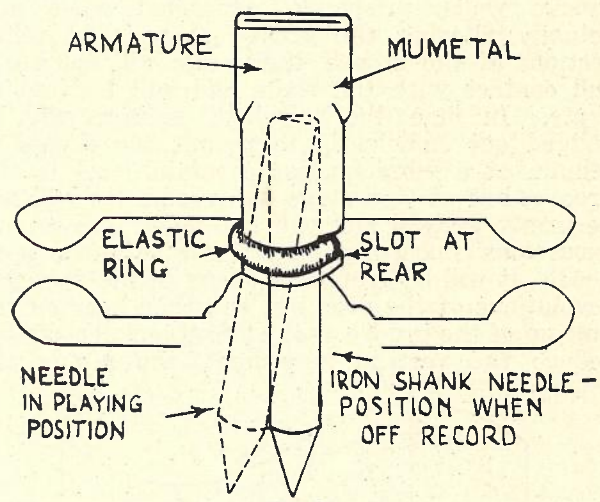

Fig. 3b.

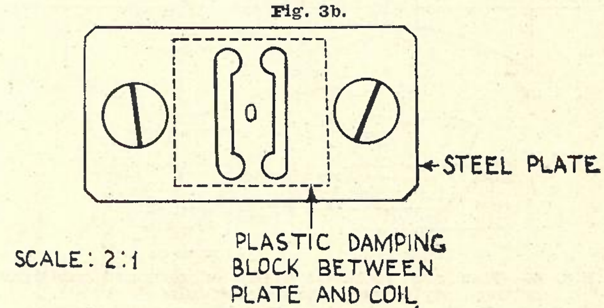

Fig. 3c.

Fig. 3.—Magnetic gramophone reproducer designed to use miniature needles.

(a) Reproducer with cover removed.

(b) Armature assembly with needle. When reproducer off record, needle held magnetically and by rubber ring. When on record, needle is clear of rubber ring and is wedged into position by the downward thrust of reproducer and drag of revolving record.

(c) Steel base plate with slots to permit the lateral movement of the armature.

output is low, being in the order of —43 dbm for a matched load. Since the winding forms a part of the movement, it is difficult to reduce the mass to a low enough value but, in one design, the coil consists of a single turn of flat ribbon phosphor bronze with a sapphire fastened directly to the ribbon. The impedance, however, is very low, hence the matching transformer with heavy primary leads is mounted in the arm of the pick-up.

An examination of Fig. 6, Part 1, will show that the cutting stylus will not cut a modulated groove of constant width. With sinusoidal modulation, the width of the groove reaches a maximum at the peaks of the waveform but, at other points in the wave the groove is, in effect, narrower, and if, as should be the case, the needle bears on the walls of the groove, it must rise and fall twice during the tracing of a sine wave, as shown in Fig. 4. Unless there is a vertical compliance either in the actual stylus or in the armature movement, the mass of the arm and head, which in themselves will not vibrate at signal frequencies, will force the needle into the groove at the "pinched" sections. This gouges out the groove walls, producing additional noise and actually altering the groove shape. At other sections of the groove, the needle will not be in full contact with the walls and will be free to skate. In time, the "pinched" sections will be gouged out sufficiently to permit the stylus to remain at a more or less constant level in the groove, but at this stage the needle tip will not be firmly wedged and will not follow the groove excursions faithfully. In the case of a steel needle, it will be ground to shape in the first few revolutions of the disc, but will then bear on the bottom of the groove and, while this will certainly reduce the vertical movement, the stylus can

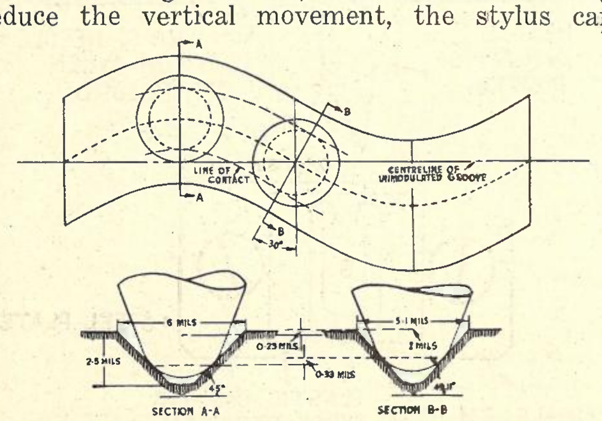

Fig. 4.—Plan and sectional views of assumed relations between stylus and laterally modulated groove.

never be positively driven by the groove. A similar condition will exist if a sapphire stylus with too small a tip radius is used.

These undesirable effects can be reduced to a negligible order by providing a vertical compliance either to the needle or to the armature movement. Fig. 5A shows such a needle, while Fig. 5B shows how the same effect can be obtained by using a cantilever movement which, in effect, is really a part of the needle. This latter method has its greatest use for lightweight pick-ups where a sapphire stylus is fitted to the movement. This compliance has the added advantage that it reduces the acoustic output of the pick-up. All pick-ups produce a direct acoustic output, which is a combination of surface noise and recorded programme, and is generally undesirable, particularly where the electrical output is to be heard in close proximity. The major cause of this trouble is due to insufficient vertical compliance, but can also be due to the lightweight metal enclosing the reproducer.

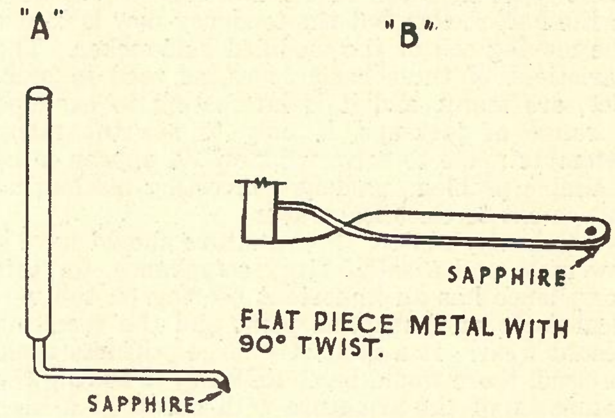

Fig. 5.—Examples of stylii with vertical compliance.
"A"—Replaceable needle.
"B"—Cantilever movement.

The Arm

Although the primary function of the arm is to carry the reproducer, it must also permit the needle to move on a radial line towards the centre of the disc. In the majority of recording machines, the overhead mechanism is designed to cause the cutter to follow such a line, but it is not practicable to provide such a mechanism for replay purposes; instead, an arm pivoted at one end is used. If the arm were infinitely long, the needle would move across the record on a radial line, but in the practical case the arm cannot exceed about 15 inches, and may even be as short as 6.5 inches. These lengths refer to the distance between the centre of the pivot and the needle point, and will be used to mean this distance throughout. It will be apparent that with a straight arm, the needle will move over the disc in an arc and can only be on the radial line at two crossover points. Unless the needle follows the radial line closely, three effects are produced. Firstly, record wear is excessive. This should be avoided at all times, particularly with equipment which is capable of reproducing records with an extended frequency range. As already shown, record wear not only results in increased noise but also excessive groove distortion. Secondly, second harmonic distortion and frequency modulation products are produced. Thirdly, the arm causes the needle to have excessive side thrust upon the record grooves. While a small amount of side thrust, which can be readily recognised as a force which tends to pull the arm to the centre of the record, may be useful to overcome pivot bearing friction, an excessive amount may pull the needle out of the groove, across the record to the centre, which would result in serious damage if cellulose nitrate discs were being replayed.

Tracking Angle: In Fig. 6, an arm with an offset head is shown on a record. The offset head or an arm bent to give an offset angle is now in general use. Let the arm have an effective length l inches with the centre of the pivot d inches away from the centre of the record. Then θ is the angle included between the line l and a radial line drawn from the centre of the record to the needle point, and ϕ is an angle between l and a line tangent to the groove at the needle point.

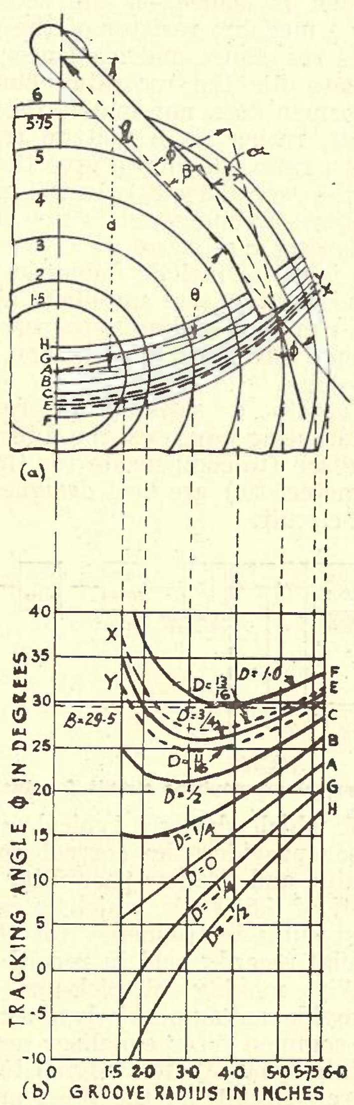

Fig. 6.—Dimensions and angles involved in pick-ups' design and curves showing how tracking angle varies with groove radius for different values of needle overhang "D."

ϕ is the tracking angle, and in a straight arm infinitely long would be zero, i.e., θ would be 90 degrees and the arm would always be at a tangent to the groove at the needle point. The angle β is the offset angle of the head and is measured clockwise from the line l to the centre line of the head, and should not be confused with the angle between the centre line of the arm and the centre line of the head. Fig. 6 also shows graphically the values of ϕ for various values of arm overhang D (swing of the needle point beyond the centre of the turntable), and it will be seen that for this arm when D is 13/16 inches for groove radii ranging from 1.5 to 6 inches, the tracking angle varies from 32 degrees at 6 inches through 27 degrees at 3.3 inches back to 32 degrees at the 2 inch radius. Now, if the head were given an offset angle β of 29.5 degrees, the departure of the needle from tangency is reduced to only 2.5 degrees on either side. This is the tracking error α and is the difference between the tracking angle ϕ and the offset angle β. The important point should be noted that the overhang D as well as the offset angle β, determine the tracking error.

While it was the practice to design for some permissible maximum value of tracking error, it has been found that it is equally as important to keep the tracking error changing at a uniform rate while a record is played. This applies more particularly to steel needles which are ground almost to groove shape after the playing of the first few grooves. As the tracking angle varies throughout the playing of the grooves, the needle is turned with respect to the grooves and is constantly reground, thus increasing record wear. At first sight, it may be thought that this would not apply to a sapphire stylus but, in fact, the results can be more serious for, although the grinding process is much slower, the fact remains that the sapphire is ground, and in turning must do greater damage to the grooves, due to its hardness.

