The Telecommunication Journal of Australia

VOL. 6, NO. 3

Registered at the General Post Office, Melbourne, for transmission by post as a periodical.

FEBRUARY, 1947

CONTENTS

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The
Telecommunication Journal of Australia

Vol. 6, No. 3 *February, 1947*

THE SHEPPARTON INTERNATIONAL BROADCASTING STATION, "RADIO AUSTRALIA"

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DESCRIPTION OF EQUIPMENT
PART I.

The reasons for the establishment by the Postmaster-General's Department, during the war, of an International High-Power Broadcasting Station at Shepparton, Vic., known throughout the world today as "Radio Australia," together with a general description of the facilities which were provided, have already been published in the October, 1946, issue of this Journal, in an article by Mr. S. H. Witt, A.M.I.E.E., M.I.E. (Aust.), F.I.R.E. (Aust.).

As this installation represents the largest radio engineering work of its kind in the Southern Hemisphere, and contains design features of an unusual nature, it is proposed to follow up the previous article with a more detailed account of the equipment which has been installed. The design of equipment for the station involved the use of transmitters of powers near the limit of those designed in overseas practice, the use of radio frequency voltages in outdoor feeders and aerials approaching the limits of practicability, and the use of remotely controlled aerial switching systems handling high powers. These introduced problems of structural and radio engineering and line construction involving an approach different from that which would have been necessitated by a station of lower power.

For convenience, the description is divided into two parts, the present article covering the radiating systems, radio frequency transmission lines, aerial switching system, main transmitter building and power supply equipment; and the second, the transmitters and programme control equipment, which will appear in a later issue of the Journal.

General Design of Aerial Systems: In deciding the type of aerial system to be adopted for international broadcasting, the first question to be decided is that of horizontal or vertical polarization. Although the relative merits of the two systems may be debatable, and there is no completely conclusive evidence in favour of either type, present practice in this connection favours the use of horizontally polarized waves, and the Shepparton aerials were designed on this basis. Horizontally polarized aerials are used by the B.B.C., the various American broadcasting systems, and the German and Japanese administrations.

Three main types of horizontally polarized aerial characterize present practice, viz.:—

(a) The rhombic aerial.
(b) The Koomans or "pinetree" array, comprising a number of half-wave elements fed from balanced vertical feeders and provided with means for reversing and slewing. This type has been adopted by the B.B.C.
(c) An array of similar construction to the above, but arranged for operation of two transmitters simultaneously on one aerial at two frequencies. This type has been used extensively in the United States.

There are numerous other types, of course, but for the particular purpose in mind these appeared to have no advantages over the three types listed.

The rhombic is cheap, and is suitable for operation on a wide band of frequencies. The latter advantage is partly theoretical, since a long feeder such as is used in a transmitting station of this type, cannot easily be designed for multi-frequency operation, owing to the necessity for balancing out the effects of irregularities due to supporting insulators by suitable spacing of the insulators at odd integral numbers of quarter-wave lengths. This makes the feeder ideally unsuitable for the whole band of frequencies. The rhombic also has the disadvantage of requiring the dissipation of approximately half the input power in a terminating resistance, power which in the other types may be usefully radiated by proper design. At powers of 50 kW or more, it is considered uneconomical to dissipate half the power. It is possible to overcome this disability by designing the rhombic to be re-entrant, i.e., to feed the output power back in correct phase to the rhombic input. This arrangement, however, although resulting in a gain of between 2 and 3 db, has the disadvantage of converting the rhombic into a single-frequency device, or involves the complication of switching for each frequency. Furthermore, it is considered that the array allows for greater freedom in the design of suitable horizontal and vertical polar curves.

The choice then lay between the single-frequency array and the twin-frequency type. Probably the economics favour the twin-frequency array. American practice favours this type mounted on wooden poles of height about 100 feet for frequencies down to 9 mC. As no experience had been obtained with this type, and it appeared that even when operating on a single frequency at powers of the order of 100 kW the voltages would be fairly close to their working limits, it was decided to adopt the single-frequency array, such as is employed by the B.B.C. While it is considered that the dual-frequency aerial is a neater solution of the problem than the slewed single-frequency aerial, it is thought that the economic superiority is not great, and the latter type is simpler to adjust and maintain. Another probable advantage of the type of aerial erected at Shepparton is in greater frequency coverage. The Shepparton arrays cover a frequency band of about 2%, and in each case accommodate the broadcast band of frequencies. On the other hand, the dual-frequency type is probably suitable only for spot carrier frequencies.

Another important consideration in the design of the aerial systems is the angle of vertical radiation. The calculation of the optimum angle of radiation from consideration of distance and reflecting layer height leads to a rather inconclusive result when the reception area is to have a long radial distance. Such considerations would, however, appear to favour low angles below 10°, with the object of reducing the number of hops in transmission. Experimental figures published for angles of arrival favour rather higher angles.

The B.B.C. practice is to use a multi-element array, with the lowest element a wave length above ground. The Daventry arrays employ vertical angles of maximum radiation of from 5° to 8°. On the other hand, the aerials employed by the Columbia Broadcasting System at Brentwood usually employ two elements spaced approximately half a wave length and a wave length above ground. The vertical angles involved are from 14° to 18°. These aerials are mounted usually on wooden poles of height about 100 feet, and the high angle of radiation may have been adopted as an economic compromise. Further, these aerials are employed for the comparatively short transatlantic and South American paths. At Shepparton the aerials adopted were as follow:—

	Vertical Tiers
6.1 and 7.2 mC	2
9.6 mC	3
11.8, 15.2, 17.8 and 21.6 mC	4

All the aerials have the lowest element half a wave length above ground and the others spaced at half-wave intervals. These aerials can all be accommodated from the 210 ft. steel masts standardized for the station. The vertical angles of radiation are as follow:—

6.1 and 7.2 mC	17°
9.6 mC	12°
11.8, 15.2, 17.8 and 21.6 mC	9°

The vertical angles of radiation are higher than those used by the B.B.C. and lower than those used in American practice. They increase with reduction in frequency, and this would seem to be a reasonable arrangement, the lower frequencies being used for shorter distances when shorter hops might reasonably be employed. The angles adopted appear to be justified by the successful reception of Radio Australia reported in Britain, the United States, the Phillipines and other countries of the world since transmission began in 1944. It is probable, however, that the angle is not at all critical.

The gain of an aerial is necessarily obtained at the expense of the horizontal or vertical width of the main lobe of the polar curve. As the aerials are employed for broadcasting, it is not desired to provide too high a gain at the expense of horizontal coverage. The aerials have been designed with four half-wave elements located end to end horizontally in every case, giving a horizontal width of lobe of 18° on either side of the maximum for a reduction in gain of 6 db from the maximum. Nulls of zero radiation occur at 30° on either side of the maximum. All aerials are provided with reflectors parasitically excited, consisting of the same number of elements as there are radiating elements, spaced one-quarter of a wave length behind the radiators, except in the case of the 6.2 mC and 7.2 mC arrays, where the spacing is reduced to 0.16 of a wave length. The aerial gains relative to a horizontal half-wave element located at a height above earth necessary to give the same vertical angle of maximum radiation are as follow:—

6.2 and 7.2 mC	11.0 db
9.6 mC	12.5 db
11.8, 15.2, 17.8 and 21.6 mC	13.7 db

Where the aerials are slewed, the gains are slightly less by a figure not exceeding a decibel. Owing to the comparatively sharp directivity in the vertical plane, it is thought that these aerials have a greater gain than any re-entrant rhombic which could be designed, with the same wide horizontal polar curve.

The aerials are each fed from a pair of two-wire vertical feeders spaced horizontally by one wave length and each feeding the required numbers of pairs of horizontal elements. Three types of aerial are used, first, a unidirectional type; secondly, a reversible type, and, thirdly, a four-directional type in which the direction of propagation may be slewed as well as reversed. Reversing of the aerials is effected by interchanging the functions of radiating and reflecting curtains of elements. Slewing is effected by causing one-half of the radiating curtain to

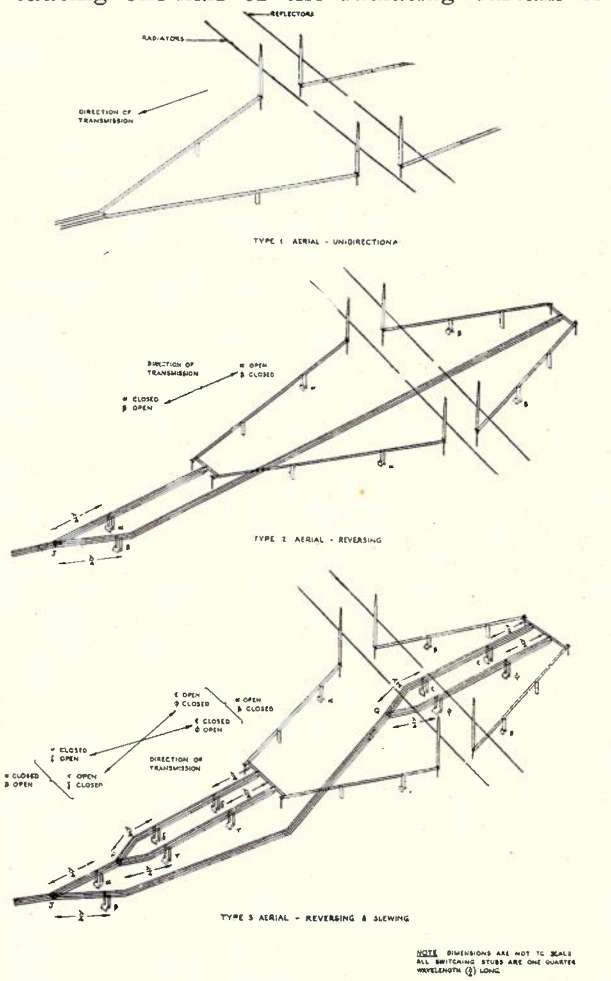

Fig. 1.—Switching arrangements of three types of aerial.

be slightly displaced in phase from the other half. This causes the direction of maximum radiation, that in which waves from the two halves of the curtain are in phase, to be displaced from that at right angles to the curtain. The phase displacement is effected by making the feeders to the two halves of the curtain slightly different in length. The arrangements adopted in feeding and switching the three types of aerials are shown in Fig. 1. In the unidirectional type the reflector elements are permanently tuned (for minimum backward radiation) by means of short circuits on the reflector feeders. The radiator element two-wire feeders are matched by means of short circuited stubs. The junction of the two-wire matched feeders is fed by means of a four-wire feeder, whose characteristic impedance is approximately half that of the two-wire feeders. Correct matching of the two-wire feeders therefore results in approximately correct matching of the four-wire feeder.

In the other two types of aerial, switching is effected by means of quarter-wave switching stubs, which operate by virtue of the fact that a short circuit on a transmission line involves a high impedance looking toward the short, a quarter wave length away. In the cases of the reversing type of aerial shown in Fig. 1, the switching of power to either curtain is effected at the junction J by means of two quarter-wave four-wire switching stubs terminated in switches and shunted across the branch lines a quarter wave length from the junction. Assuming each branch line terminated in its characteristic impedance, a closed switch at either stub causes the stub to be a high impedance shunt on the branch. If power is to be fed along one branch the switch on this branch is closed while that on the other is open, producing the equivalent of a short at the junction of the stub with the branch, and a high impedance looking away from the junction J along the branch, so that it draws only a very small amount of power. In addition, two-wire switching stubs are provided at appropriate places on the two-wire feeders. so that when the switches are opened they effectively short the feeders and cause the curtain to operate as a reflector. Of the six switches, the three marked α are open when those marked β are closed, and vice versa. The directions of maximum radiation of this type of aerial need not be 180° apart, as slewing of the radiation is effected as already described by making the two-wire lines between the junction with the four-wire lines and the vertical curtain feeders of appropriately unequal length. As in the first case, matching stubs are provided on the two-wire lines.

In the third type of aerial four directions of transmission, as shown in Fig. 1, are provided by means of 14 switches. The reversing is effected in the same manner as in the case of the second type of aerial. Slewing is effected by feeding the two-wire radiator feeder system at either of two branching points, P or Q, the appropriate branching line being rendered ineffective by the switching stubs. Where switching stubs are connected to two-wire lines, they consist of sections of two-wire lines; and for four-wire lines they consist of sections of four-wire lines. Fig. 2 shows two short circuiting switches attached to four-wire switching stubs.