Information is available (1) which enables the optimum design and correct overhang of an arm of any length to be determined for various sizes of discs and for the two speeds 33-1/3 and 78 r.p.m. From this design data the tracking error and its rate of change can be reduced to negligible values, with a resulting reduction in record wear, distortion and arm side thrust.

Arm Design: The much discussed question of arm construction, its mass, counterbalance versus springs, and the position of the vertical bearings is still not finally answered, as will be seen in commercial pick-ups available today. Even so, it is possible to discuss the more important factors that determine the design of the arm.

In the ideal case the arm with its associated reproducer should have a mass great enough to prevent it vibrating while the needle is following the excursions of the grooves and, in any case, the pick-up should not resonate with the compliance of the armature at a higher frequency than about 30 c/s. If it does and the equivalent "Q" of this resonant circuit is not high the lower frequencies will be accentuated. Naturally, it should not resonate at frequencies above 50 c/s, otherwise a peak will be experienced in the response curve. On the other hand, the pick-up should not have excessive mass, otherwise records which are not perfectly flat will have the grooves damaged, for the greater the mass, the greater the inertia and the more difficult will it be for the groove to lift the arm as it rotates, and the longer will it take for the arm to restore. Again, the arm must have sufficient mass to ensure that the correct vertical force can be applied to the needle point, but this represents no difficulty because, in general, it is more difficult to reduce the vertical force to the correct value.

To do the counterbalancing with a weight is, from a mechanical viewpoint, most satisfactory, but, in so doing, the mass of the arm is increased, and the alternative is to construct the arm in a much lighter manner. This, in the extreme case, would mean that parts of the arm would resonate in the audio-frequency range and so produce peaks and dips in the frequency response curve. The most satisfactory construction at present appears to be cast aluminium, using a "U" section, plastics in a "U" or "box" section or light-gauge metal tubing.

An alternative method of reducing the downward thrust is by means of a leaf spring with one end fastened to the base of the pick-up and the other pressing against the underneath side of the arm. If well designed, this method is satisfactory, but care must be taken that the workmanship is good and that the vertical force at the needle point is constant.

In the case of the counterweighted arm, the bearing providing the vertical movement of the arm should not be positioned too low, otherwise, on records which are not flat, the arm will tend to float and, in the extreme case, the needle may even leave the groove. The vertical bearing of the pick-up arm should be free, but should not have excessive play, otherwise the needle may not be upright in the groove or the arm may not be rigid enough for the needle movement.

In the case of the bearing which permits the rotational movement of the arm, this also should be of good design, and the use of ball bearings for this purpose is not unusual. It will be apparent that a bearing with little friction will give a high "Q" value at the resonant frequency of the arm mass and the compliance of the armature movement. However, this may not be a desirable condition, for, if the damping due to friction is not sufficient, the gramophone pick-up will be unstable when shock-excited, and may even tend to jump out of the grooves on a warped or uneven record. In many designs the bearing is large and of the simple sleeve type for this reason alone.

To summarise the above, it will be seen that the arm should be light in weight but rigid in construction, and should resonate below 50 c/s. It should be no longer than is necessary to reduce the tracking error to a satisfactory minimum for the largest disc to be used. For instance, a 15 inch arm would be unnecessarily long if 12 inch records were the largest to be played. In addition, the bearings should be of good mechanical design and, if the arm is to be used for broadcasting, the head should turn to facilitate needle-changing.

Terminating Circuits

These fall into two main categories, those for pick-ups required for domestic use and those for broadcasting use. In the former case the output should have as high a voltage as practicable so that the pick-up can be connected to the grid circuit of a radio receiver. It is usual now to supply with the pick-up an audio-frequency transformer, which is loaded on the secondary side with a $\frac{1}{4}$ or $\frac{1}{2}$ megohm resistor of the grid circuit and a series resistance and condenser in parallel to compensate for the recording characteristic. The transformer does not match the pick-up to the load but, rather, is a voltage transforming device with a ratio which will give the maximum voltage on the secondary (2). In the broadcasting case, the above arrangement is not satisfactory, for the following reasons:—

(a) It is usual to include faders in the gramophone circuits, and amplifiers are not, as a rule, near the pick-ups, therefore, low impedance circuits are necessary, preferably 600 ohms.

(b) To obtain a satisfactory response for broadcasting purposes, the filter and record equaliser (to compensate for the recording characteristic) are best designed for a 600 ohm circuit.

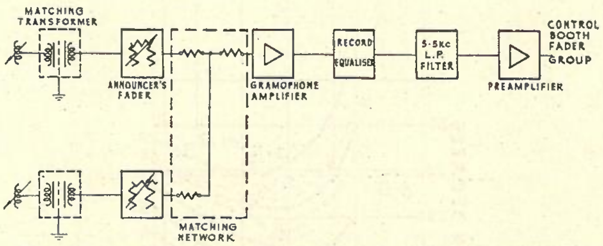

Fig. 7.—Typical gramophone circuit for dual machines.

In Fig. 7, which shows a typical arrangement, the equaliser provides the correct compensation to close limits, and the low pass filter is designed for a cut-off of 5,500 c/s, which is considered to be the most suitable frequency for the majority of commercial records held in record libraries at present. With moving coil pick-ups, it is necessary to provide an amplifier between the fader group and common filter equaliser network. This is to maintain a satisfactory signal to noise ratio of the overall circuit, as the filter and equaliser are subject to noise producing electro-magnetic fields.

Although the above arrangement has been in use in this country for many years, it is debatable if this practice should continue. In America, for instance, the equaliser and filter is associated with its individual pick-up. This permits a more simple arrangement, as the networks are not of the constant impedance type. Again, the equaliser does not follow the required curve as accurately nor does the filter cut off as sharply. On the other hand, these units are arranged to give two or three filter curves and at least two equaliser curves, one for the National Association of Broadcasters standard and the other for the standard 250 c/s crossover. There is the point also that it is undesirable to have the signal level too low at the faders. If in Australia the control booth operator performed all fading adjustments, the American method would be of use here.

Crystal Pick-ups

Until recently the crystal pick-up was in general use in broadcast studios, but at no time was it considered entirely satisfactory, for the following reasons:—

(a) The frequency response is not constant with time, temperature and humidity.
(b) It is fragile and does not withstand the handling received under broadcast conditions.
(c) The armature stiffness is too great, and record wear excessive.
(d) It is a high impedance device and it is necessary to use special circuits to adapt it for 600 ohm working.

Although the above list is formidable, for the period that they were in general use, there were no electro-magnetic types available which could have provided the same service. In spite of their disadvantages, crystal types are cheap and the cartridge can be replaced readily. In addition, the distortion introduced is low, and there is sufficient uniformity in their performance to enable almost any two to be used as a pair. For domestic use, the above disadvantages are not quite so serious, with the possible exception of record wear. The output into the grid of a tube is high and, with a little care, they will have an appreciable life. In the latest designs the needle chuck is coupled to the crystal element by means of a torsion bar or other isolating device which makes them more rugged. When operating into a high-resistance load, a compensation device is not required, as the pick-up itself is designed to provide the compensation.

The crystal element until recently was of Rochelle Salt, and usually consisted of two parallel plates fastened at one end while the other was actuated by a fork extension of the needle chuck. The basic response of the crystal is the inverse of constant amplitude and, to obtain the constant velocity characteristic above about 250 c/s, the movement was made to resonate at about 4,500 c/s. The movement, in addition, was damped with rubber to obtain a satisfactory response to 6000 c/s. With time, the rubber aged, and a typical response showed a dip at about 3000 c/s and a peak at about 4500 c/s. Fig. 8 shows the construction of an earlier type, while Fig. 9 shows a typical response and illustrates the points discussed.

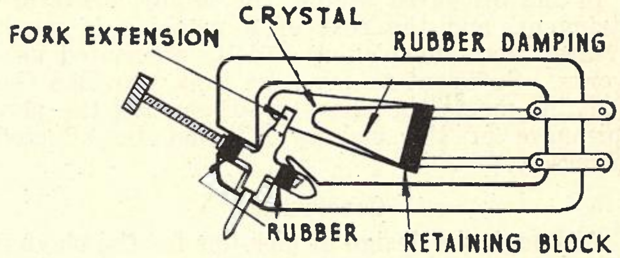

Fig. 8.—Crystal cartridge.

Although this type was originally supplied to operate with a vertical force of $2\frac{1}{4}$ oz., the armature stiffness was too great and it required a figure of almost 4 oz. to play all frequencies satisfactorily. One type which was stated to be satisfactory with 1 oz. required that the vertical force be increased to $2\frac{1}{4}$ oz. It would appear, therefore, that the crystal cartridge cannot be classed in the lightweight group.

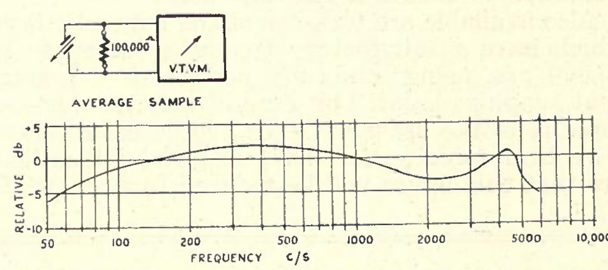

Fig. 9.—Frequency response of typical crystal cartridge.

Pick-up Testing

The most important tests which can be applied to a pick-up are as follow:—

(a) Mechanical inspection.
(b) Vertical force.
(c) Tracking error.
(d) Frequency response, including acoustic noise.
(e) Armature stiffness.
(f) Harmonic distortion.
(g) Impedance.
(h) Listening tests.

The majority of tests listed above follow normal practice but, regarding (d), (e) and (f), it has been found that these are best achieved by using constant frequency records, the characteristics of which have been determined previously. In the case of the armature stiffness, as this is not of value unless the vertical force is considered also, it has been found that constant frequency discs recorded at a relatively high amplitude can be used to ensure that the pick-up under test will play all frequencies without leaving the grooves.

The Gramophone Machine

As the gramophone machine has to turn the record, it is necessary that it does so at the correct speed, without short or long period variations, without vibration, and with the minimum acoustic noise.

In the broadcast studio, the requirements are stringent, and the cost of a machine is much greater than the pick-up and its associated networks. Sufficient to say here that, provided the machine meets the above requirements, the performance of the pick-up will not be affected adversely.

Conclusions

Although the design of pick-ups for the playing of cellulose nitrate discs has not received special attention, the factors involved are generally the same, except that the vertical force should not exceed $\frac{3}{4}$ oz. (3). Therefore, the replay stylus will be of sapphire or even diamond. The latter jewel is available in a few types, but the cost is high. It will be necessary to prevent such a pick-up being used for the playing of domestic discs. Where a pick-up is of a type which requires steel needles, "shadowgraphed" needles are used. This means that each needle has been examined to ensure a faultless point.