The degree of slewing which can be tolerated is limited by the fact that if too great an angle of slewing is adopted, the main lobe of the polar curve is reduced in magnitude at the expense of the minor lobes. In practice, the direction of radiation may be slewed about 13°

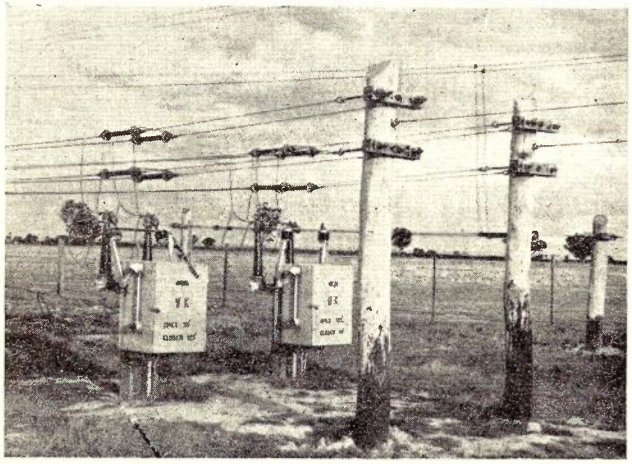

Fig. 2.—View of two short-circuiting switches attached to four-wire stubs.

from the direction at right angles to the plane of the radiator curtain. In the case of the third type of aerial, this means that the two directions of maximum radiation may be separated by 26°, and this amount of slewing has been adopted.

In all, 19 aerials have been erected, with directions as follow:—

Type	Direction of max. radiation	Frequency	Gain
Unidirectional	342°	7.2 mC.	11.0 db.
		9.6	12.5
		11.8	13.7
		15.2	13.7
Unidirectional	354°	9.6	12.5
		11.2	13.7
		15.8	13.7
Reversing	63°/239°	9.6	12.5
		11.8	13.7
		15.2	13.7
		17.8	13.7
		21.6	13.7
Reversing	109°/294°	6.1	11.0
		7.2	11.0
Reversing and	99°/125°	9.6	12.5
Slewing	279°/305°	11.8	13.7
		15.2	13.7
		17.8	13.7
		21.6	13.7

The gains are expressed relative to a half-wave horizontal aerial having the same vertical angle of maximum radiation, and are calculated accurate to about a decibel.

Mechanical Design of Aerial Systems: The layout of a typical aerial bay (two aerials) is shown in Fig. 3.

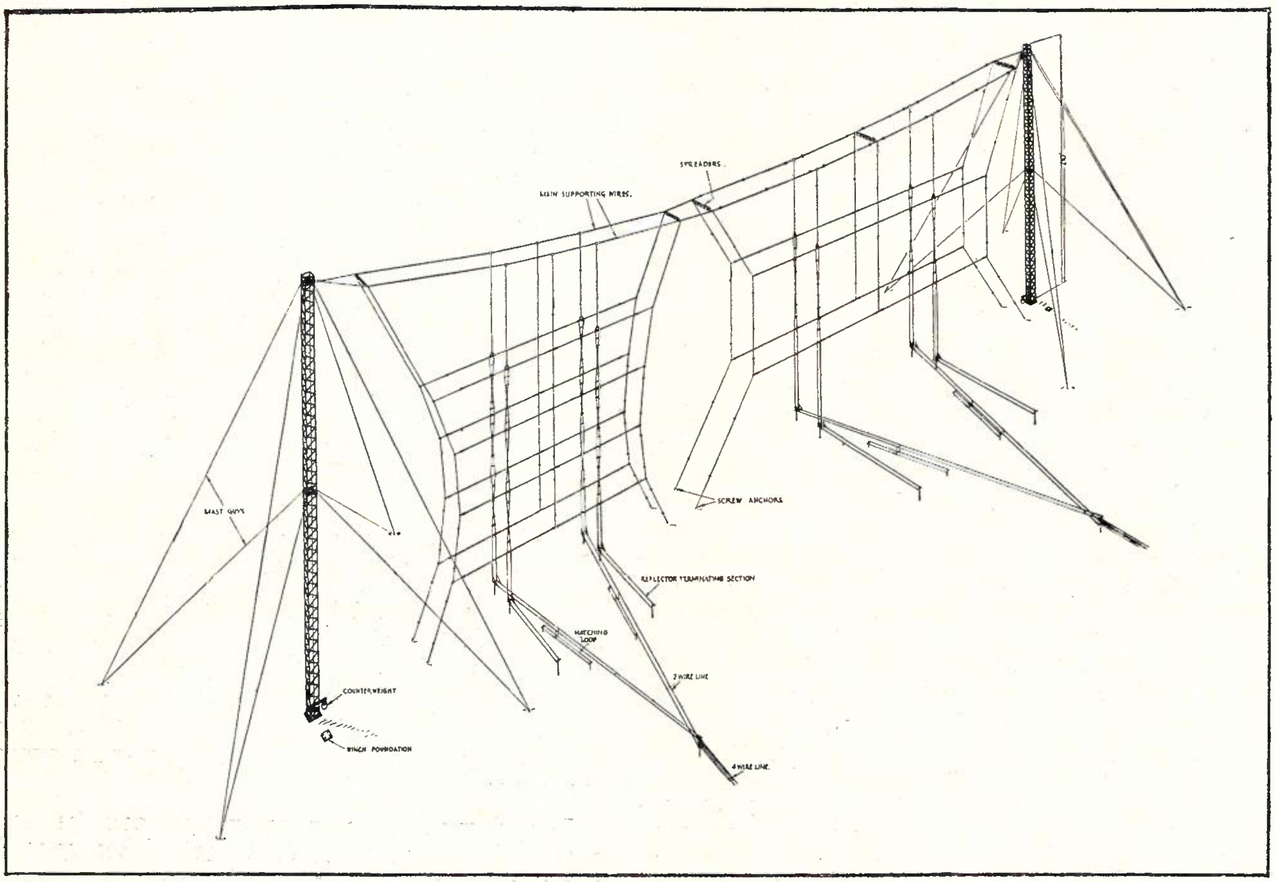

Fig. 3.—Layout of typical aerial bay (two aerials).

The aerial wires are of 7/0.048″ stranded cadmium copper wire, and the supporting and straining wires of 7/0.064″ galvanized stranded steel wire. The main supporting triatic is of 6/19 flexible steel wire rope, $1\frac{3}{8}$″ circumference. The supporting triatic and all supporting and straining wires are broken up with standard departmental egg-type insulators, where a dipole is within 0.5 wave length distant.

Due to the capacity of the insulators at the end, the velocity of propagation along the dipole is reduced, and it is necessary to make the length of the dipole somewhat less than a half-wave length in space. The length of the dipoles are all 0.45 wave lengths, and the vertical spacing between rows of elements is 0.475 wave length. In order to accomplish the necessary 180° phase shift between adjacent rows of elements, the feeder was continuously twisted on a series of spacing insulators 16″ long.

As the span between masts is in some cases as great as 650 feet, and some of the spreaders are located towards the centre of the span, it was necessary to keep the weight of the spreaders to a minimum, if undue sags in the supporting triatics, with consequent increase in mast heights, were to be avoided. The spreaders used are of welded steel lattice construction, triangular in cross-section, and constructed of seamless steel tubing, the main members being $1\frac{1}{4}$″ x No. 18 S.W.G. and the bracing members being $\frac{1}{4}$″ x No. 18 S.W.G. This construction produced a rigid but light structure, the largest spreader being 25′ 6″ long, and its total weight, including end castings and fittings, being only 90 lbs. All spreaders were designed to withstand an axial load of 1 ton.

In arrays of this size it is necessary to compensate for the effect of wind, in order to avoid excessive loading of the masts. The usual method of doing this is to connect either the main supporting halyards or the aerial downleads and straining wires, to counterweights. To have connected the downleads and straining wires to counterweights would have necessitated an excessive number of small weights, with their associated tackle, and it was therefore decided to use a small number of heavy weights connected to the main halyards at each end, the downleads and straining wires being anchored securely at their lower ends. The aerials have been erected for some three years and only one mechanical failure has occurred, this being due to the twisting of a length of stranded copper wire during initial erection.

The type of structure used for supporting the aerial was considered as an integral part of the aerial design, the final design of the aerials and supporting system being bound up with the supporting mast structure provided.

Two types of construction were considered:—

(a) Using self-supporting towers, with fixed crossarms at the top, and suspending each curtain from an independent triatic.

This method had the advantages that—

(i) Each curtain could be raised or lowered independently.

(ii) Spreaders throughout the span were eliminated.

The disadvantages are that—

(i) It is difficult to adjust the spacing of curtains of aerials of differing frequency between the same pair of towers to their appropriate values.

(ii) The towers would be subject to considerable torsional stresses when one curtain was lowered.

(b) Using guyed masts, with the transmitting and reflecting curtains separated by spreaders, and with one main halyard supporting the whole of the aerials supported between two masts.

The second alternative was considered the more satisfactory arrangement, and a four-sided mast, 210 feet high, guyed in four directions at the 110 foot and 210 foot levels, was decided upon. A standard height of 210 feet was adopted, as it was considered that the proposed higher frequency aerials requiring lower heights might at some future date be replaced by lower frequency aerials. As a three-sided mast would not be satisfactory at intermediate positions in any case, and at the end positions provision has been left in most cases for possible aerial extensions, it was decided that a four-sided mast in all cases was the most suitable.

The masts are of the conventional lattice steel type, with 5-foot sides and earthed at the base, as are the uninsulated guy ropes. Concrete winch blocks are provided adjacent to the mast foundation, and portable 3-ton winches are used for lowering and raising aerials.

The pull in the triatic and supporting halyard is the same in all aerials, being approximately $1\frac{1}{2}$ tons in each triatic and 3 tons in the supporting halyard, which is taken over a pulley at the top of the mast and to the counterweight assembly at the base. With this tension, the greatest sag in the triatic, without wind, is 55 feet, with a 15mC, 17 mC and 21mC aerial suspended between two masts 650 feet apart.

Design of Transmission Lines: The type of transmission line to be adopted for feeding the aerial systems requires some consideration. The limiting factor of importance for powers of the order of 100 kW is the occurrence of corona on the lines, which, of course, limits the voltage which can be accommodated and the power which can be transmitted. In the case of clean electrodes, corona at high frequencies occurs when the voltage gradient at the electrode surface exceeds the 50 cycle "critical disruptive gradient," which is subject to calculation. Corona at high frequencies is accompanied by considerable power loss.

For 600 lb. copper wire spaced 12 inches apart, forming a transmission line having a characteristic impedance of 590 ohms, the corona occurs at about 60,000 volts r.m.s. provided that the wire is bright. If the wire is tarnished, as occurs in practice, the corona voltage falls to about 20,000 volts r.m.s. The corona occurring is manifested as a flare from the wire outwards into the air. It does not normally occur between the wires of opposite polarity. It involves a considerable loss of power, and will melt the wire on which it occurs. It may be induced at a lower voltage by any foreign body touching the wire, such as an insect. It will be appreciated that it is necessary for the working voltage to be low enough at full modulation for corona, once started by such a foreign body, to quench itself. For a two-wire 600 lb./mile copper line of characteristic impedance 590 ohms, a limiting voltage of 20,000 volts corresponds to a power of 85 kW if the standing wave ratio on the line due to mismatch of impedance is 2, a not unreasonable limit. Allowing some factor of safety, this means that such a line can transmit not much more than 50 kW. Clearly, some other type of line is necessary. The type adopted in the United States is a two-wire line employing stranded wire about ½ inch in diameter. The type of line adopted for the Shepparton station employs four 600 lb./mile copper wires spaced at the corners of a 12 inch square and having two wires in the same sides of the square of the same polarity. Such a line has a characteristic impedance of 307 ohms, and the power which it will accommodate on the same basis as previously discussed for a two-wire line is 160 kW. Such a line is evidently adequate for powers of the order of 100 to 140 kW. Its lower characteristic impedance involves the additional advantage in comparison with a two-wire line of minimizing the effects of supporting insulators and switching gear in producing standing waves. The objection to a high standing wave ratio is twofold, firstly, because of the consequent increase in line voltage; and, secondly, because of the varying impedances presented to the transmitter as the aerials are changed. Increase in loss in the line is not a limiting factor, and only becomes of importance when the line currents are unbalanced.

In the design of the aerial systems it is necessary to ensure that the voltage on the aerial two-wire feeders and aerial elements be kept down to suitable limits, which logically should be the same as for the four-wire feeders. This was ensured by keeping the standing wave ratio on the two-wire feeders within the same limit of 2, since each aerial feeder carries half the power fed over a four-wire feeder, and has approximately twice the characteristic impedance. The voltage at the free ends of the aerial elements is the same as the highest voltage on the two-wire feeders. Stranded wire of 7/.048 gauge cadmium copper has been employed for the aerial elements and feeders, and has an overall diameter slightly smaller than the 600 lb. solid copper wire employed for the four-wire feeders.