Also available are pick-ups of the magnetic type which have a satisfactory frequency response to 10,000 c/s, using miniature needles or a permanent sapphire point. For general use, the vertical force is in the order of $1\frac{1}{2}$ oz., while others have a vertical force as low as $\frac{1}{2}$ oz., and indications are that this figure will be reduced further, while the frequency will be extended to 15,000 c/s at least. The armature stiffness is being reduced in a comparable manner.

Records which have a frequency response to 15,000 c/s and an excellent signal to noise ratio have been heard by the author. As far as could be judged by ear, the distortion due to all causes was negligible. It may be of interest to state here that the frequency characteristic was constant amplitude to 250 c/s and constant velocity thereafter, which proves that pre-emphasis, with its inherent distortion, can be avoided. It is understood that records of this high standard will be available in Australia in the near future.

Finally, it can be said that the past developments which have resulted in such marked improvements in pick-ups and records will enable the discriminating listener to enjoy entertainment of an exceedingly high technical standard.

Part 3, which will deal with other methods of recording, will be published in a subsequent issue.

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LEVELLING OF EQUIPMENT RACKS IN AUTOMATIC EXCHANGES

T. F. Robson

In erecting and fixing racks in a 2000 type exchange, it is essential to arrange for the top angle-iron of all racks to be in the one horizontal plane over the whole floor area. If this is not done, difficulty will be experienced in erecting the overhead ironwork, runways and battery busbars.

In the construction of new automatic exchange buildings care is taken during the pouring of the concrete floors to obtain a level surface. However, present-day conditions have made it necessary to instal exchange equipment in locations not originally designed for the purpose. As a result, changes up to $1\frac{1}{2}''$ maximum have been found to occur in floor levels. To compensate for these variations, the wooden plinths on which the racks are mounted may be either built up with wood or cement grouting over the low parts or cut down and planed at the high parts. In general, for small variations up to one inch, the former method is satisfactory alone, but for larger variations a combination of both methods may be applied, as shown in Fig. 1. To set up the plinth before the grouting is laid, two small wooden blocks or strips of sheet lead are cut to size and placed under it as shown in Fig. 1. A strip of bituminous felt is tacked to the underneath surface of the plinth to protect it from the moist cement, and to assist in bedding down the plinth.

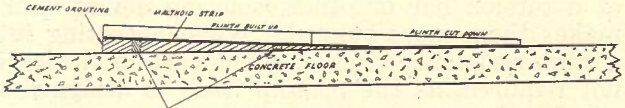

Fig. 1.—Method of laying plinths.

In order to determine accurately point to point variation in floor level, an ordinary spirit level may be used in conjunction with a straight-edge or a dumpy level used with sighting boards. However, it is proposed to describe another useful device which is accurate, simple to construct and capable of giving the required measurements quickly. It consists of two open glass tubes connected together by a flexible rubber or plastic tube of adequate length and of sufficient diameter to avoid the formation of air locks. One glass tube is mounted in a fixed position against a reference scale as shown in Fig. 2 and the other is mounted, but movable in front of a similar scale. The glass tubes, with the flexible tubing attached, are placed together and filled from one end with liquid, usually water, until both glass tubes are approximately half filled. Both tubes are then corked until a reading is to be taken. To measure the height between two points, A and B, the reference scale is placed at point A, and the second scale placed at point B. The corks are then removed and the tube associated with

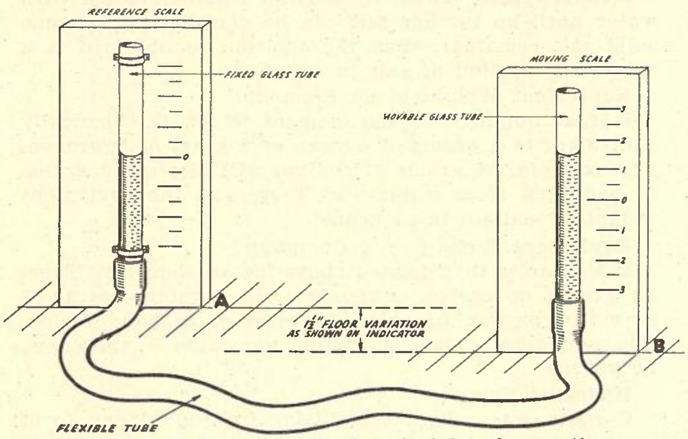

Fig. 2.—Glass tube method—principle of operation.

the second scale is moved up or down, as required, until the level of liquid in the reference tube (A) is at zero. The difference in height between the points is then read directly from the second scale (refer Fig. 2). If point B is lower than point A, the level in the second tube will be above the zero on the scale, and vice versa. With both scales fixed, lowering or elevating of the movable tube in effect increases or decreases the length of tube between the scales, resulting in a corresponding fall or rise of the water level relative to the scales. It is thus possible to bring the water level to the zero mark on the fixed scale without difficulty by adjustment of the second tube. This enables a direct reading of level difference to be made from the second scale and so avoids the need to subtract readings in order to obtain a result as would be necessary with both tubes fixed in relation to their scales. It is advisable to make readings to the bottom of the meniscus at both tubes, and, when working on floor levels, it is an advantage to have the reference scales attached to similar uprights sufficiently high to bring the reference scale to eye level. To ensure that the uprights are held vertically when in use, a plumb-bob or spirit-level may be fitted to them. By this means a complete survey of an exchange room floor can readily be made and the most satisfactory method of packing up or cutting down the plinths decided upon. This device has many other useful applications where height measurements are required. One typical example is the marking of the same heights in different rooms where walls prevent a sight measurement. In this case the tube is run via a doorway or other convenient opening between the rooms. Another example is the setting-up of an angle-iron header on a wall to carry tie bars from racks, and where the top of the header is to be exactly the same height from the floor as the top of the rack. This particular measurement is illustrated in Fig. 3.

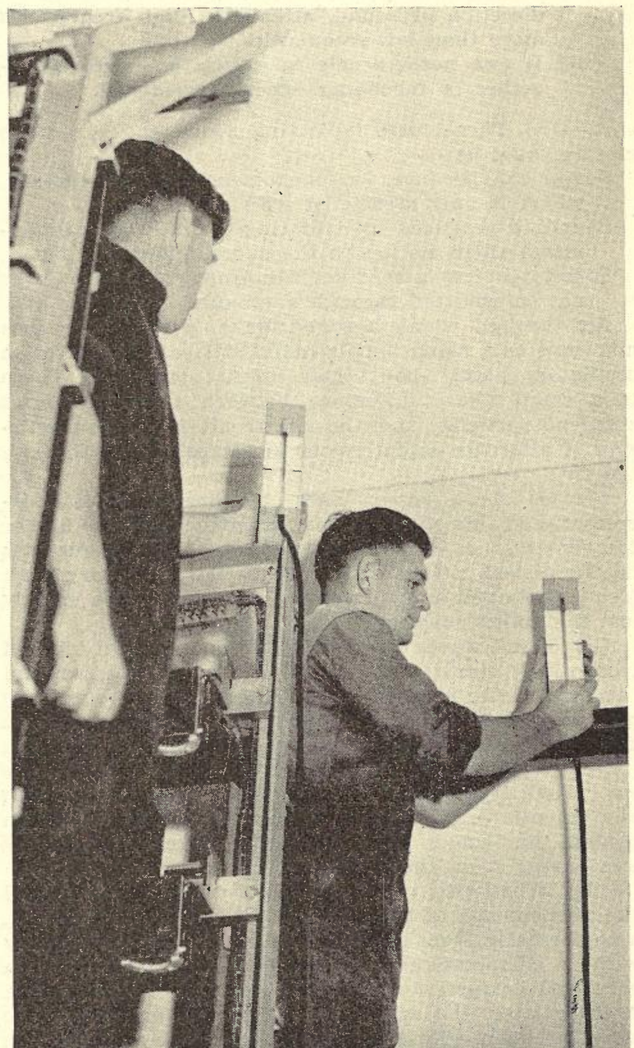

Fig. 3.—Measurement of floor levels using glass tubes.

ANSWERS TO EXAMINATION PAPERS

The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.

EXAMINATION No. 2721—ENGINEER—NATURAL SCIENCE

S. Chivers, B.Sc., P. R. Brett, B.Sc.

PART 2

Q. 11.—(a) Give three reasons why sound is considered to be a wave motion. Describe concisely how the air, through which the sound travels, is moving.

(b) Explain briefly the following observations:—

(i) Old people, generally, cannot hear the squeak of a flying bat.

(ii) The open hand held, say, 2″ from the ear in the direction of sound, attenuates high frequencies more than low frequencies.

(iii) If two notes nearly in unison are sounded together, a throbbing effect is produced.

A.—(a) Three facts indicating sound to be a wave motion could be:—

Sound can produce the phenomenon of interference, which is only associated with wave motion.

Sound is produced by vibrating bodies that communicate their motion to the surrounding medium.

Sound requires a medium for propagation, i.e., it is not transmitted through a vacuum.

Air through which a sound wave is travelling does not move as a mass, but its individual particles describe oscillatory paths about their normal position. There is a small phase difference between the motions of adjacent particles, and the net result is the transmission of alternate compressions and rarefactions through the air.

(b) (i) As a person ages, his hearing acuity decreases, and this effect is most pronounced in the higher frequencies, i.e., his ability to hear high frequencies is diminished. The squeak of a bat is a very high frequency sound and, therefore, old people have usually lost the ability to hear it.

(ii) Sound waves impinging on the hand are blocked from direct entry to the ear, but are diffracted around the edge of the hand to enter the ear. Low frequencies have a wavelength which is large in comparison with the width of the hand and its spacing from the ear, and, therefore, produce practically their full effect on the ear. High frequencies have a much smaller wavelength and, therefore, produce a marked interference pattern behind the hand. The ear thus receives considerably less energy from these waves.

(iii) When two notes nearly in unison are sounded the phenomenon of beats is produced. If, at any instant, a compression from one source reaches the ear together with a compression from the other source, then an enhanced compression force is experienced by the ear. A little later, the arrival of a compression will arrive simultaneously with a rarefaction from the other source, and the ear will experience a very small effect. The ear will, therefore, perceive a low frequency note, equal to the difference of the two frequencies, superimposed on the original notes.

Q. 12.—Explain, with a suitable example in each case, four of the following terms:—Saturated Solution, Equivalent Weight of an Element, Equivalent Weight of a Compound, Hydrated Salt, Reversible Reaction, Atomic Heat, Allotropy, Oxidising Agent.

A.—Saturated Solution.