The four-wire transmission lines have been supported on standard P.M.G. undressed poles spaced approximately 100 feet. Actual spacing is determined by local circumstances; and between the switching centre and the aerials, where the line is a single-frequency feeder, is made an odd number of quarter-wave lengths, so that insulator irregularities, introducing a degree of standing waves, are balanced out. Strain poles are introduced at intervals of about 500 feet. The 600 lb. copper wire is strained to a tension of 400 lb. at 32°F. Special strainer fittings are provided at all termination poles for adjustment of tension. Three types of insulator have been employed for supporting the transmission lines and aerials. These are shown in Fig. 4:—

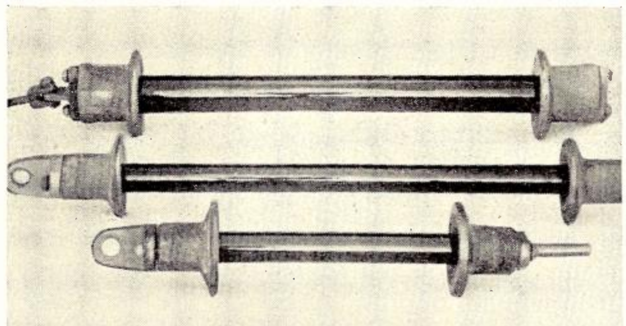

Fig. 4.—View of three types of aerial and transmission line insulators.

- Type 1, for use at the ends of aerial elements;
- Type 2, for use in supporting four-wire lines at intermediate poles and for use as spacers in two-wire aerial upleads;
- Type 3, for use at strain poles.

Insulators are constructed of porcelain cemented caps provided with corona rings, which have the object of ensuring uniformity of voltage gradient along the length of porcelain and minimizing local heating in the porcelain. Four types of end fitting may be mounted on the insulators:—

- An eye fitting;
- A flat strip for clamping over wire at intermediate poles or on spacing insulators;
- A fitting which may be crimped over the end of 600 lb./mile wire at terminating poles
- A fitting which may be crimped over the end of 7/.048 stranded wire on the aerial

elements. This fitting is provided with a swivel joint to avoid bending fatigue in the wire.

Proof loads in tension for the insulators were: Types 1 and 2, 800 lbs.; Type 3, 1800 lbs. The working stress on types 1 and 2 is negligible. That on type 3 is 400 lbs. at 32°F, giving a factor of safety of 4.5. A section of line, showing intermediate and termination poles, is shown in Fig. 5.

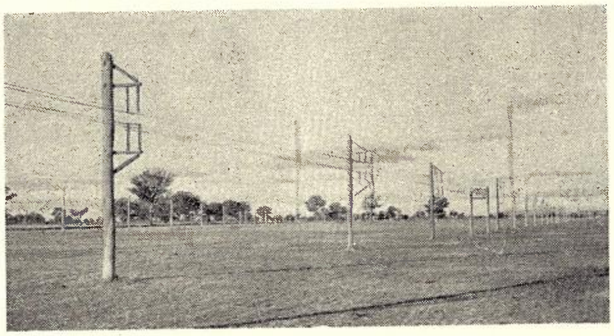

Fig. 5.—View of four-wire line.

Inside the building a balanced, shielded type of line is employed for transmission of power between the transmitters and the outside wall. These were of two sizes, a line employing a shield 20 inches in diameter with 1 inch conductors spaced 9 inches for transmission of 50 or 100 kW, and a smaller line employing a shield 4 inches in diameter and 600 lb. copper conductors spaced 2 inches for transmission of 8 kW from the driver stages of the 100 kW transmitters. Polystyrene insulators were employed in these lines, of the disc type in the 4 inch lines, and of 1 inch rods in the 20 inch lines. In the 20 inch line polystyrene plates $\frac{3}{8}$ inch thick and 20 inches diameter were used at the ends of the line to prevent insects, &c., from entering. Fig, 6 shows a cross-section of a 20 inch line. Before deciding upon the type of insulating material flash-over tests were carried out on experimental sections of these lines at 15 mC, to determine the relative advantages of polystyrene and steatite.

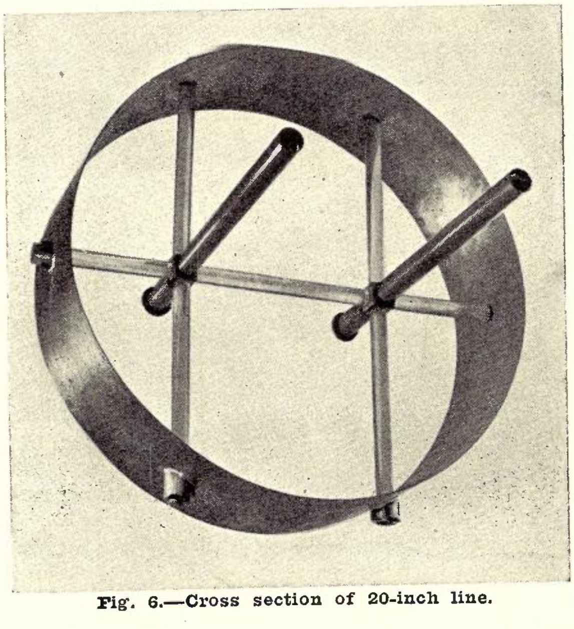

Fig. 6.—Cross section of 20-inch line.

Polystyrene has the disadvantage of being inflammable and having a low melting point, and it was desired therefore to use steatite if its electrical properties were satisfactory. The ratings of the lines are:—

	Working Voltage (S.W. ratio 2) kV	Arcing Voltage Theoretical kV	Arcing Voltage Tested kV
Polystyrene insulators:			
20-inch line	15 (100 kW)	76	40
4-inch line	4.4	16	16
Steatite insulators:			
4-inch line	4.4	6.6	6.6

(Voltages are r.m.s. at peaks of 100% modulation.)

The inferiority of steatite is due to its higher dielectric constant, with consequent increased flux density in the air space around the line conductors. Attempts made to eliminate this air space by spraying the inside edges of the steatite insulators with metal were unsuccessful. Polystyrene was therefore adopted in preference to steatite. The insulators in both types of line are readily removable, "windows" being provided for access to the 20 inch line, and the insulators in the 4 inch line are slotted to take the inner conductors and mounted on semicircular copper clips fitting over slots alternately on opposite sides of the shield. From each of six transmitter power amplifiers the 20 inch diameter lines are approximately 36 feet long to the outside wall of the building. They are fabricated of 18 gauge copper sheet in 12 foot lengths, with flanged ends bolted together.

As far as possible in the aerials and outdoor lines, soldering of wire was eliminated to avoid reduction in tensile strength and fatigue failure due to wire vibration. At the terminating points the wire is crimped into appropriate fittings of the "nicropress" type. A special crimping tool was developed for the purpose, having arms about 2 feet long. This one tool was designed to operate on three types of fitting. Soldering, where adopted for electrical continuity, was effected between wires with the aid of short sections of jointing sleeves, so that only a small mass of metal required heating, with consequent minimization of temperature necessary and reduction of softening of the wire. Bound joints were avoided as far as possible, to avoid sharp edges caused by the ends of binding wires. Sharp edges were generally avoided throughout the aerial and transmission line installation, with the object of minimizing corona troubles.

Aerial Switching: The switching of the aerials to the three transmitters was accomplished by a remotely controlled outdoor system of switching, which was designed to minimize loss of programme time. Complete availability of aerials was not adopted, but each aerial was made available to two transmitters. In the system provision was made for five future aerials. Each transmitter has two or three outlets, and for each transmitter any of these outlets is made available to either of two outgoing lines at an outdoor transmitter selector switch. From these switches, about 100 feet outside the building, six lines run to two outdoor switching centres, at which are located three- and two-position switches. The function of these will be understood from the line schematic of Fig. 7.

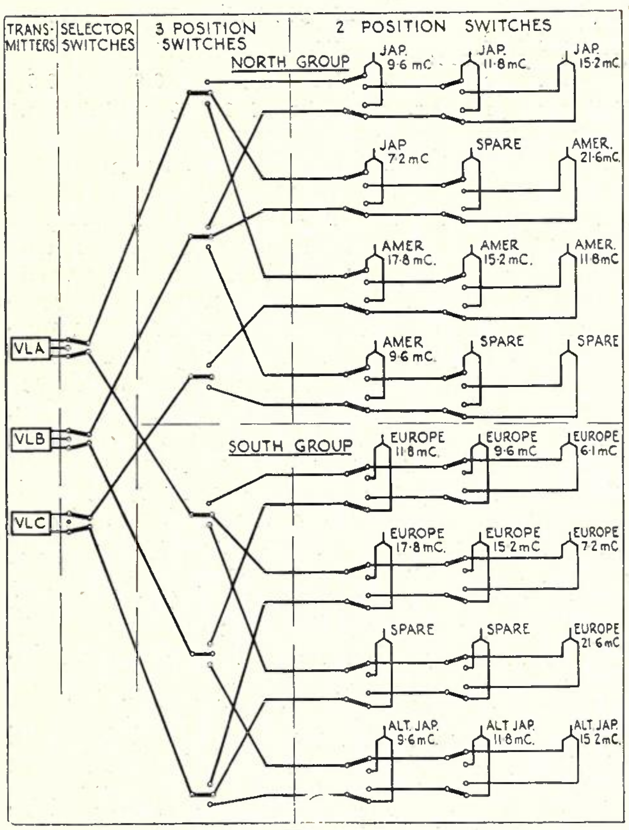

Fig. 7.

The outgoing lines from the final two-position switches are branched in pairs to the lines feeding the aerials. These branches are adjusted to a length of half a wave length for the particular operating frequency, and when power is fed through one branch, the other branch is always left open circuited so that it produces little impedance irregularity on the operating branch. The two-position switches are mounted in pairs one above the other. Fig. 8 shows the actual junction of lines at a half-wave switching junction.

The switches consist of angle iron frames on which are mounted porcelain pedestal insulators carrying switch contacts and arms of $\frac{3}{4}$ inch copper tube spaced 12 inches. These con-

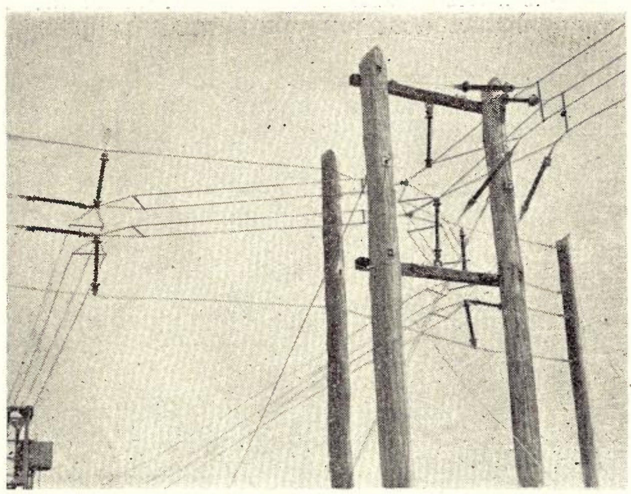

Fig. 8.—View of half-wave switching junction.

stitute a two-wire line of characteristic impedance higher than the four-wire lines in which they are inserted. The characteristic impedance has been reduced to the required value in the lining-up of the system by mounting 600 lb. copper wire "wings" on the arms. This procedure was adopted to allow for the incalculable effect of stray capacities due to insulators and adjacent earthed metal.

The switches are operated by means of $\frac{1}{2}$ H.P. three-phase motors operating through gear boxes in conjunction with Geneva star wheels. Control is effected by means of a 48 volt relay, which operates in conjunction with contacts in a drum controller. Contacts are included on the drum controller which prevent application of power to the final stage of the transmitter unless the appropriate switch contacts are closed. The whole control gear for each switch is mounted inside a weatherproof steel box.

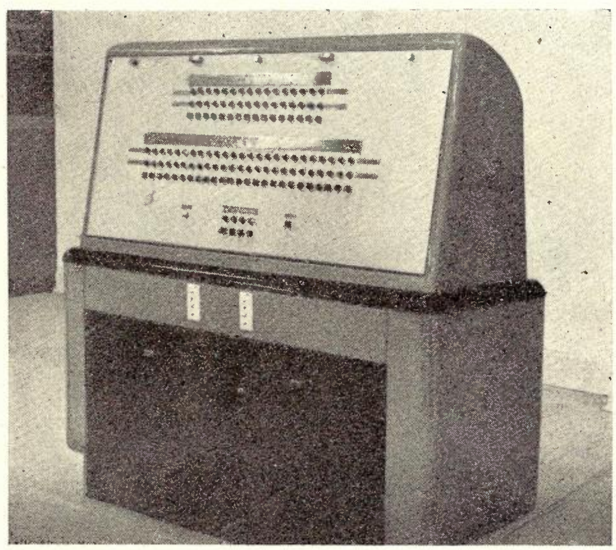

Fig. 9.—Aerial control desk.

Underground power and control cables are employed.

Control of the switches is effected by means of push buttons mounted on desks associated with the appropriate transmitter. Fig. 9 shows a view of the aerial switching control desk for No. 3 transmitter. On each desk there is a push button for each aerial and aerial direction available to its associated transmitter. Associated with each push button is a 3000 type relay and two supervisory lamps, one on the same desk as the push button, and one on the desk associated with the other transmitter to which the aerial is available. Momentary depression of a push button causes the associated relay to operate and the previously operated relay to release. Operation of the relay is prevented by appropriate contacts if the aerial selected is already in use with another transmitter. On operation of the relay its associated supervisory lamps operate and all outdoor switches move to their assigned positions. When the switches are in position their chain contacts cause a lamp to light on the desk and an associated relay to operate, after which power may be applied to the final stage of the transmitter. After application of power to the transmitter the 48 volt supply is automatically removed from all the push buttons on the desk, preventing shifting of the power carrying switches. A photograph of a pair of two-position switches is shown in Fig. 10.

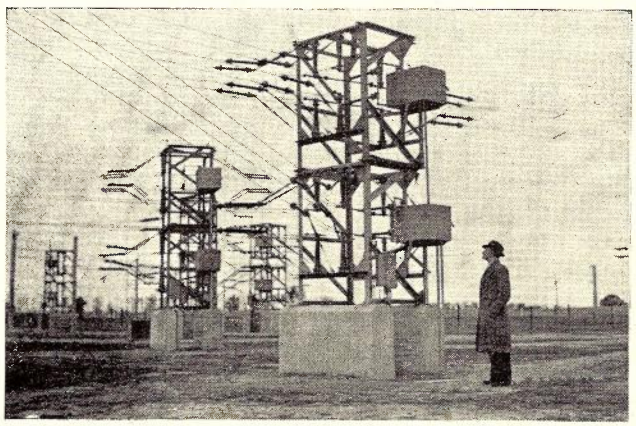

Fig. 10.—View of two-position switches.

Line-up of Aerials: Information on the aerial system would be incomplete without a brief description of the procedure of lining-up an aerial. As a typical example, the process adopted in connection with a reversing aerial is as follows: The aerial curtain is excited by means of a portable oscillator at the mid frequency of the band employed on the aerial. A communications receiver with an S meter is set up about 1000 feet behind the aerial, using a dipole aerial about 30 feet above ground. Some care is necessary to avoid longitudinal pick-up, the criterion of absence of this being that the received signal must drop below the tuning minimum described below, when the oscillator output and receiver input are short circuited. Telephone communication is provided between the receiver and the aerial being adjusted. Short circuits are moved along the reflector feeders until a minimum signal is obtained.

Signal dips of the order of 30-70 db were obtained, and shorts could be adjusted to within three to six inches. The shorts are then removed, and the reflector switching stubs erected. These are made slightly less than a quarter-wave length long from feeder to switch contact. With switches open, tails of 600 lb. copper wire about 2 feet long are mounted on the switch contacts and act as trimming capacitors. The length of these is adjusted until the received signal is again a minimum. The procedure is now repeated with radiator and reflector interchanged and receiver on the other side of the aerial.

The next step is the adjustment of matching stubs on the two-wire lines. This is carried out with reflector stub switches appropriately adjusted. A trolley meter is employed, consisting of a tuned horizontal loop incorporating a thermocouple meter, resting on pulleys on the line wires.

It is necessary for the unmatched standing wave ratio to be less than 2 to reduce aerial voltage to suitable limits. On the 6.2 and 7.2 megacycle aerials, with only two tiers of elements, it was necessary to provide two- or three-wire elements, wires being spaced about 1 foot apart to effect this limit. Matching stubs are now erected and trimmed for a standing wave ratio of less than 1.1.

The next step is the adjustment of the reversing stubs, which must be of four-wire construction. The position is located by mounting a trolley meter at the junction on the branch being adjusted. For this adjustment one branch is fed into the radiator element, and the other branch is opened and terminated in a 300 ohm resistor. The position of a short on the branch is adjusted for minimum current in the trolley meter. The four-wire switching stub is then erected at the position of the short and made slightly less than a quarter-wave length long. A receiver is now employed with a horizontal loop mounted on the line in the aerial side of the stub to detect residual power fed past the stub. With the switch open, tails are adjusted for a minimum receiver signal. The switching stub is then erected and adjusted on the other branch, with the switch for the first branch closed. It is found that the stopping effect of these switching stubs is of the order of 30 to 50 db.

The switching stubs, when closed, being less than a quarter of a wave length long, present a slightly inductive bridging impedance across the line. Tails are now mounted at the top of the stub at its junction with the line, and adjusted to give a good standing wave ratio of about 1.1 at the input to the junction pole. It has sometimes been necessary to mount this capacity tail on the line some feet from the stub.

The next step is to check standing waves on the four-wire line for frequencies at the extremities and mid point of the band at appropriate points along the line through the switching system back to the transmitter building, the limit of 2 being imposed. In this connection, adjustments in the initially erected lines were necessary to the spacing of wires at the termination poles, to the lengths of the half-wave switching junctions, and to the "wings" on the switch arms.

The power fed into a 21.6 mC aerial at the end of a feeder approximately 3000 feet long was measured by connecting a quarter-wave section terminated in an ammeter and used as a voltmeter, across the line. Due corrections were applied for the small amount of standing wave on the line. The measured power fed into the aerial was 40 kW for a transmitter output of 50 kW.

Buildings: The general layout of the buildings has been described in the previous article, in the October, 1946, issue of the Journal. The transmitter building is of brick construction, with concrete floors and flat concrete roof over the gangway and cubicle sections and the front portion of the building, while a pitched roof, on light, steel-framed trusses, is provided over the transmitter hall. There are no windows in the building, the design being undertaken in 1942, when the Japanese menace appeared very real, and solid walls were felt necessary as a measure of protection to equipment and personnel from bomb blast in the event of enemy attack.

Due to the improvement in the war situation, a last-minute change in the roof construction, after the walls had been constructed, resulted in the replacement of the flat concrete roof in the original design by a pitched roof of corrugated asbestos-cement sheets, in which it was possible to provide skylights, by which some natural daylight was introduced into the transmitter hall. Due to these restrictions on the entry of natural light into the building, the subject of artificial lighting received careful thought.

As the building is staffed on a 24-hour day basis, and artificial lighting is necessary for the greater part of the time, the transmitter hall and programme control room, together with the supervising technician's office, are provided with fluorescent lighting. In the transmitter hall, 146-80 watt strips provide a lighting intensity of 15 foot candles on the working plane. It is interesting to note that the power consumption for the transmitter hall is 11.6 kW, but if filament lighting had been installed, the power consumption would have been 32 kW, with consequent undesirable increase in transmitter hall heating. While the costs of initial installation and replacement of elements are considerably higher with fluorescent than with filament lighting, this great saving in power consumption results in an overall economy in favour of the fluorescent lighting.

The front section of the building is divided into two floors, a ground floor, slightly below the floor level of the transmitter hall, and a mezzanine floor. On the mezzanine floor the emergency studios and programme control room are electrically screened, and the internal windows, allowing observation of studio No. 1 and the transmitter hall from the programme control room, are double glazed, with the screening wire continuously across the window opening in the space between the window glass.

The provision of conventional cable trenches in a concrete upper floor was not considered desirable; a wooden floor on 4-inch joists was therefore laid on top of the 4-inch concrete floor, the cable trenches being formed in the 4-inch space between the concrete and the floor boards and being deep enough for the light wiring used in the audio equipment. Wooden vertical risers connect trenches on the ground and mezzanine floors. On the mezzanine floor also is a monitoring room equipped with a loud speaker and associated amplifier and with a portable monitoring cabinet, fitted with casters, and mounting a monitoring panel with facilities for selecting the audio input or the transmitter outputs, and gain controls for adjusting the volume.

On the ground floor is the supervising technician's office, a small laboratory and the valve and light equipment store. A valve cabinet, storing several thousands of pounds' worth of valves, is constructed along two walls of the store and is divided into sections, the various types of valves being stored in separate sections. Each section of the cabinet is divided into two parts:—

(a) The lower half, having sliding wooden doors, for storing valves still in their cartons or cases.

(b) The upper half, with ¼-inch plate glass doors, sliding on rollers, the type of valve stored being worked on to the plate glass door.

In this upper compartment the valves are stored in rows, with an indicator showing the next valve to be used. As a valve is removed from the cabinet, a new one is unpacked from the lower compartment, put in the vacant position and the indicator moved on to the next position. This system ensures that the valves are used in rotation, no valve being allowed to deteriorate by being left in the cabinet while newer ones are taken for replacements in the transmitters. The remainder of the store room is occupied with double-sided wooden racks, storing all the lighter spare components, such as small condensers and transformers, resistors, lamps, nuts and bolts and the like.

Under the floor of the basement and wiring tunnels is laid portion of the building earth system. This earth system was designed to overcome the difficulties due to electrolysis frequently associated with earth systems consisting of steel stakes driven into the ground and connected together with copper cables. It consists of ½-inch diameter copper rods, 6 feet long, driven into the ground at 8 foot centres both ways and joined by 600 lb./mile wire welded on. At convenient places 600 lb. copper leads are run from the earth system to copper plates mounted on the wall of the building. The ½-inch copper rods were also used for the external building earth systems and also for earthing the masts and guys.

This, as far as is known, is the first case in which thin copper rods have been used for the earth systems at any of the Department's radio stations, and a description of the technique of driving may be of interest. Owing to the high slenderness ratio, 576, of the 6-foot copper rods, only a light blow must be given the top in driving, if buckling is to be avoided. The plan adopted was to use driving apparatus giving light but frequent hits. Using a 500 watt electric hammer, having a stroke of $^1/_{16}$ inch and a rate of 1500 strokes a minute, it was demonstrated that the rods, suitably pointed, could be readily driven through the loam and underlying clay found at Shepparton. It was found, during the progress of the work, that by slipping a length of ¾ inch pipe over the copper rod more weight could be put on the top of the hammer, and driving facilitated. Each rod was driven to its full depth of 6 feet in about five minutes.

Mechanical ventilation is provided throughout the transmitter building, with the dual object of—

(a) Dustproofing the building;
(b) providing a measure of cooling in the warmer weather.

Air is drawn from outside the building, through a battery of viscous oil filters, to an air-washing plant, where the temperature of the incoming air is reduced to approximately 70°F. During the cooler portions of the year, the air-washing plant is not used. After washing and cooling, the air is delivered to the building by a supply fan of 54,000 cubic feet per minute capacity, the quantity of air delivered to the various sections of the building

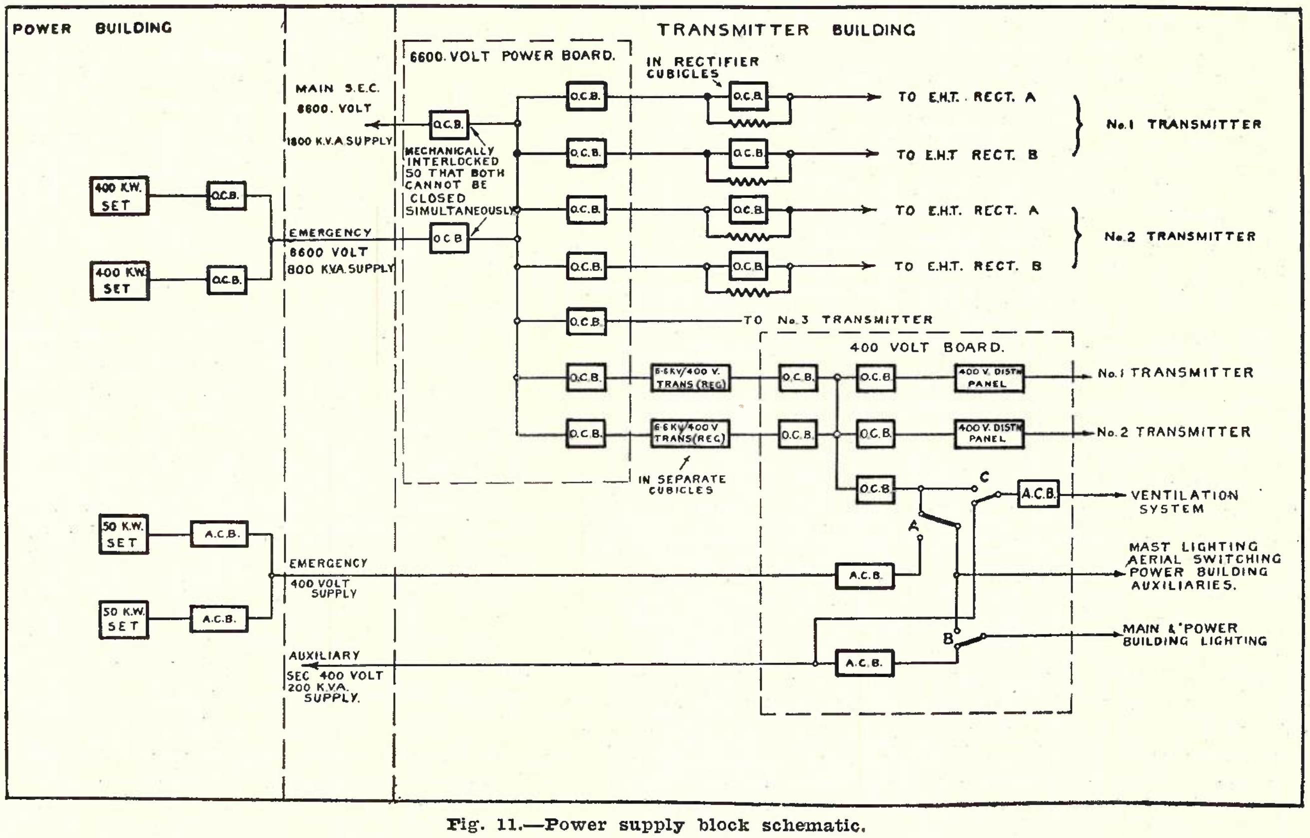

Fig. 11.—Power supply block schematic.