If a solvent be agitated with a solute until no further solute can be dissolved, then the solution so obtained is known as a saturated solution at the temperature of the experiment. Thus, if common salt be shaken with water until no further salt can be dissolved (i.e., some solid salt remains), then the solution so obtained is a saturated solution of salt in water.

Equivalent Weight of an Element

is that quantity of the element which is chemically equivalent to 8 grams of oxygen or 1 gram of hydrogen. For example, 46 grams of sodium will displace 2 grams of hydrogen from water and, therefore, the equivalent weight of sodium is 23 grams.

Equivalent Weight of a Compound

is similar to that defined above for an element. Thus, 28 grams of carbon monoxide will combine with 16 grams of oxygen to give 44 grams of carbon dioxide. The equivalent weight of carbon monoxide is, therefore, 14 grams.

Hydrated Salt

Certain salts, when crystallizing from a solvent, form crystals which contain, as an integral part of their structure, molecules of the solvent. When the solvent is water, such crystals are known as hydrated salts. For example, copper sulphate crystallizes from water with 5 molecules of water to every molecule of copper sulphate, and forms blue crystals, the formula of which is written as $CuSO_4.5H_20$.

Atomic Heat

is defined as the number of calories required to raise the temperature of one gram atomic weight of the element by 1 degree Centigrade. Dulong and Petit found that this value was about 6.5 calories for many elements, but there are many notable exceptions.

Reversible Reaction

When certain compounds are mixed they react chemically to form other materials known as the products of the reaction. In some cases, by alteration of the conditions of the experiment (temperature, pressure, etc.), it is possible to cause the products so obtained to react again and regenerate the original compounds. Such a reaction is said to be reversible. For example, at normal temperatures, carbon dioxide will combine with calcium oxide to form calcium carbonate, but, at a red heat, calcium carbonate breaks down into calcium oxide and carbon dioxide again.

$$CaO + CO_2 \underset{\text{red heat}}{\overset{\text{normal temps.}}{\rightleftharpoons}} CaCO_3$$

Allotropy

When an element can exist in differing physical forms it is said to exhibit the phenomenon of allotropy. For example, carbon can exist in the form of diamond (clear, cubic crystals) or as graphite (black, hexagonal crystals), etc.

Oxidising Agent

Any material which can contribute oxygen or other negative ions to a reaction can be termed an oxidising agent. For example, hydrogen peroxide is unstable and prone to dissociate into water and oxygen, thus

$$H_2O_2 \longrightarrow H_2O + (O)$$

and, therefore, usually behaves as an oxidising agent in chemical reactions.

EXAMINATION No. 2721—ENGINEER—TELEPHONE EQUIPMENT GROUP 2

W. B. Wicking

Q. 4.—The installation work at a branch automatic exchange has been completed. The new exchange is situated in a metropolitan area and the equipment provided is of the 2,000 type, comprising line finders, D.S.R's, 3rd, 4th and final selectors, together with all necessary apparatus for the complete exchange.

(a) Enumerate the final tests to which the exchange and sub-station equipment should be subjected immediately prior to the date of cut-over.

(b) Give a brief description of each of the tests you have enumerated.

Any reference to the progressive testing and adjustment of the equipment during the installation work at the exchange should be omitted from your answer.

A.—(a) (i) On completion of the installation and prior to the cut-over of the plant, all L and K relays, line finders, allotters, discriminating selector repeaters, group selectors, final selectors, meters and items of auxiliary equipment, are tested individually to ensure that each performs its complete functions correctly.

(ii) A test is made of all subscribers' lines and extensions.

(iii) A call through test involving every line and every switch in the exchange is performed immediately prior to the cut-over.

(b) The tests of the individual switches are made by means of the appropriate routiner or installation test set, and cover every function of the switch concerned, such as—vertical and rotary stepping, guarding, testing outlets, feeding battery, application of tones and ring, cutting in on free, and passing over busy contacts, and release. When automatic routiners are provided, these tests are usually applied several times before cut over, to ensure that marginal adjustments and intermittent troubles which may test O.K. on one occasion are detected by subsequent tests. Repeated tests also serve to distribute lubricants and run in new mechanisms. Additional tests which should be made are:—

L and K Relays: Test for ground on marking commons to W9 lead to ensure that line finders will cut in on all levels. Test by connecting battery via test lamp to common and operating all K relays, one at a time.

Line Finders: Test each control set separately by busying out other control sets. Test for double-finding by initiating two calls simultaneously. Check control set with all but one TB relay operated. Check S and Z pulses for each control set and test for wrong cut-in by earthing 5th level marking lead, originating a call on this level, and observing that finder does not cut in. Check each finder for change-over, and from direct to indirect operation, by busying all finders and observing that relay RFZ operates. Originate a call with all finders busy and observe that allotters do not hunt.

Group Selectors: Observe that switches do not stop on a busy link, but test in correctly on the first free trunk by busying all outlets from 1st, 5th and 10th levels, and dialling each of these levels several times. Also, unbusy a contact in each level and observe that it is seized when the level is dialled.

Final Selectors: Make a check of the jumpering of P.B.X. groups.

Discriminating Selector Repeaters: Manual tests are made over all junctions under long and short line conditions.

Meters: Each meter is given a cycle of operations under limiting conditions, and observed for correct operation.

Sub-station Equipment: Tests are made from the test desk via a test distributor, with a technician at the subscriber's instrument, for the following:—

(i) Conductor resistance and freedom from earth or foreign battery on either line.
(ii) Insulation resistance.
(iii) Condenser capacity and bell.
(iv) Transmission.
(v) Dial operation, speed, ratio and number of impulses.

Call-Through Tests: This is made by setting up two calls from, and two calls to, each subscriber's number, through the exchange equipment, under long and short line conditions, and ensuring that all links between ranks of switches are used in sequence to establish the connections. Two telephones are connected to test shoes on the main distributing frame, each telephone being provided with a change-over key so that long and short line dialling tones may be imposed. One shoe is connected to the first line in the exchange and the other shoe to a line midway in the numbering scheme. With the key in the long line position the first testing officer dials number two test telephone. The ring is received, testing officers speak, and both restore receivers; the key is now restored to the short line dialling position and second call made. Testing officer No. 2 now calls the line connected to No. 1 testing telephone, using first long line and then short line conditions. The test shoes are now moved to the next respective numbers and the procedure repeated until all the lines have been tested. During the tests each rank of switches is supervised, and only one switch in each rank is available for a call, the remaining switches being busied. After each call the switch used in busied and another made idle. In this way every switch in every rank is completely tested under limiting working conditions.

Q. 5.—(a) Draw the circuit diagram of a 200 outlet group selector of the 2,000 type.

(b) Explain fully the factors in this type of group selector which may possibly contribute to carriage bounce, and indicate any modifications which you would suggest might be made to the switch frame or mechanism with the view to reduce to a minimum any possibility of carriage bounce.

A.—(a) (The complete circuit is shown in Drawing C.E. 65, latest issue 6).

(b) Carriage bounce in this type of switch occurs when the wiper carriage in restoring falls vertically from the level to which it has been raised prior to being rotated by the restore spring to the home position. On striking the shaft clamp the carriage tends to recoil upwards, and being, at this stage, free of the rotary detent, at the same time starts to rotate. If the recoil or bounce is appreciable, damage to the 12th rotary tooth and rotary detent may result, and the switch may fail to restore, due to the wipers fouling the bank contacts. In practice, some bounce is almost inevitable with this type of movement, since the momentum of the falling carriage tends to bend the bridge plate which, in restoring to its normal position, throws the carriage upward again. The factors which tend to produce bounce are, therefore—

(a) The momentum of the wiper carriage.

(b) The resilience of the bridge plate assembly which is accentuated when, as sometimes happens, the shaft clamp is set high, giving the upper leg of the clamp some clearance and introducing a spring-board effect.

(c) Absence of such restoring influences as cushioning, friction, etc.

It is not practicable, short of re-designing the switch movement, to reduce (a), since the carriage must fall freely and quickly by gravity from the level dialled, "the 0 level being the worst case." However, resilience of the bridge plate (b) may be simply and cheaply reduced by clamping a rigid bar of metal to it, thereby reducing its flexibility. The spring-board effect of the clamp may also be practically eliminated by setting the clamp lower on the vertical shaft so that the shaft is held in compression between the bridge plate and its upper cone setting. In these cases it is usually necessary to insert an additional metal disc on the bottom of the vertical shaft in order to restore the correct clearance when the wiper carriage is normal. Alternative (c) is difficult to overcome. Air or oil between the bottom surface of the carriage and the clamp or washer serve this purpose, but their effectiveness depends largely on the flatness, area, and intimacy of contact, of the two surfaces and with regard to oil on the characteristics of the oil used. All of these factors are variable and difficult to maintain constant in practice, and have little influence in reducing bounce.

Modifications to the switching frame which should effect improvement are: (i) The provision of a more rigid type of bridge plate and the fixing of the upper end of the vertical shaft rigidly to the frame, with a grub-screw or other suitable means, so that the shaft serves as a supporting member for the centre point of the bridge plate, minimising bending and the resulting recoil. (ii) Avoiding clearance when setting the shaft clamp or, alternatively, re-designing the clamp to eliminate the spring-board effect.

Q. 6.—(a) A subscriber's line, being faulty, is connected to N.U. tone. Explain fully the methods adopted to connect the tone and the precautions which must be taken in the use of the standard method of N.U. tone connexion.

(b) Give a list of the deferred alarms provided in an automatic exchange of the 2,000 type. In each case the delay period of the alarm should be stated.

A.—(a) Faulty subscribers' services are connected to N.U. tone at the exchange side of the main distributing frame. For this purpose, N.U. tone battery is distributed to tone bars mounted on the fanning strips on the arrestor side of the frame, one bar being provided for each 8 verticals. Each faulty line is connected to tone by means of a double-ended cord and plug, one end of which is plugged into the tone bar and the other inserted between the "in" and "out" springs on the negative side of the subscriber's arrestor in such a manner that the exchange spring is disconnected from the external line and connected to N.U. tone. An insulating wedge is also inserted between "in" and "out" springs on the positive side of the arrestor, disconnecting the exchange from the external line. At the same time, the cut-off springs of the faulty line are insulated by means of paper sleeves. In connecting the faulty services to N.U. tone, care must be taken to ensure that the line is not grounded on the exchange side of the protector and that the plug is inserted on the negative protector springs in the correct manner, i.e., with the conducting side against the exchange line spring. The method of connecting is shown in Fig. 1.

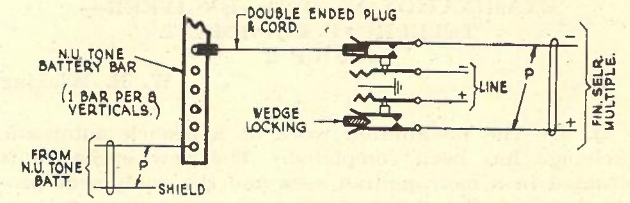

Fig. 1.