varying with the locations of the heat emitting apparatus. Air is removed from the building via ducts by an exhaust fan of 34,000 cubic feet per minute capacity and discharged to the outside atmosphere.

Special precautions were taken to sound-proof the ductwork to the emergency studios, monitoring room and programme control room, to prevent excessive noise in this section of the building.

Power Supply Equipment: A block schematic of the power supply equipment is shown in Fig. 11. Power may be drawn either from the S.E.C. mains at 6600 volts 3-phase of 1800 kW capacity, or from an auxiliary S.E.C. supply at 400 volts 3-phase of 200 kW capacity.

These power supplies are derived from the S.E.C. substation on the site, power being supplied to the substation at 66,000 volts by a special overhead line, giving a regulation of better than 2% for the full load of the station. This close tolerance is necessary because of the fluctuating nature of the load consequent on the use of class B modulation at high power. The connections between substation and transmitter building are by underground cables.

Emergency power is obtained from engine alternators in a separate building. The emergency plant, when complete, will consist of two 400 kW 6600 volt sets and two 50kW 400 volt sets. At present only one set of each type is installed. Each 400 kW set comprises a Crossley PCT6 vertical six-cylinder 800 H.P. compression ignition supercharged engine operating at 375 r.p.m. and direct coupled to a Brush three-phase 50 cycle 6600 volt generator. A special flywheel of weight 5 tons is provided to cope with load fluctuations caused by the high power class B modulators. To cope with these overloads, the specification required the engines to be capable of withstanding 25% overload for periods of 15 seconds not exceeding 20% of the total time. These engines are air started, with a motor-operated and an engine-operated auxiliary compressor. The 6600 volt generators may be synchronized by means of switchgear in the power building. The capacity of the two engines is sufficient to operate two of the three transmitters at full power, or three transmitters at reduced power.

The 50 kW sets are Crossley BWB6 vertical six-cylinder compression ignition engines of 84 H.P., operating at 1000 r.p.m., and direct coupled to Brush three-phase 50 cycle 400 volt generators. These engines are battery started. They may be synchronized at the power board in the engine room. The power board in the engine room is of the steel panel type, and employs Westinghouse truck type withdrawal switches for the 6600 volt generators. Voltage regulation is supplied on both 6600 volts and 400 volts busbars, B.T.H. "Tirrill" type regulators being supplied for the 6600 volt machines and B.T.H. carbon pile regulators for the 400 volt machines.

In the main transmitter hall are two power boards for controlling respectively the 6600 volt and 400 volt supplies. A picture of the former is given in Fig. 12. The boards are of metal panel construction. Oil circuit breakers are of the Westinghouse truck draw-out type. Air circuit breakers are Westinghouse "De ion" type. The 6600 volt board employs two main oil circuit breakers for the control of 6600 volt S.E.C. and emergency power. These are mechanically interlocked so that only one can be closed at a time, thus preventing paralleling of the S.E.C. and emergency supplies. Paralleling of this type is undesirable as a principle, since it may involve feeding of power from emergency sets to the S.E.C. mains and the necessity of careful liaison between the consumers' staff and S.E.C. staff to safeguard personnel.

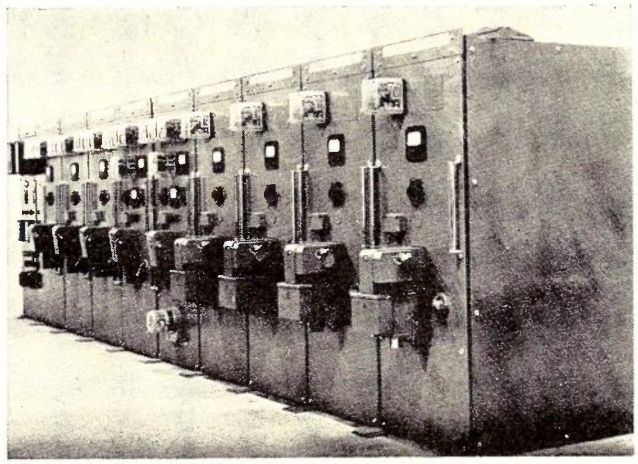

Fig. 12.—6600-volt power board.

From the 6600 volt bus are fed oil circuit breakers supplying the power E.H.T. rectifiers for transmitters Nos. 1 and 2, which are push button controlled from their respective transmitters (all other oil circuit breakers on the board are manually operated), as well as a main circuit breaker for the No. 3 transmitter and circuit breakers which feed the regulated transformers for the main 400 volt supply busbar. In addition, a voltage control panel is provided for these transformers, which are of the on-load tap changing type and may be parallelled. Oil circuit breakers of a similar type to those on the 6600 volt board are located in the rectifier transformer cubicles and short circuit the starting resistors. These circuit breakers are also remotely operated from their respective transmitters.

On the 400 volt board are truck type circuit breakers controlling the outputs of the 400 volt transformers, two oil circuit breakers feeding the No. 1 and No. 2 transmitter 400 volt circuits, as well as distribution panels for these transmitters. A fifth oil circuit breaker controls the "main 400 volt supply" for building and other auxiliary services. The power for building lights and auxiliary power is normally obtained from a 400 volt S.E.C. "auxiliary supply" giving up to 200 kW. This supply and the emergency supply are controlled by air circuit breakers operated from the 400 volt board. Two automatically operated changeover contactors on this board control the operation of the "main," "auxiliary" and "emergency" 400 volt supplies. Under normal operation, the contactors are operated so that the "main" supply feeds auxiliary services associated with the transmitters and the "auxiliary" supply feeding exclusively building services and ventilation system. In the event of power failure, one of the 50 kW sets (preselected by hand in the engine room) starts up automatically, contactors A and B change over, and the emergency set supplies all the auxiliary power. To avoid overloading this set, the building distribution boards are provided with automatic switches which cut off a considerable number of "non-essential" building supplies. The ventilation system also is switched off. For transmitter operation, the 400 kW sets must be started up by hand. Contactors A and C may now be switched by push button to the "main" supply, and the "essential" lighting supplies can be restored by push button. Return of the auxiliary power automatically restores contactors A and C to this supply.

Part II. of this article will describe transmitters and programme control equipment, and will appear in the next issue of the Journal

THE STANDARD A.P.O. 50/200 LINE R.A.X.

W. B. Wicking

The probable lines of development of the exchange system in rural areas in Australia were discussed in Vol. 6, No. 1, June, 1946, in which the part to be played by the rural automatic exchange was generally outlined. This article will deal chiefly with the design of R.A.X. equipment to fit into the structure of the rural telephone scheme and provide for future developments as they become necessary. Although units of at least two and possibly three ultimate capacities will be required, only one type, namely, 50/200 (initial capacity, 50 lines; ultimate capacity, 200 lines) has as yet been developed, and it is this unit that will be dealt with particularly herein.

The original R.A.X. scheme contemplated three types of unit, with ultimate capacities of 10, 50 and 200 lines respectively. No satisfactory 10 line unit has as yet been produced; and from experience gained to date it is doubtful whether a unit of such small capacity would serve a very useful purpose. 50 and 50/200 line exchanges have been in service for some years, and have given fairly satisfactory performance. Those at present in use were supplied by four of the principal overseas exchange equipment manufacturers and differ from each other in many respects, including the circuit arrangements and the items of equipment used to perform the various circuit functions. This equipment has been to some extent of an experimental nature, and has served to provide the local experience necessary before a standard design could be undertaken. Future developments will necessitate R.A.X.'s being closely associated, and it is therefore necessary to standardize circuit design and, as far as possible, physical features and types of equipment, before any extended programme is undertaken.

R.A.X.'s are, almost without exception, unattended, and are usually located at considerable distances from their maintenance centre. The maintenance of the equipment, therefore, necessitates considerable travelling, and the number of subscribers usually involved is insufficient to justify frequent visits. It is essential, therefore, that the circuit arrangements should be of as simple and reliable a nature as possible in order to minimize the fault liability, facilitate testing and reduce maintenance and consequent travelling costs. The use of common equipment should, as far as possible, be avoided, as comparatively trivial faults in this portion of the apparatus frequently lead to the complete interruption of service, necessitating special visits by technical staff to restore it.

For the foregoing reasons, in designing the standard unit allotters have been passed over in favour of a simultaneous search for the calling line by all free connecting links, with an adequate safeguard against double finding. Similarly, a straight step-by-step switching scheme with group and final selectors operated directly by the impulses dialled by the subscriber has been adopted in preference to a "control" or "register" system. The chief advantage of the latter system is its economy in equipment, achieved by reducing the complexity of a comparatively large number of connecting circuits by limiting certain common functions to one or two even more intricate mechanisms. However, the overall economy of equipment resulting from this is offset by the disadvantages previously mentioned. In the standard unit reasonable economy in equipment is gained by separating the apparatus required for normal operating functions, such as providing straight-line subscribers' service, from those performing special functions such as party line subscribers' service and trunk line service. This arrangement is flexible, permitting the minimum equipment to be provided to meet the requirements of each particular case. Thus, for an exchange having all straight-line services and a manual parent office, auto-manual trunk relay sets only would be supplied, no party line or code ringing equipment being required. However, if it is desired to connect party lines subsequently, all that is necessary is to add the appropriate special relay sets to the existing unit. Similarly, if the manual parent is converted to automatic working, auto-auto trunk relay sets would be substituted for the auto-manual sets by simply jacking out the one type and jacking in the other.

The standard 50/200 type unit employs 2000 type equipment and practice as far as is practicable; the group and final selectors are 2000 type bi-motional switches, with the circuit arrangements modified to perform the slightly different functions required under rural conditions. The relay sets are likewise 2000 type, the trunk line relay sets being auto-auto repeaters modified to permit two-way working, and either, dialling in and out, or, magneto signalling in either direction, according to the type of exchange into which the R.A.X. is required to work. Uniselectors are of the A.P.O. or similar type. The equipment is mounted on standard shelves and enclosed in a dustproof metal cabinet measuring 8 ft. 3 in. high x 3 ft. wide x 1 ft. 9 in. deep, the front and rear covers being readily removable to facilitate maintenance.

The use of 2000 type equipment avoids manufacturing special or obsolescent types of equipment and reduces initial costs. It also ensures interchangeability of parts as between Metropolitan and Rural exchange areas and minimizes the number of special items to be stocked for maintenance. Further, it reduces the space requirements for mounting the equipment and permits the use of a unit of smaller overall dimensions. It standardizes general adjustment methods, data and tools, and induces confidence in maintenance staffs, who are, in most cases, familiar with the details of 2000 type equipment.

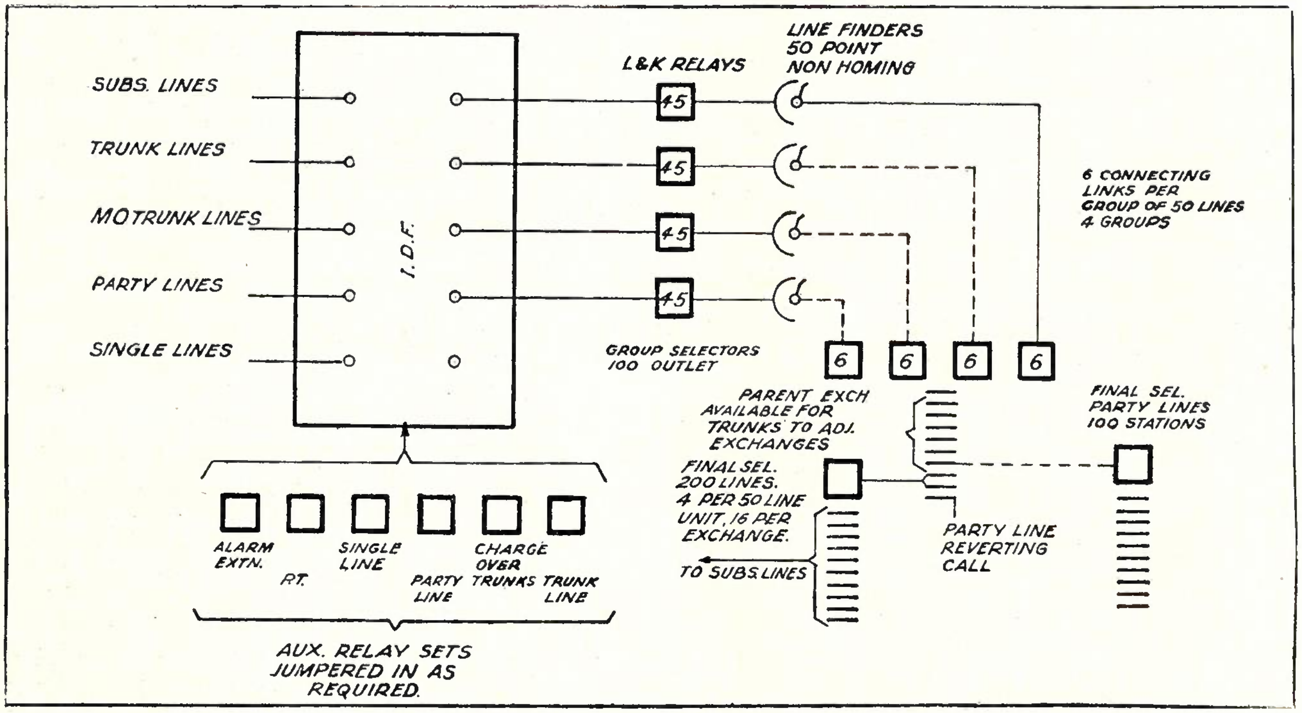

Fig. 1.—A.P.O. standard 50/200 line R.A.X.

Fig. 1 shows the general trunking diagram of the 50/200 unit. The M.D.F., which is not included in the diagram, is a floor type, supplied and mounted separately from the unit itself, on which each of the other items required for any particular installation are accommodated. The I.D.F. comprises a group of terminal blocks, and provides a convenient point for terminating internal cable from switch banks, relay sets, etc., and facilitates the connection, by means of jumper wires, of special relay sets for alarm extension, party lines, trunk lines, etc.

The L and K relays are shown in four groups of 45. Each group is accommodated on a separate 50 line unit and, with five additional

L and K relays reserved for, and included in, the trunk line relay sets, the capacity of each unit is increased to a total of 50 lines. Associated with each unit is a group of six connecting links, each link comprising a 50 point non-homing uniselector, arranged as a line-finder, connected to a 100 outlet group selector. Calls originating in any 50 line group or unit are connected via one of the six connecting links associated with that particular group. The banks of the group selectors are allocated as follows:—

Level 1: For releasing the connecting link when a call is made between parties on the same party line.

Levels 2 and 3 are trunked to the common group of 200 line final selectors, giving each 50 line group access to the full subscribers' multiple of 200 lines.

Level 4 is trunked to special party line final selectors provided only when party lines with more than two parties connected are associated with the exchange.

Levels 5 to 9 inclusive are available for connecting trunks to adjacent exchanges if required.

Level 0 is trunked via trunk line relay sets to the parent exchange. Provision is made for jacking in trunk relay sets suitable for use with either manual or automatic exchanges. In each case, both-way working is provided for. For manual exchanges signalling is by 16 cycle ringing, with provision for ring-off signals to the manual equipment from both calling and called subscribers. For automatic exchanges normal both-way dialling arrangements are provided.

The general arrangement of the equipment on the unit is shown in Figs. 2, 3 and 4. Fig. 2 shows the front elevation, while Figs. 3 and 4 show the side and rear elevations respectively. Careful consideration has been given to the mounting arrangements with a view to facilitating maintenance of the apparatus. For this reason, trunk line relay sets which are jack mounted and comprise 3000 type relays only are placed on the lowest position, as in this case the equipment can be readily removed for adjustment. L and K relays, which are of the 600 type and not jacked, are mounted next above the trunk line relay sets, together with

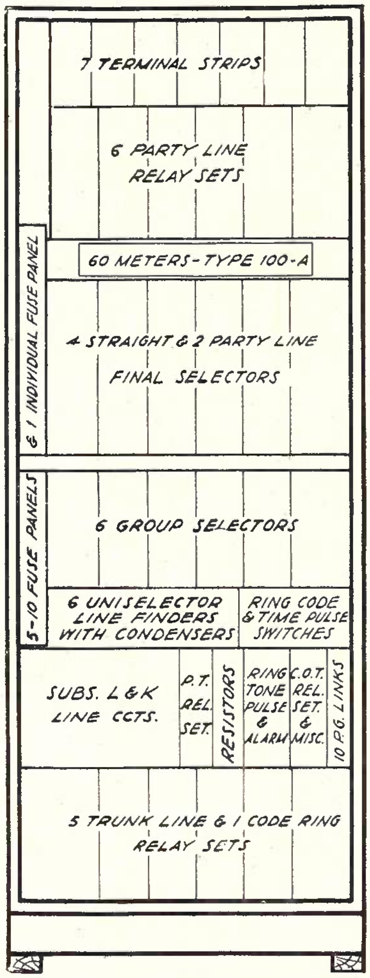

Fig. 2.—Front elevation.

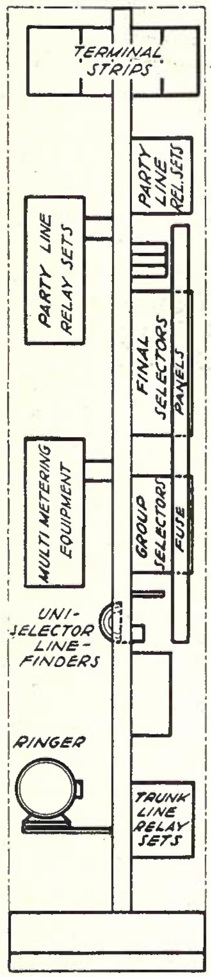

Fig. 3.—Side elevation.

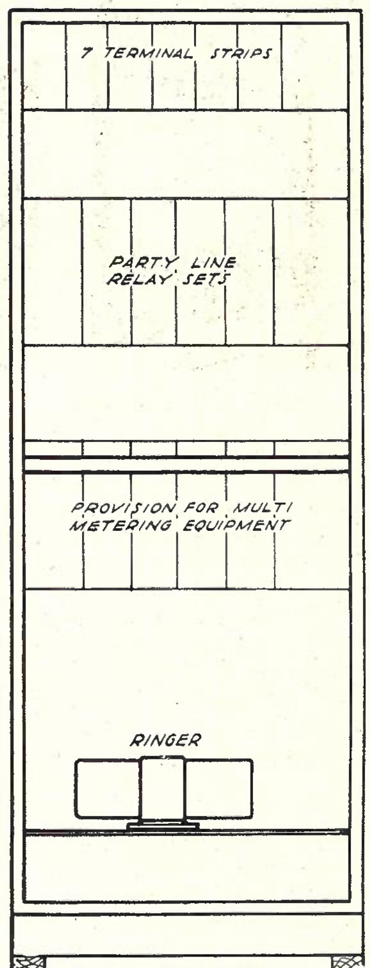

Fig. 4.—Rear elevation.

ringing and tone pulse and miscellaneous relay sets, in which position they are readily adjustable in situ. Immediately above the line relays are mounted the uniselectors and group selectors comprising the links, which are also readily adjustable in situ; and above these again are the final selectors for regular lines and party lines. The meters are 100A type, and are placed at a convenient height for reading. Immediately above the meters are the party line relay sets.

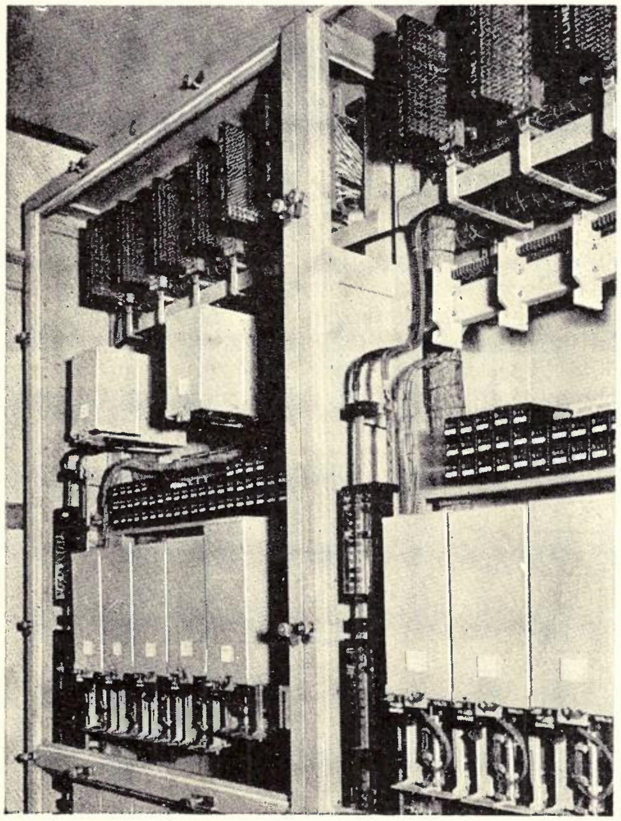

Fig. 5.—Front elevation. Upper portion.

In many cases party lines will not be associated with the unit, and therefore this position will not be often occupied; but in any case the relay sets can be readily removed for any adjustment required. At the top of the unit is the I.D.F., this position being most suitable as wiring and cabling are carried out during installation, when arrangements can easily be made for providing access to the top of the unit.

On the rear of the unit the only equipment normally provided will be the ringing dynamotor mounted on a shelf at the bottom. This equipment is jack mounted, and requires little or no maintenance. In this position it is quite accessible. Provision is made for ultimately mounting multi-metering equipment if required, and the relay sets of 4 to 10 parties. At present no multi-metering facilities are being provided; and, as in many cases party line relay sets of 4 to 10 parties will not be needed, the rear of the unit will, in the majority of installations, be unoccupied. The side elevation in Fig. 3 shows provision for cabling at the rear of the I.D.F. blocks. These facilitate units standing side by side being cabled direct by means of short, straight lengths of cable. The shallow cable trough permits turning of cables without causing congestion at the rear of fanning strips. Fig. 5 shows a general view of the upper portion and Fig. 6 of the lower portion of the front elevation. The photographs show considerable detail of the mounting arrangements and cabling, and should be read in conjunction with Figs. 2, 3 and 4.

The circuits which are given in Drawing C.E.303 are not reproduced because of space limitations, and it is not proposed to give detailed circuit explanations, but rather a general description of the equipment, with emphasis on new or unusual features. The best features of

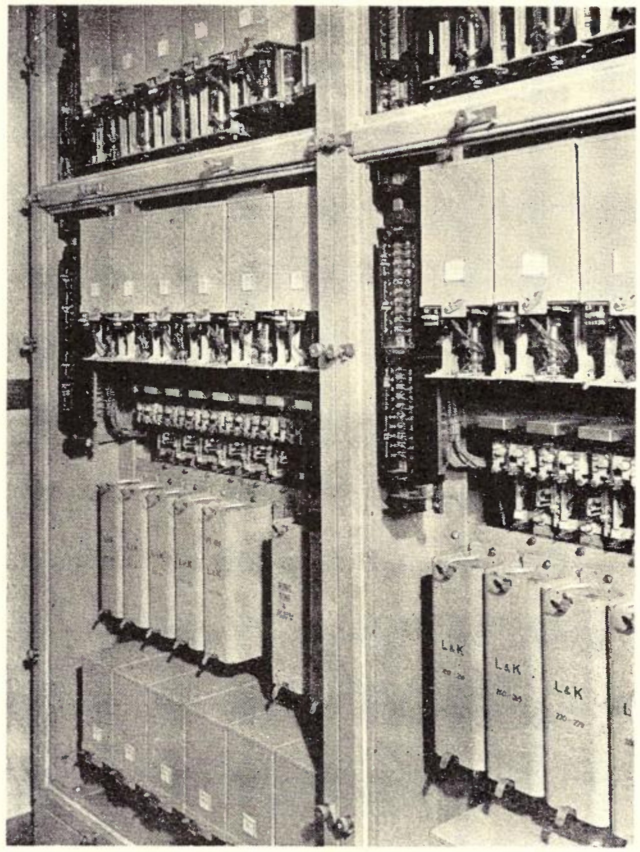

Fig. 6.—Front elevation. Lower portion.

the existing units are included in the standard unit, which also makes provision for additional facilities such as multi-metering, which may be required at a later date. The circuit arrangements necessary for providing the facilities have been modified somewhat to obtain the desired results by the simplest possible methods.