(b) The following are the deferred alarms and the delay periods provided:—

Alarm	Cause	Delay Period
P.G.	First selector held for excessive period before dialling.	6 minutes
Called subscribers Held	Calling or called subscriber holding connection for undue period after the other party has cleared.	3 minutes
N.U. tone Supervisory	Subscriber maintaining connection to a cancelled line for excessive period.	9 seconds
N.U. tone Overload	Low resistance earth fault on a line connected temporarily to N.U. tone.	No delay
Failure of ringing machine No. 1	Failure of power supply.	No delay

EXAMINATION No. 2721—ENGINEER—TRANSMISSION

SECTION 2

J. C. Wadsworth, A.M.I.R.E.

Q. 9.—The two undermentioned types of 10 kilowatt medium-frequency broadcasting transmitters are in service in the National system:—

(a) Low power modulation type, having two amplifier stages following the modulated stage;

(b) High power modulation type using Class AB modulator.

With the aid of block schematic diagrams, give a brief description of each type (omitting protective, alarm and cooling details, but including anode, filament and grid bias supply units), and discuss their relative merits.

A.—(The low power modulation type transmitter—Type (a)—has been fully described by Robertson[1], and also in examination form by Dodds[2]. The relative merits of each type are considered, in examination form, by Hyett[3]. The listed disadvantages in the answer are the advantages of the low power modulation system. In view of these previous answers, only a description of the high power modulation type transmitter—Type (b)—will be given here.—J.C.W.)

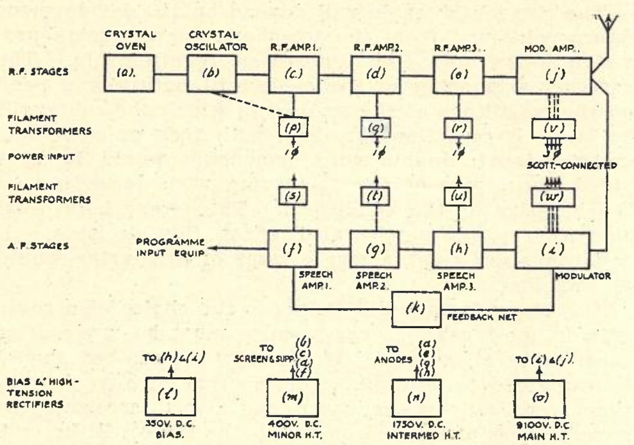

Fig. 1.

The block schematic (Fig. 1) shows a Type (b), i.e., high power modulation type transmitter, in which the various stages are as follow:—

(a) **Crystal Oven,** which keeps the temperature at which the crystal operates to within ± 1° C. to hold the crystal operating frequency to within ± 10 cycles per second under any conditions.

(b) **Crystal Oscillator** which, when stabilised by the crystal in the oven, produces the transmitter carrier frequency, and is capacitively coupled to—

(c) **R.F. Amplifier 1,** which is a class A operated amplifier having an output of 10 watts. It acts, too, as a buffer to the oscillator to prevent frequency variations with changing Modulated Amplifier load conditions. The amplifier is coupled through a π network to—

(d) **R.F. Amplifier 2,** and

(e) **R.F. Amplifier 3,** which are two class C stages of amplification, interconnected through a π network. The amplifiers have outputs of 150 watts and 600 watts respectively, and are capacitively coupled to the Modulated Amplifier (j).

(f) **Speech Amplifier 1,** and

(g) **Speech Amplifier 2,** which are resistance coupled to each other, are Class A amplifier stages capable of amplifying the 1 milliwatt output of the Programme Input Equipment to 300 watts, and are resistance coupled to—

(h) **Speech Amplifier 3,** which is a class AB amplifier cathode coupled to the modulator and providing the 400 watts required to drive the—

(i) **Modulator,** which is a class AB power amplifier. The 7.5 kilowatt output of the modulator is fed via the modulation transformer and inductor to the anode circuit of the—

(j) **Modulated Amplifier,** which is a class C plate modulated power amplifier with an unmodulated power output of 10 kilowatts.

(k) **Feedback Network.** 20 db. of negative feedback is applied from the output of the modulator stage back to the input of Speech Amplifier 1. This causes a reduction in noise and phase and harmonic distortion, an improvement in overall stability and frequency response and the linearity of the modulator output impedance.

(l) **Bias Rectifier,** which supplies 350v. D.C. to the grids of Speech Amplifier 3 and Modulator tubes.

(m) **Minor H.T. Rectifier,** which supplies 400v. D.C. to the Crystal Oscillator, R.F. Amplifier 1, R.F. Amplifier 2 (Screen and Suppressor grids), and Speech Amplifier 1.

(n) **Intermediate H.T. Rectifier,** which supplies 1750v. D.C. to the R.F. Amplifier 2 (Anodes), R.F. Amplifier 3 and Speech Amplifiers 2 and 3.

(o) **Main H.T. Rectifier,** which supplies 9100v. D.C. to the Modulator and Modulator Amplifier.

(p), (q), (r), (s), (t), (u) **Single-Phase Filament Transformers** supply the filament power at either 6.3 or 10 volts to the Crystal Oscillator, R.F. Amplifiers 1, 2 and 3, and Speech Amplifiers 1, 2 and 3.

(v) and (w) **Scott Connected Filament Transformers.** Convert 3-phase primary power to 2-phase, 11 volts/phase, filament power for the Modulator and Modulated Amplifier tubes.

References: The Telecommunication Journal of Australia.

1.—H. S. Robertson, 3GI, Gippsland Regional Broadcasting Station, Vol. 1, No. 1, December, 1935, pp. 45-50.

2.—R. G. Dodds, Answers to Exam. 2255, Q.4, Vol. 3, No. 2, P. 114.

3.—H. W. Hyett, Answers to Exam. 2295, Q.5, Vol. 4, No. 1, p. 58.

Q.10.—Describe, with the aid of sketches, the causes of fading in the following cases—

(i) that of a medium-frequency station within the range of the ground wave,

(ii) that of a high-frequency station beyond the range of the ground wave.

Discuss the methods adopted to overcome the effects of fading with each of the above types of transmission.

A.—1. **Causes of Fading.**

(a) **In case (i)**—The causes of fading of medium-frequency stations are considered by McKenzie[1], and in examination form by Freeman[2] and Hatfield[3].

(b) **In case (ii)**—The causes of fading are described by Smith[4], and in examination form by Freeman[2] and Hatfield[3], whose answers are applicable to both cases.

2. **Methods adopted to overcome effects of Fading.**

(a) **In case (i)**—Meaures to overcome the effects of fading may be applied at both the transmitting and receiving points, e.g.:

At the transmitter, the aerial used shall be such as to ensure a maximum of radiation in the horizontal plane, and as little high angle radiation as possible. McKenzie[1] discusses the design of various radiators, whilst Kaye[5] deals with the matter in examination form.

At the receiver, the effects of fading in the receiver may be minimised by the use of automatic volume control, which has been covered in examination form by Read[6] and Dodds[7].

(b) **In case (ii)**—Measures cannot be adopted at the transmitter in this case, because, when the optimum working frequency and angle of propagation have been chosen for a particular path, depending upon the predicted height and ionization of the ionized layers, the fading is due entirely to layer conditions. However, at the receiver, automatic volume control, as discussed for case (i), may be employed. Due to the large degree of fading which may be experienced at high frequencies, automatic volume control is unable to handle satisfactorily the wide variation in signal strengths and diversity reception, which assists in keeping the received signal strengths more uniform and within the range of the control of the receiver automatic volume control. Diversity reception has been covered in examination form by Hyett[8].

References: The Telecommunication Journal of Australia:

1.—A. J. McKenzie, Developments in Broadcasting Aerials, Vol. 1, No. 3, June, 1936, pp. 58-62.

2.—J. E. Freeman, Answers to Exam. 2377, Q.4, Vol. 4, No. 6, February, 1944, pp. 373-4.

3.—W. H. Hatfield, Answers to Exam. 2473, Q.4, Vol. 5, No. 4, June, 1945, pp. 251-2.

4.—N. S. Smith, Short Wave Radio Transmission, Vol. 3, No. 6, February, 1942, pp. 331-338.

5.—A. H. Kaye, Answers to Exam. 2106, Q.4, Vol 2, No. 3, February, 1945, pp. 189-190.

6.—J. W. Read, Answers to Exam. 2194, Q.6, Vol. 2, No. 6, February, 1940, p. 406.

7.—R. G. Dodds, Answers to Exam. 2255, Q.7, Vol. 3, No. 2, October, 1940, pp. 115-116.

8.—H. W. Hyett, Answers to Exam. 2295, Q.6, Vol. 4, No. 1, June, 1942, pp. 59-60.

NOTE: The student should realize that, in each of these answers, he has been referred to several previous answers to cover the one question. In order to answer the question in the allotted time, therefore, he would require to combine the previous answers in précis form.

EXAMINATION No. 2721—LINE CONSTRUCTION PART B—CONDUITS AND CABLES

Q. 4.—It is proposed to lay a length of submarine cable to provide services for a number of telephone subscribers on an island about one mile from the mainland.

(a) Briefly describe the type of cable you would instal.

(b) What factors would govern your selection of a route for the cable, and what preliminary investigations would you make?

(c) Describe the method of laying such a cable, omitting any jointing operations.

A.—(a) There are three main types of cable from which a selection could be made. These are insulated with paper, rubber and gutta percha or similar material.

The insulating material selected will depend mainly on the sea-bed conditions and depth of water. For depths greater than 100 fathoms and severe bottom conditions, rubber, gutta percha or similar material is preferred. Where bottom conditions are favourable, paper-insulated cable is satisfactory, as an appreciably greater number of conductors can be accommodated in the cable, a paper-insulated cable being much smaller in diameter for a given number of conductors than either a rubber or gutta percha cable. The cost of armouring this smaller cable would also be less and, as it would be a lighter cable, it would be easier to handle.

It is assumed that an economic comparison into the relative merits of establishing a telephone exchange on the island and only providing a cable for junction purposes instead of laying a submarine subscribers' cable has been carried out.

The size of the cable will depend on the development figures obtained from the telephone survey, some provision being made for unforeseen requirements. The external armouring of the cable will naturally depend on the conditions of the sea-bed in which the cable will be laid. If conditions are bad, with rock or coral outcrops present, double wire armouring would be provided, the gauge of the armouring wire depending on the severity of the conditions. The strength of tidal sets and currents will also affect this decision. If conditions are good, a single layer of armouring would be sufficient.