The L and K relay group comprises two 600 type relays which, under fault conditions, lock to a faulty line, releasing the connecting circuit. Except for the type of relay employed, this arrangement is similar to that in general use with R.A.X.'s. No assigner is provided. Upon a call being originated, the line-finders associated with all connecting links search. The first finder to locate the calling line tests in and removes the marked condition from the calling line. Thereupon, all the remaining finders immediately cease hunting. Double finding, even if two finders are standing on the same contacts when the associated line originates a call, is prevented by the fact that two test-in relays will not hold if they test in simultaneously. In such cases both relays release, and another finder takes over the call.

The group selector is of the battery testing type, and functions similarly to a standard group selector. A 100 outlet switch is used, as this requires less space and provides all of the facilities necessary, and for the small groups of trunks required, no advantage is gained from the use of a 200 outlet switch. Two levels of group selectors are trunked to final selectors, namely, levels 2 and 3, level 2 being trunked direct and level 3 via the wiper switching relay of the 200 line final selector, in accordance with normal 2000 type practice.

Two types of final selector are provided, one for regular and one for party line service. The former is similar to a standard straight line final selector, except for minor changes chiefly to provide for battery testing and 4th wire metering. The latter is required only where multi-party lines are connected, and is a 2000 type 100 line switch modified to give code ringing via the bank contacts. This arrangement avoids the necessity of providing complicated switching arrangements to give code ringing on the normal final selector and, as in many cases party lines will not be connected to an exchange, it permits a comparatively simple circuit arrangement to be used in such cases.

The trunk line relay sets are adapted from auto-auto repeaters, the circuit arrangements providing for two-way working and for either dialling to adjacent automatic exchanges, or for magneto signalling to adjacent manual exchanges. The latter type provides for a standard ring-off signal for calls in either direction, and the former for standard automatic supervisory signals, including the battery reversal.

Three types of special party line auxiliary relay sets are provided for, namely, two party line, which is based on each subscriber having a separate number and using normal ringing on the "A" side of the line for one party and the "B" side for the other party. No special code ringing equipment is required for this type of service, which can be given with normal final selectors. For party lines having three parties a comparatively simple auxiliary relay set is used, with code ringing signalling arrangements. For party lines having from four to 10 parties, a special relay set associated with two uniselectors is provided. Code ringing is used for this type of service. For all party lines individual metering is given, a separate meter being included for each party. For party lines of three or more parties, party line final selectors are necessary. All calls between parties on the same party line are effected by dialling 1 to release the connecting link and then code ringing the required party by means of a hand generator. For this reason, each party subscriber will use a local battery magneto telephone with suitably modified circuit to permit dialling. Parties connected to a line having more than three parties will have a dial with an additional cam arranged to mask any desired impulse. This feature is necessary to permit the appropriate meter to be associated with the connecting link, which function is achieved by the subscriber dialling a preliminary "0" before the number of the required line. The call cannot proceed unless the initial "0" is dialled.

From the trunking diagram it will be seen that subscribers' numbers are of three digits, comprising a numbering group from 200 to 399 inclusive. Party lines have a special group of numbers, namely, 400 to 499 inclusive, while trunks to adjacent exchanges have single digit codes, i.e., 5, 6, 7, 8, 9 and 0.

Although the unit is regarded as having an ultimate capacity of 200 lines, if necessary it is possible to increase this number by providing a second group of final selectors trunked from other levels of the group selector. The provision for accommodating the additional final selectors is limited to a maximum of 16 regular final selectors plus eight party line final selectors.

The party line final selector is unusual, in that it has a 400 point bank, with a fourth wiper in addition to the normal negative, positive and private wipers. The bank contacts of this switch are connected normally for the negative, positive and private wires; but the P2 contact is wired via the code ring switch to the appropriate ringing code, that is, contacts Nos. 1, 2, 3, etc., are wired to codes Nos. 1, 2, 3, etc. This arrangement permits the switch to be used for 10 ten-party lines, one being connected to each level of the party line final selector; or, alternatively, for 50 two-party lines or any combination of party lines, so long as the total number of parties does not exceed 100. It is not suitable for connecting straight lines, as the code ring is in the form of an interrupted earth, and requires an auxiliary relay set to convert it to 16 cycle ring.

For public telephone working, arrangements somewhat more complicated than those which apply in metropolitan networks are necessary. It is, of course, essential that local calls be obtained without the intervention of the parent exchange telephonist. This is provided for in the normal manner by the removal of the shunt from the subscriber's transmitter and receiver on the insertion of coins. In order to obtain trunk calls, however, it is necessary to permit the caller to talk to the trunk telephonist without inserting coins. This is achieved by means of a special dial which, when "0" is dialled, removes the shunt permitting both-way speech. In order to enable the telephonist to distinguish between calls originated from P.T.'s and those made by regular subscribers, a small relay set, comprising a quick-acting relay and a thermostat type relay, is introduced in the P.T. circuit. Upon the operator answering the P.T. call, one relay releases, breaking the circuit of the other and applying N.U. tone to the trunk during the release period of the thermo relay, approximately 15 seconds. This signal serves to warn the telephonist that the call is from a public telephone.

The unit briefly described herein does not represent the "alpha" and "omega," particularly the latter, of R.A.X. development. However, it does standardize present practice and provides for the incorporation of future requirements as these become necessary. This alone is an important step forward, permitting a programme of conversion to be undertaken at once and releasing substantial quantities of magneto equipment to meet developments in other magneto areas.

In the previous article, the desirability of an early review of existing unit fee areas, trunk line charges, metering arrangements, etc., as a prelude to the redesign of rural networks and equipment was stressed. Many of the most important problems associated with R.A.X. development depend on the particular conditions to be met; and such a review, if undertaken at an early date, would fix these requirements and give a sound basis for the development of the necessary equipment. At this stage, it is practicable only to design for existing conditions, and make such allowance as seems reasonable for future development. This course has been adopted in connection with the 50/200 line unit and will be continued in the design of smaller capacity units now being undertaken.

POSTAL ELECTRICAL SOCIETY OF VICTORIA

Annual Report, 1946

The year under review has been one of reorganising to meet the post-war period. At the beginning of this year the Committee decided that the time was opportune to arrange for bi-monthly lectures and a lecture programme was drawn up accordingly. Appreciation for the delivery of lectures during this year is expressed to the following gentlemen:—

Messrs. C. J. Prosser, E. D. Curtis, R. W. Boswell, W. B. Wicking, S. H. Witt and A. H. Kaye.

These lectures were held in the Radio Theatre, Melbourne Technical College. This has been made possible by the courtesy of the Principal, Mr. F. Ellis, M.A., B.E., and Mr. R. R. Mackay, M.I.R.E., and we are indebted to them for the material assistance they are rendering the Society.

On 13th May a Special Meeting was held in the G.P.O. Dining Room, at which Messrs. G. J. S. Little, G.M., A. Murphy, R. L. Bell and H. C. Andrews, from the British Post Office, were the guests of the Society. Messrs. Little, Murphy and Andrews gave short addresses, at the conclusion of which the President, Mr. H. G. Kuhn, presented each of the guests with an ash tray in mulga wood suitably inscribed.

The resignation of Mr. R. M. Osborne from the Board of Editors was received with very real regret. Mr. Osborne had been an Editor of the "Telecommunication Journal of Australia" since its inception in 1935, and as a mark of appreciation of his outstanding services in this capacity, and also as Honorary Treasurer for many years, he has been made a Life Member of this Society.

Mr. S. T. Webster has been appointed to the Board of Editors in place of Mr. Osborne.

The increase in the Annual Subscription from 4/- to 6/-, which was decided at the 1945 Annual Meeting, has been implemented. The number of Members and Subscribers as at December, 1945 and 1946, is:—

	1945	1946
Members	1,085	1,027
Subscribers	1,369	1,501
	2,454	2,528

To assist in the handling of subscriptions and the distribution of the Journal, the Committee appointed Miss I. Owens as Distribution Manager, and wishes to express their appreciation of the splendid service she has rendered during the current year.

It is desired to express thanks to the authors of articles and members of the Drafting Staff, who have given freely of their time in preparing articles and illustrations for the Journal, and also to those members who have so willingly assisted in collecting subscriptions.

MECHANICAL AIDS USED IN LONG LINE EQUIPMENT CONSTRUCTION WORK

C. Anquetil and E. A. Welsh

With the general intention of economizing in floor space occupied by long line equipment racks there has been a marked swing during the past few years to double-sided mounting of equipment as well as a closer and more compact arrangement of components. This tendency has resulted in heavier units of equipment, and a fairly serious problem became evident as to the most efficient way in which to handle the heavy, narrow 10′6″ racks without hazard or excessive demands on physical effort necessary under "man-handling" methods. Point was lent to this necessity by the acute prevailing staff shortages, and the undeniable fact that volunteer assistants for difficult rack shifting jobs do not abound in the average office.

In Victoria the problem was met by the design of a vertical rack shifting trolley, which, when used in conjunction with standard lifting tackle, very effectively overcame the handling difficulties. It gave facilities enabling two men to comfortably set up a rack in its allotted position, whilst any prior movement of the upright rack about the floor of the office could be readily effected by one man.

Other accessories have been developed or adapted for use on long line equipment construction work, and brief descriptions are given in the following paragraphs of the undermentioned devices:—

- Vertical rack handling trolley;
- Portable gantry;
- Tubular scaffolding;
- Rack support pillars;
- Indoor portable bench;
- Rack protecting frames;
- Mobile tables;
- Tubular battery stillage.

No particular claims are made for originality in the ideas underlying these devices, as in many cases they were more or less based on established principles. The interest lies in the adaptations to departmental purposes. All the items were made up in the Postal Workshops, Melbourne, where most helpful co-operation was received.

Vertical Rack Trolley (Fig. 1): The first rack trolley was made for use at City West, Melbourne, where, in addition to new installation work, rearrangements of existing racks are being carried out continually, and there was a need for some shifting device which would make the job easier for the staff.

The long line equipment installation at City West comprises a large number of rows of racks 10′ 6″ high and of widths ranging from $20\frac{1}{4}$″ to 22″. Except where pillars occur, there are 17 racks in a row. Clearances between equipment covers of adjoining rows are, minimum 2′ 6″, maximum 2′ 11″. Racks are mounted on wooden plinths of approximately $1\frac{1}{4}$″ thickness, and are anchored, at the top, to flat iron bars associated with a fixed angle iron superstructure. All racks should be within range of the trolley. The spacing between racks suggested an optimum width of 2′ for the trolley base, which proved satisfactory.

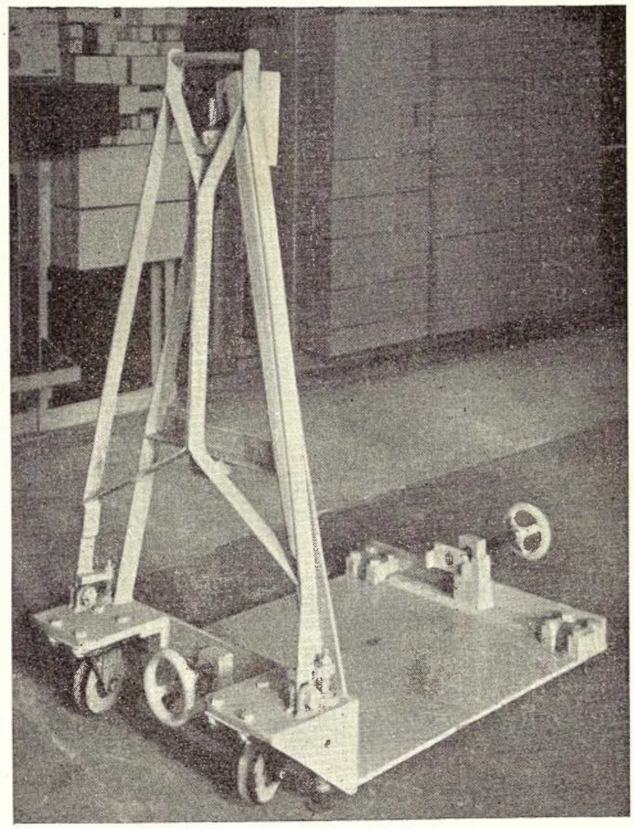

Fig. 1.—Vertical rack trolley.