(b) Many factors will influence the choice of a route and, in most cases, a compromise must be made after considering all aspects. If possible, the sea-bed should be examined to determine the position of any obstructions, coral outcrops or rocks, and also to ascertain the general class of sea-bed on which the cable will be laid. A sandy or muddy sea-bed is desirable.

Navigation charts should be carefully examined and local residents or fishermen interrogated to obtain the benefit of any local knowledge. The proposed route should also be discussed with the authority controlling the waterway. The cable should be laid in a position where the risk of damage by ships' anchors is at a minimum, otherwise it may be necessary to dredge a trench for the cable. Consideration should also be given to the land approaches on each side of the crossing. As submarine cable is an expensive item of material, the overall length should be kept to a minimum, but this length will, of course, depend on the results of investigations made into the points mentioned in the foregoing.

(c) The method of laying the cable will naturally depend on many factors, such as weight of cable, tides and currents in the channel, availability of barges or motor launches, etc. It is preferable to have the cable in one complete length, but this is dependent on whether the cable drum can be readily handled and mounted on the vessel used in the cable-laying operations. The cable drum is mounted on jacks placed on the vessel, and one end landed. The method of landing adopted depends on the surroundings, but it may be possible to pull the end straight to the landing point. On the other hand, if the vessel cannot approach the shore, the cable would be floated ashore by attaching airtight drums at intervals. The drums are removed later, when the cable is in position. The vessel then proceeds across the waterway, laying the cable over the stern along the predetermined route, preferably previously laid out with marker buoys. The remaining end is then landed by either of the methods previously mentioned.

This method is not suitable on all occasions, as the cable may be paid out too fast, and there would be difficulty in stopping the drum rotating. Due to the type of boat available, it may also be difficult to mount and secure the cable jacks, and there is always the possibility of the cable drum overturning. An alternative method is to arrange the cable on the deck of the barge in figure 8 formation and then pay it out by manpower during laying operations.

Where the length of crossing is too great for laying in one operation, the end of the first length is sealed and buoyed until the second length is ready for laying. A joint is then inserted and laying operations continued.

Before laying the cable, the lengths must be tested for insulation resistance, continuity, etc., and tested with gas (if a paper-insulated cable) for a period of at least 24 hours, at a pressure of 20 lbs. per sq. inch.

Q. 5.—Describe the various types of protective coatings and armourings for lead-covered, paper-insulated cable, which are used by the Department.

Under what circumstances is each used?

Enumerate any special steps you would take to check the need for these coatings or armourings.

A.—Protective coatings are applied to lead-covered cable during manufacture, and can be divided into three types—

(a) Jute and bitumen covered.
(b) Steel tape armoured.
(c) Steel wire armoured.

(a) The paper-insulated, lead-sheathed cable, after careful scrutiny for defects, is passed through a bath of a bituminous compound and then wrapped with two overlapping layers of paper. The cable is compounded, served with jute yarn and again compounded before finally passing through a revolving drum containing powdered limestone. The limestone is applied to prevent the layers of cable sticking together when wound on to the cable drum.

(b) The general make-up of the steel tape armoured cable is similar to the jute and bitumen-covered cable, except that two overlapping steel tapes (width and thickness depending on the diameter of the cable being armoured) are applied over the jute yarn. A coating of compound is applied immediately after the armouring, and the cable is again covered with jute yarn and compounded, before finally passing through the limestone bath.

(c) is similar to (b), except that steel wires are used in lieu of the steel tapes. Double wire armouring is sometimes used and, in these cases, the layers of wire are separated by an intermediate layer of jute yarn. The steel wires are applied with a left-hand lay, both layers for a double wire armoured cable being applied in the same direction.

Protected cables are used in locations where it is not practicable to lay ducts or where such cable is more economical than the provision of a duct. Jute-protected cable is also used where protection from corrosion is desired but where the risk of mechanical damage is unlikely.

Tape-armoured cable is used where greater mechanical protection than provided by jute and bitumen protection is required. Long trunk cables are laid in ducts through towns and built-up areas, but in the open country, tape- or wire-armoured cable is provided. The wire-armoured cable is used for river crossings and in difficult ground, such as mountain-sides, where additional strength is needed. It can also be used for attaching to bridges, as it reduces the possibility of damage due to inter-crystalline fracture by vibration, but it is preferable to keep the cable off the bridge and lay it in another location, if possible.

The lead sheath of wire-armoured cables contains 1% of antimony, to reduce the likelihood of damage due to crystallisation by vibration.

The principal circumstances under which special tests will be required are:—

(a) Use of protected cable for corrosion purposes.
(b) Use of wire-armoured cable for submarine purposes.

The need to lay a protected cable would be determined by a soil resistivity survey along the route of the cable and a chemical analysis of soil samples from representative points. Normally, tape-armoured cable would be used for trunk cables in open country but, for various reasons, such as a shortage of steel tape, it may be necessary to use a jute-protected cable. In these cases the route would be carefully examined for the presence of stones likely to damage the cable, and the jute-protected cables only used in areas where such potential troubles do not exist. A surface examination will not always be sufficient, and test bores to the proposed depth of the cable would be necessary.

Before laying a submarine cable, the route should be carefully selected, so as to avoid any rock outcrop or coral formations. Examination of navigation charts should be made and all sources of possible information regarding the route exploited. The result of these investigations would determine the type and size of armouring to be used on the submarine cable.

Q. 6.—Give a list of material and approximate total man-hours and total cost for—

(a) A single 4″ R.C. pipe over a distance of one mile. Assume half rock excavation and asphalt reinstatement.

(b) A 200 pair 10-lb. S.Q.L. cable in the pipe nnder (a).

How many men would you employ in each of the parties required for the conduit installation and for drawing the cable in (b)? Indicate how you would allocate the various functions to the members of each party.

A.—The pipe to be laid is a 4″ concrete pipe, reinforced and supplied in 6 ft. lengths, with spigot and socket ends, which are designed to provide satisfactory aligning and sealing features, when employing moulded rubber rings. The route involves rock excavation and asphalt reinstatement over half the distance, i.e., for half of the mile, and it is assumed that the balance of the route is in a generally undeveloped area without formed footways. The position of jointing chambers should be determined. It is assumed that joints will be made at approximately 120 yd. intervals and that double cover footway covers and frames will be required. Provision should be made for drainage of the jointing chambers. Average cover for the pipe has been taken as 1′ 6″. The cable to be drawn into the pipe is a 200 pr. 10-lb. S.Q.L. type and, it is assumed, will be jointed through straight—without lateral connections, there being 15 intermediate joints.

The material and labour requirements are as follow:

(a) **Single 4″ R.C. Pipe**

(i) **Material**

Item	Quantity
Pipes, Concrete, 6′ x 4″	880
Rings, Rubber	880
Sand (Packing for Pipes)	150 cu. yds.
Covers and Frames, Footway No. 5	15
Cement	210 bags
Metal Screenings, ½″	45 cu. yds.
Sand	30 cu. yds.
G.I. Wire, 200 lb.	240 lbs.

(ii) **Labour.** Trench 2 ft. deep by 1′ wide.

	Unit	Qty.	Man-hours
Excavation	161	410	1435
,, ...	161A	95	380
,, ...	161B	205	615
Filling in	165	415	830
Laying pipe (drains)	601	2400	182
,, ,, ...	619	5130	168
Building manholes ..	184	15	360
Travelling, Recording, etc.			992
Total			4962

(iii) **Total Cost**

The total cost of laying a mile of conduit depends on the class of soil through which the pipe is laid, and the type of labour available. The present-day average cost is approximately £1500.

(b) **200 pr. Cable**

(i) **Material**

Item	Quantity
Cable, P.I.Q.L., 200 pr./10 lb.	1800 yds.
Lead Sheet, 5 lb.	240 lbs.
Solder Wiping	30 lbs.
Sleeves, Paper, Jointing	7500
Tags, Linen, Identification	1000
Acetylene Gas	300 cu. ft.
Paper Wrapping	3 rolls
Cable-Pulling Compound	160 lbs.
CO_2 Gas	75 lbs.
Sundries—Kerosene, Sperm, Cotton Waste, etc.	

(ii) **Labour**

	Unit	Qty.	Man-hours
Drawing in	111	1800	162
Testing cable with gas	117	40	80
Testing cable with megger	117A	4	16
Identifying	118	400	28
Jointing	120	3000	260
Capping Cable	124	8	32
Plumbing	125	15	30
Travelling, Recording, etc.			150
Total			758

(iii) **Total Cost**

The total cost of providing, drawing in, testing and jointing one mile of 200/10 P.I.Q.L. cable is approximately £1,000.

Arrangement for Parties

(a) Conduit

The conduit gang proper will consist of the Party Leader, second-in-charge, one pipe-layer and 6 conduit workers. Attached to the party should be a manhole builder and assistant for the period necessary for manhole construction. In addition, for the purpose of breaking up pavement and breaking rock, two compressor and pneumatic drill operators will be required during portion of the work.

The various members would be employed as follows:

Party Leader. Second-in-charge.	General direction of work. Setting out alignment for excavation and fixing grade for trench. Measuring and recording. Preparation of reports and progress statements.
Conduit Workers.	4-5 men continuously employed opening up trench. Filling in at end of day. 1-2 men laying out pipes and assisting pipe-layer, removing spoil and filling in trench.
Compressor Operator. Drill Operator.	Operating compressor and pneumatic drill as required.
Manhole Builder and Labourer.	Setting out and building manholes.
Truck Driver.	Driving and loading truck. Assists in excavation.

(b) Cable

The Cable-Hauling Party should include:—

1 Party Leader.
1 Second-in-charge.
1 Winch Operator.
4 Linemen, including Truck Driver.

The functions of these men may be set as follow:—

Party Leader: General direction, and in charge of operations at hauling end. Recording and reporting.

Second-in-charge: In charge of operations at drum end.

Winch Operator: Controlling winch under direction of Party Leader.

1 Lineman: At hauling end to assist in setting up winch and hauling gear. Observing travel of hauling rope, and reporting.

2 Linemen: Rolling drum and feeding cable into manhole.

1 Lineman: Guiding cable into duct and applying cable-pulling compound.

PART C.—AERIAL WIRES

Q. 7.—A new main trunk pole route of considerable length is to be erected, largely through timbered country.

(a) Give a list of any special equipment which might be needed to carry out the work economically and as speedily as practicable.

(b) Briefly explain the field of use of each item and how you would organize the work to ensure efficient use of the equipment.

A.—(a) Tree-felling saws.
Bulldozers.
Winch trucks.
Pole hole-borers and pole-lifting attachments.
Pole trailers.

(b) Tree-felling saws may be of the chain type, which can be used to fell trees up to 2 ft. in diameter, the chain being driven by a petrol motor. Two men are required to operate it. The saws may also be of the circular type, which are generally suitable for felling only the smaller trees, the diameters of which are limited by the radius of the saw blade. Another saw is the motor-driven fore and aft type, which is suitable for cutting up logs on the ground. This saw is much slower to operate than either of the two types mentioned previously. The chain and circular types can also be used to cut up felled timber. Bulldozers clear away undergrowth and felled timber. The blade may be fitted with an attachment enabling pressure to be brought against the smaller varieties of standing trees at a high enough point to push them over. The 'dozer is a great time- and labour-saver on timbered routes. Winch trucks are very useful for dragging away logs, and general purposes on clearing work.

Pole hole borers, as the name implies, are used for boring the pole holes. The borer may be of the self-contained type, operated by a power take-off from the engine of the truck. The machine is generally fitted with an attachment for lifting and then erecting the poles. Another type is a borer mounted on skids and then temporarily attached to a suitable truck. In this case, a separate power unit is employed. Pole trailers are useful for moving poles to other positions along a route if required. The unsprung, single-pole type would be the most convenient on a work of this nature.

To ensure efficient use of the mechanical equipment available, it will be necessary to arrange the progress of the work so that any single item of equipment will have a minimum period of idleness in any one day throughout the whole job.

Before the pole hole borer is brought on to the job, the route should be surveyed and the positions of all poles clearly marked. It may be necessary to do a certain amount of clearing before the survey, the remainder being done when the route is being erected. The heavy clearing would be done first, followed by the light clearing, cutting up, stacking, removing, burning off, etc. The poles would all be fitted by an advance party and then erected by the party with the pole hole borer. Alternatively, it may be preferable to have the pole hole borer only bore the holes, and a truck, fitted with a winch, to follow on and erect the poles. After the poles have been erected, the wire-stringing party will erect all wires and complete the work.

Q. 8.—It is proposed to use steel pipe, 18 feet long and $3\frac{1}{2}$ inches external diameter, for poles on a new route. The section modulus of the pipe is 1.7, and spans will be $2\frac{1}{2}$ chains each. 200 lb. H.D.C. wire (diameter 0.112") will be erected on 8 pin arms. Assuming a maximum wind pressure of 12 lb. per square foot and a safe working stress for steel of 18,000 lb. per square inch—

(a) What would be the maximum allowable bending moment at the ground level?

(b) What would be the maximum number of wires you would permit?

(c) How many additional wires would you permit if the poles were provided with a base section of pipe of 4 inches external diameter, having a section modulus of 2.25?

Show all calculations.

A.—(a) Assuming that the maximum bending moment occurs at the ground level—

Where M = bending moment (inch lb.)
f = safe stress (lb./inch^2)
Z = sectional modulus (inch^3)

Then, from data given, allowable bending moment at ground level

$M = fZ = 18{,}000 \times 1.7$ (lb./inch^2 $\times$ inch^3)......(1)
= **30,600 inch. lb. Ans.**

(b) Wind loads.

(i) per wire $= 0.112/12 \times 2.5 \times 66 \times 12$ (feet $\times$ feet $\times$ lb./feet^2)
= 18.48 lb.
for 8 wires $= 8 \times 18.48 = 147.84$ lb.

(ii) on pole (assumed 3′ 6″ in ground)
$= 14.5 \times 3.5/12 \times 12$ (feet $\times$ feet $\times$ lb./feet^2)
= 50.75 lb.

Bending moments due to wind loads

(i) one arm of wires (wire level assumed 3″ above pole top)
$12 \times 14.75 \times 147.84$ (inch $\times$ lb.)
= 26,180 inch lb.

(ii) one pole (considered concentrated at half pole height)
$12 \times 14.5/2 \times 50.75$
= 4430 inch lb.

Total Bending moment
$= 26{,}180 + 4430$
$= 30{,}610$ inch lb.

$\therefore$ This is sufficiently close to the allowable bending moment to permit **8 wires, i.e., 1 arm. Ans.**

(c) If base section modulus be increased to 2.25 inch^3
Total bending moment from (1)

$M = 18{,}000 \times 2.25$
$= 40{,}500$ inch lb.

$\therefore$ the additional allowable bending moment
$= 40{,}500 - 30{,}600$
$= 9{,}900$ inch lb.

Assuming second arm 14″ below top arm
height of wires $= (12 \times 14.75) - 14$
= 163 inches

$\therefore$ loading permissible at 163″ above ground
$= \dfrac{9900}{163}$ (inch lb./inch)
= 60.35 lb.

$\therefore$ number of wires
$= \dfrac{60.35}{18.48}$ total load lb./load per wire
= 3.28

$\therefore$ 3 additional wires could be permitted on the second arm.

EXAMINATION No. 2721—ENGINEER—TELEGRAPH EQUIPMENT

A. F. Hall

Q. 3.—(a) Discuss modern trends in connection with the testing of polarized telegraph relays. Give a list of normal tests and show by means of sketches how the tests would be carried out.

(b) What are the correct normal relay contact adjustments for a relay working on a channel at, say, 90 bauds?

A.—(a) Before a polarized telegraph relay is accepted, it is necessary to ensure—

(i) that the magnetic materials used in its construction are of sufficiently high-grade for the service required;

(ii) that the workmanship will ensure satisfactory life and service;

(iii) that it will be sensitive and will faithfully reproduce the signals received;

(iv) that it will introduce as little distortion as possible into the circuit in which it is used;

(v) that its working adjustment will be simply and rapidly achieved and positively maintained.

Tests formerly applied to polarized telegraph relays covered these requirements fairly satisfactorily, but knowledge of what happened at the contacts of the relay under varying signal values and circuit condition was a matter for conjecture, except perhaps in the laboratory.

Furthermore, after a relay was taken into service very little attention in the way of testing was given until the relay was withdrawn from service for major repair.

The modern trend is to divide the testing of polarized telegraph relays into two sections, viz., general tests and routine maintenance tests.

The introduction of the oscilloscope into the telegraph workshop has provided an excellent means of obtaining accurate knowledge of the response of relays. Not only does it enable the comparison of the performance of different relays undergoing acceptance tests but, by its use, faulty relay operation can be traced to its source and a desirable high standard of relay performance can be maintained.

The regular routine maintenance of polarized telegraph relays used in a main telegraph office has proved to be advantageous in reducing loss in working time, due to faulty relays. A simple test set used after each relay has been serviced indicates whether the relay is fit for service or requires workshop attention.

Relays at present available comprise a number of different types according to the intended service or some outstanding feature of design. The acceptance tests listed below, being general tests, may not apply to all types of relay, but should be modified to suit the particular type.

GENERAL TESTS

1. Visual examination covering—
(a) pivots,
(b) contact alignment,
(c) operation of biassing mechanism,
(d) general workmanship, presence of foreign matter,
(e) resistance test to verify type of relay.

2. **Continuity of Windings and Response to Signal Polarity:** See Fig. 1. Continuity of windings will be indicated by milliammeter A. The response of the relay will be observed on meter B. When positive polarity is applied to the main windings in the direction D-U, the tongue should move to space; when negative is applied in this direction a mark should be indicated. Auxiliary windings are not always distinguished for direction, but uniformity is necessary to permit replacement of relays.

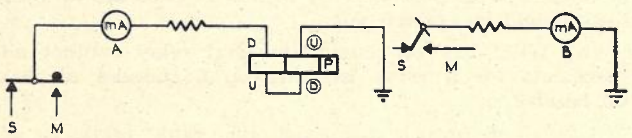

Fig. 1.

3. **Differentiality—Main and Auxiliary Windings:** The relay should first be placed in the neutral condition, i.e., with prescribed contact gap and bias screw in the zero position equal pressure will be required to move the tongue to mark or space.

With connections indicated in Fig. 2, there will be no departure from neutrality when the current through the windings is varied over the working range, provided the windings have similar electrical characteristics.

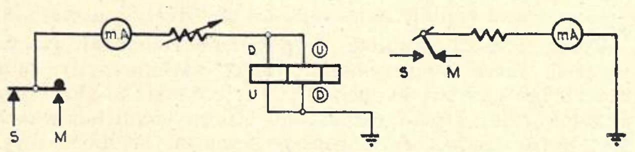

Fig. 2.

When connected, as in Fig. 3, a similar condition will apply, provided equal magnetization of the cores results.

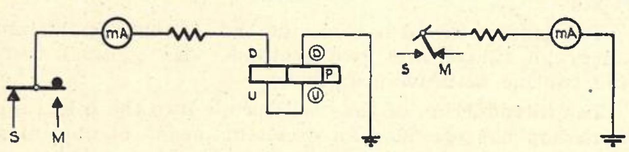

Fig. 3.

4. **Retentivity Test:** Ascertain the minimum current which will just operate the relay from Space to Mark —Fig. 4, A Branch. Pass a momentary heavy current, say, 300 m.A., in a spacing direction through the windings—Fig. 4, B Branch. Again ascertain the minimum current which will just operate the relay from Space to Mark. This value should not exceed the former by more than 1 m.A.

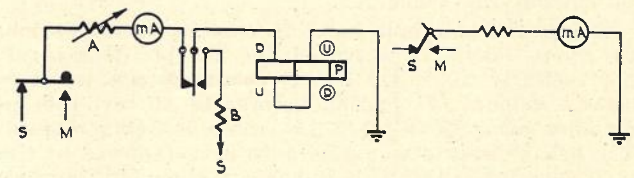

Fig. 4.

5. **Minimum Operate Current, Contact Rebound and Transit Time:** The minimum operate current is the minimum current value which will give satisfactory performance with standard contact gap and any speed in the working range. Either square top or sine wave signals may be used. The latter give the more critical test. Satisfactory operation can best be determined by using the differential milliammeter to check departure from neutrality, and observing the output from the relay on the oscilloscope, as indicated in Fig. 5.

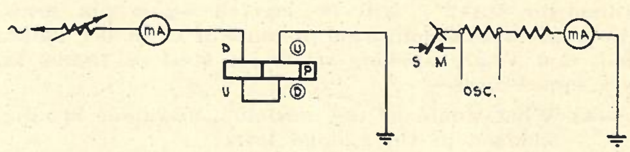

Fig. 5.

Contact rebound is indicated by loss of control of the oscilloscope beam after deflection to Mark or Space. Transit time can also be estimated by the trace on the oscilloscope, but a more accurate indication is possible by the use of the circuit in Fig. 6, referred to later.

NOTE: If windings are unbalanced, a service test under conditions somewhat more critical than acutal conditions should be substituted for 3.

ROUTINE MAINTENANCE TESTS: See Fig. 6.

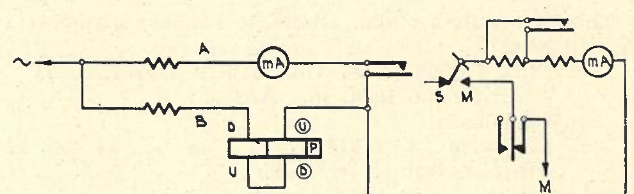

Fig. 6.

1. Neutrality test on reversals. 50 and 100 baud.

Reversals may be checked in A Branch, Fig. 6. Branch B connects the relay to the reversal feed and the output is observed on the differential meter. The minimum operate current value should be used. An additional key may be used to increase the sensitivity of the meter.

2. Transit time.

Transit time may be checked with the relay operating on reversals by first observing the reading on the differential milliammeter when both relay contacts are connected to the same polarity, then observing the reading when the relay tongue is continuously held to that polarity. The difference between the two readings is a measure of the period of time occupied by the tongue in moving between the two contacts. The transit time should not exceed 1.5 milliseconds.

(b) Normal contact adjustments for 90 baud working:—

.003″ min. .004″ max.

Q. 4.—(a) Explain how, in telegraph working, the inductive effects of a telegraph relay can be neutralized. Assume a case and indicate the value of the components you would use.

(b) Show the approximate current arrival curve at the earth end of a long telegraph cable, if the other end were suddenly connected to earth through a key and battery of "X" volts. Discuss the developments of the curve and explain the reasons for the particulars given. If the keying rate were gradually and indefinitely increased, what would happen to the received current?

A.—(a) Telegraph signals in a non-reactive circuit are square-topped in form, as shown in Fig. 7. The steady state value of current is limited by the resistance in the line. A Fourier analysis of such signals will show that a square-topped alternating wave shape is made up of a number of frequencies from zero to infinity. When all the curves are added together they represent the square-topped voltage. Only the fundamental and its odd harmonics appear, because the function is symmetrical and odd with equal positive and negative halves. If an inductive telegraph relay is connected in the circuit, the wave shape is somewhat of the form indicated in Fig. 8. The inductive relay represents a varying impedance to the signal frequencies, and the higher frequencies are more greatly attenuated. If a lower impedance can be provided for these higher frequencies, the "rise" of the signal in the receiving relay will be more rapid, and the prolongation of the signal, due to the back E.M.F. of the relay winding, will be reduced, hence the inductive effects of the telegraph relay will be mitigated.

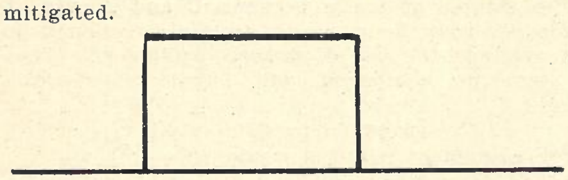

Fig. 7.

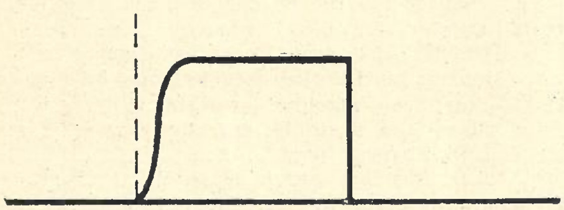

Fig. 8.

This desirable condition may be achieved by adding a capacitor in parallel with all or portion of the current limiting resistance. The steady state value of current will be unaffected, but the higher frequencies will, to a greater or lesser extent, accept the lower impedance path through the capacitor giving the effect equivalent to the instantaneous application of a higher potential to the relay.

In practical consideration of a telegraph line, many varying factors arise. Calculation of correct values for the resistance and capacity network by the application of Helmholtz' equations for rise and decay of line currents does not yield a practical solution. The optimum values are determined by trial. The ideal signal shape is as shown in Fig. 9, and the resistance capacity network is termed a "shunted condenser."

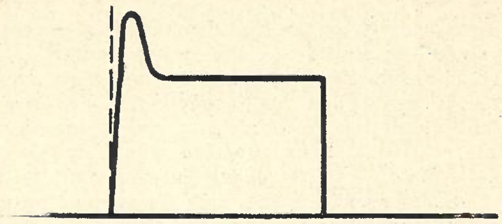

Fig. 9.

Fig. 10 shows the transmitting side of a typical teleprinter circuit:—

	L =	1000	ohms
L	L –	733	,,
R	1	200	,,
R	2	67	,,
	R	2000	,,
	C	2	microfarads
	E	120	volts

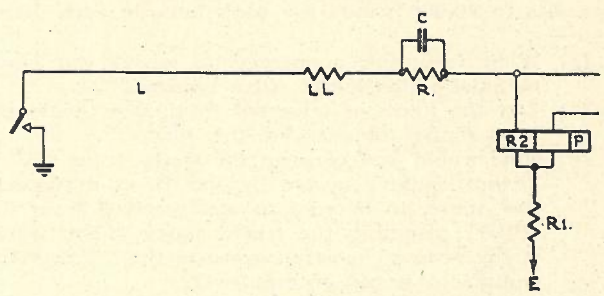

Fig. 10.

The approximate curve of arrival under the conditions stated is indicated in Fig. 11.

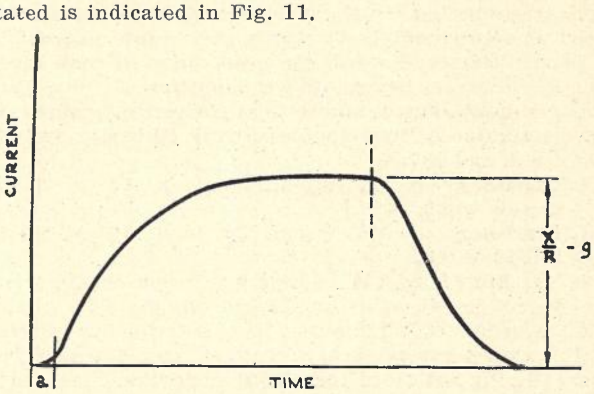

Fig. 11.

When an E.M.F. is applied to a long cable having a capacitance of K farads and resistance of R ohms, the received current rises very slowly until a time interval "a" has elapsed equal to 0.2332 × KR seconds. This interval is sometimes known as the silent interval. It is due to the effect of the resistance of the line and the charging of its distributed capacity. Immediately following this interval, the rate of growth of received current increases. As the line becomes charged, this rate becomes ever slower, until steady state is reached. The steady state value at the receiving end will differ from the value at the sending end by the leakance "g" on the circuit.

At time 8a the current will have reached 68% full value.

At time 20a the current will have reached 98% full value.

The decay curve, as the line discharges after cessation of the signal, is similar to the growth curve.

If the shortest signal were terminated at any time after steady state had been reached, there would be equivalent distortion for long and short signals.

Signals of still shorter duration would suffer characteristic distortion, as the decay curve would be superimposed on the growth curve, and the succeeding growth curve would commence before the line had completely discharged.

If the keying rate were still further and progressively increased, the final condition would be a smooth level of received current. The value, compared with steady state, Fig. 5, would be determined by the proportionate time of application of battery.

Q. 5.—An 18-channel V.F. system is provided between A, the C.T.O. and B, a main country centre and 4 channels are available for the disposal of local traffic between these centres. Assuming this traffic between A and B amounts to 20,000 words per peak hour in each direction—

(a) What telegraph arrangements would you make to handle this load? Give reasons.

(b) List the items of telegraph equipment necessary at B centre for carrying this load.

(c) How would you arrange for traffic from "C," a distant country centre beyond B on a physical line route, to be sent to and received from the C.T.O., assuming the traffic equals 2,400 words per peak hour, mostly inward to the C.T.O. What equipment would be required?

A.—(a) It is unusual for an operator to maintain an output greater than 45 words per minute on start-stop machines with a transmitting speed of 50 bauds. With tape transmission from such machines a theoretical speed of approximately 66 words per minute is possible.

Twenty thousand words per peak hour in each direction is, however, beyond the capabilities of four start-stop channels, but would be satisfactorily handled by the installation of four double Murray Multiplex systems between A and B.

4 Start-Stop @ 45 w.p.m. $= 4 \times 45 \times 60 =$ 10,800 w.p.h.

4 Start-Stop @ 66 w.p.m. $= 4 \times 66 \times 60 =$ 15,840 w.p.h.

4 Double Mux @ 45 w.p.m. per channel $= 4 \times 2 \times 45 \times 60 = 21{,}600$ w.p.h.

An 18-channel V.F. system has a frequency spacing of 120 cycles per telegraph channel, and the specification calls for not more than 25% distortion at 66 baud transmission. The transmission speed of a double Murray working at 270 R.P.M., i.e., 4.5 R.P.S. $= 4.5 \times 12 = 50$ bauds. If a triple Murray were contemplated, the transmission speed would be $4.5 \times 17 = 76.5$ bauds.

The triple Murray would introduce excessive distortion, but the double Murray would be well within the limits. It would be advisable to instal, in addition, duplex start-stop equipment for use on one V.F. channel.

A satisfactory arrangement would be to use to full capacity three Murray systems and the Start-Stop Channel to cater for normal traffic. The fourth Murray would be retained as a spare, but would be brought into use in lieu of the start-stop channel at peak periods. Periods of very light load, e.g., night-time and holidays, may be safely handled on the start-stop channel alone, enabling the Murray sets to be shut down at those times. The decision for teleprinter or teletype equipment would be governed by the type of equipment already in use in the district. It is preferable to limit diversity of equipment, not only for simplification of maintenance, but to reduce to a minimum the number of units held as spares.

(b) Working equipment at B to handle the load:—

Murray Multiplex—	**Start-Stop—**
5 Phonic motors (1 spare)	2 Start-Stop machines
5 Plateaux (1 spare)	1 L.D. carrier duplex panel
4 Connection boxes	
5 Receive relays (1 spare)	
10 Murray perforators (2 spare)	
10 Morkrum printers (2 spare)	
10 Murray Transmitters (2 spare)	

(c) It will be assumed that one additional V.F. channel between A and B can be utilized to handle the traffic between A and C. The V.F. channel will be extended to the physical line between B and C by the installation of a carrier to physical repeater at B.

The volume of traffic between C and A, viz., 2400 words per peak hour, mostly in the direction C to A, will preclude the use of manual equipment. The use of start-stop equipment will handle 45 words per minute.

$$45 \times 60 = 2700 \text{ w.p.h.}$$

The equipment required would be:—

At A—Start-Stop machine 1
L.D. Carrier Panel (Simplex) 1
(Spares covered by common spare equipment)

At B—Carrier—Physical Repeater 1
Carrier—Physical Repeater (Spare) 1
(Monitor machine covered by common monitors)

At C—Start-Stop machine—working 1
Start-Stop machine, installed spare 1
L.D. Physical panel 1
L.D. Physical panel, spare 1

50 baud reversals for testing purposes should be available at A, B and C.

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