Because of the rigid overhead structure it is not possible, if racks are to be manœuvred in an upright position, for the tray surface of any trolley to be higher than the surface of the plinth. Furthermore, whilst the trolley must be readily manœuvrable during shifting operations, it must be rigid and safe whilst the racks are being removed from it.

The solution was found in the use of boiler plate for the trolley tray, ball bearing assemblies for the rear wheels and industrial casters for the front wheels, the latter interchangeable at will with rigid feet by the operation of a lever. The centres of the ball-bearing units were mounted above the tray level so that there was a minimum clearance (approximately ¼") above the floor. To preserve the correct clearance at the front end the casters were mounted on the undersides of raised bracket details. With this arrangement of ball bearings and casters, the tray could be swung into any position, but the rear end could not slip sideways, as would have been the case had casters been used all round.

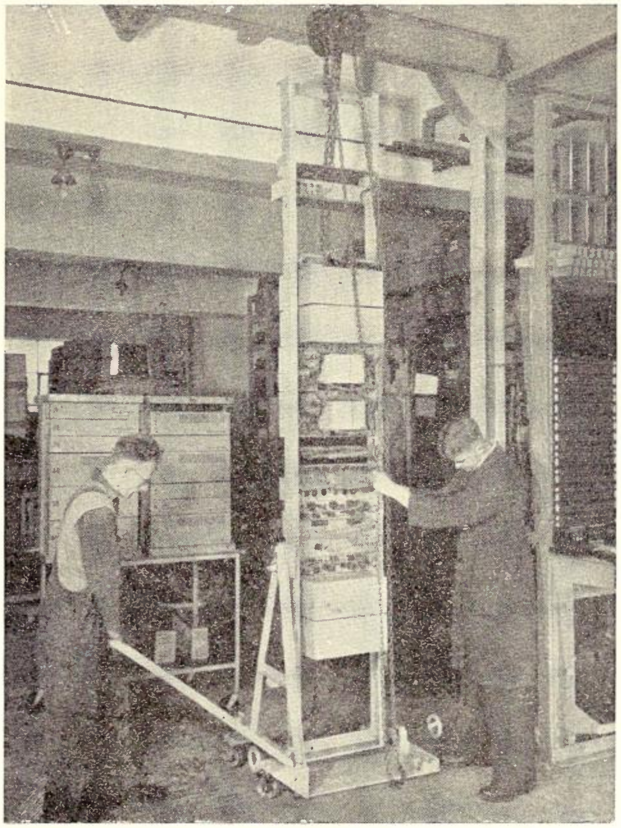

Fig. 2.—Vertical rack trolley—10'6" rack being lowered on to trolley.

A hinged drawbar is fitted to the trolley and is used in a normal towing position to manœuvre it about the floor; but when the trolley comes to rest the drawbar is placed in a vertical or "off" position and held by a latch. The action of raising the bar automatically operates a pair of plungers which relieve the front casters of the weight of the trolley. Transfer of the weight of trolley and rack to the rigid feet effectively locks the trolley to the floor. Under these conditions the vertical rack can be "walked" off the trolley without danger to the operators. Suitable screw and locknut adjustments are provided for setting the plungers correctly.

Other features of the trolley are the holding jaw, which grips the edge of the rack channel-iron, and the wheel-operated clamps, which also grip the channel near the base. The holding jaw is supported on an angle iron assembly approximately 3' above the tray, and tapers from 3⅛" wide at the lip to 2⅞" at the rear. This taper allows for minor manufacturing irregularities in the 3" channel. The front clamp near the tray surface has a hand wheel for ease in removing the rack should it become jammed by its own weight. The rear hand wheel operated clamp holds the rack rigidly in the trolley during shifting operations. This hand wheel is mounted as a plug-in attachment, which is removed from its socket when the trolley is not in use and plugged into a receptacle on the front iron detail. This arrangement was considered desirable because of possible accidents which might be sustained by personnel who might fail to observe the fairly long protruding shaft when the trolley was not in use.

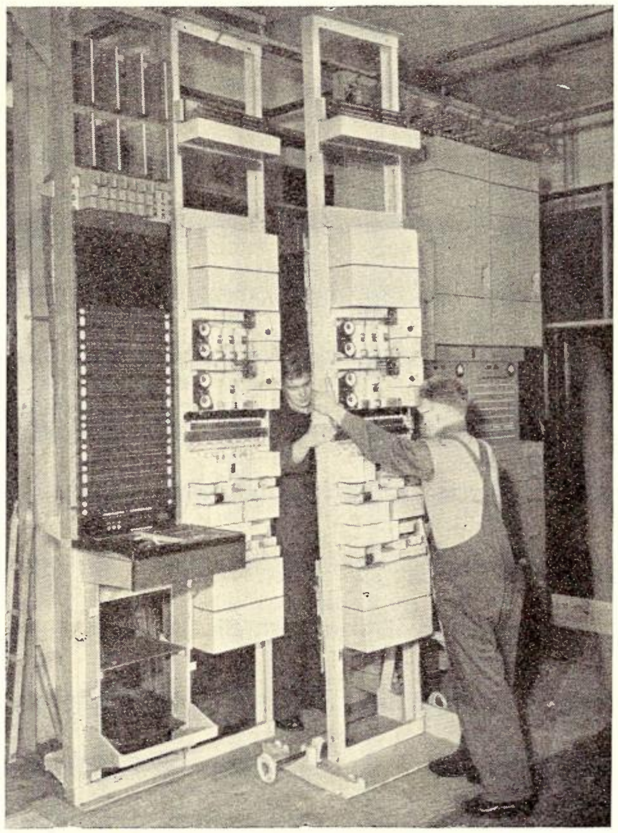

Fig. 3.—Vertical rack trolley "locked" to floor. Officers "walking" rack into its final position.

To set up a free rack on the trolley, the rack is raised to a vertical position by separate hoisting gear and lowered on to the tray. At the same time the trolley is manœuvred to the correct position, with the drawbar in the down position. The rear clamp is then screwed up. The rack is gripped at the foot between front and rear clamps, and steadied in the vertical position by means of the braced holding jaw. It may now be towed by one man to a position adjacent to where it is to be installed, and the drawbar latched in the "off" position for removal of the rack. Fig. 2 shows a rack being lowered on to the trolley, and in Fig. 3 two men are seen "walking" the rack off the locked trolley. The head of the rack will just clear the overhead ironwork in a normal long line station.

Portable Gantry: The portable gantry has proved of considerable assistance in locations where either hoisting facilities are unavailable or where a heavy unit has to be moved within the building and accurately lowered into its new position, e.g., the removal of a motor generator set.

Indoor type travelling gantries which can be taken from one part of a shop to another have been in existence for some time, and the principle has been adapted in this case. The local requirements are:—

(a) suitability for indoor use;
(b) that the unit can be readily dismantled for transport; and,
(c) that it can be effectively used to unload articles from the tray of a normal departmental truck.

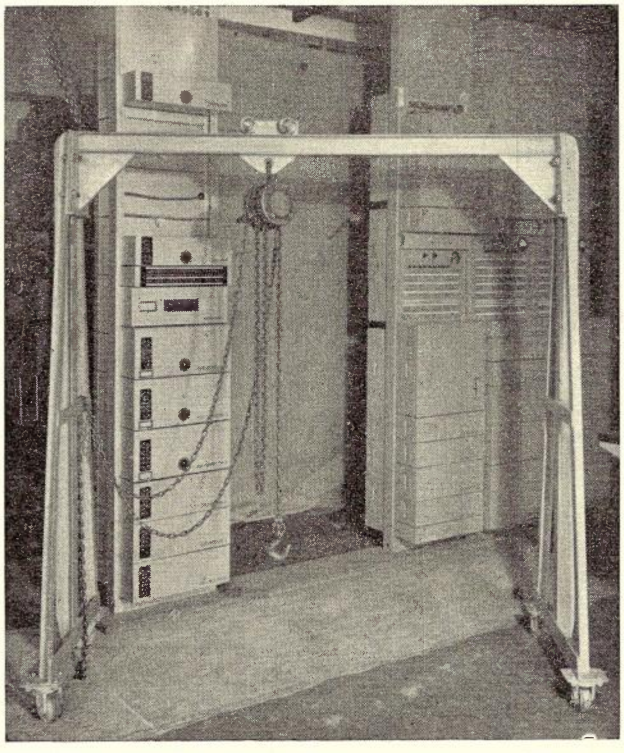

Fig. 4.—Portable gantry—short assembly.

Fig. 4 shows the portable gantry without load. It will be seen that the traveller consists of a heavy steel plate, which travels along a slot in the overhead bearer. It is supported by four steel wheels or rollers. The traveller is not anchored in any way, and can be removed when the lifting tackle is detached. The complete gantry is mobile on industrial casters. It can be dismantled readily for transport by the removal of eight bolts. Fig. 5 shows the sections dismantled for despatch.

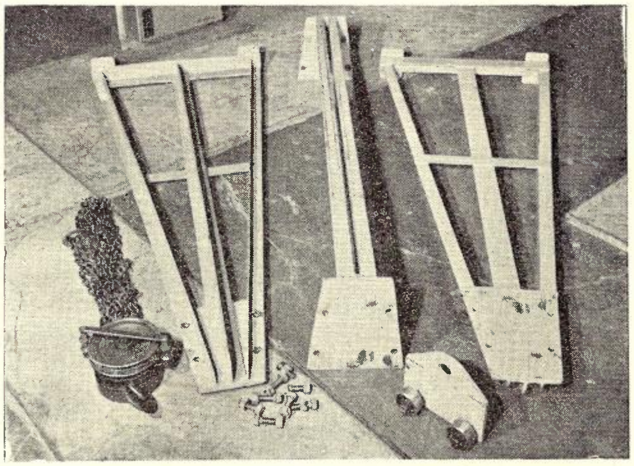

Fig. 5.—Portable gantry—sections dismantled for transport.

With the use of different sized trucks and the need to use the gantry for internal jobs as well as for unloading, it was found expedient locally to make two sets of side members for the common crossbar. Fig. 6 shows the taller assembly being used to load a motor generator set on to a truck having a fairly high tray level. (The use of steel cable sling, shackles

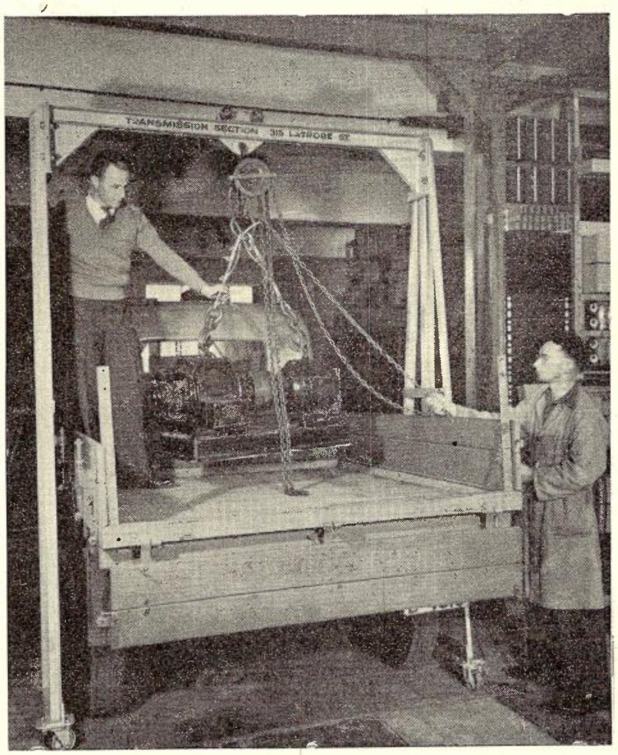

Fig. 6.—Portable gantry—long assembly—being used to load motor generator set into truck. Note use of sling and shackle assembly.

and hooks for the lifting operation will be noted.) Both gantry assemblies have been used effectively in handling long racks.

Tubular Scaffolding: For some considerable time the necessity had been felt for something better than the time-honoured plank and ladder arrangement to allow of comfortable working conditions when terminating cable or doing other lengthy jobs high up on racks. A light,

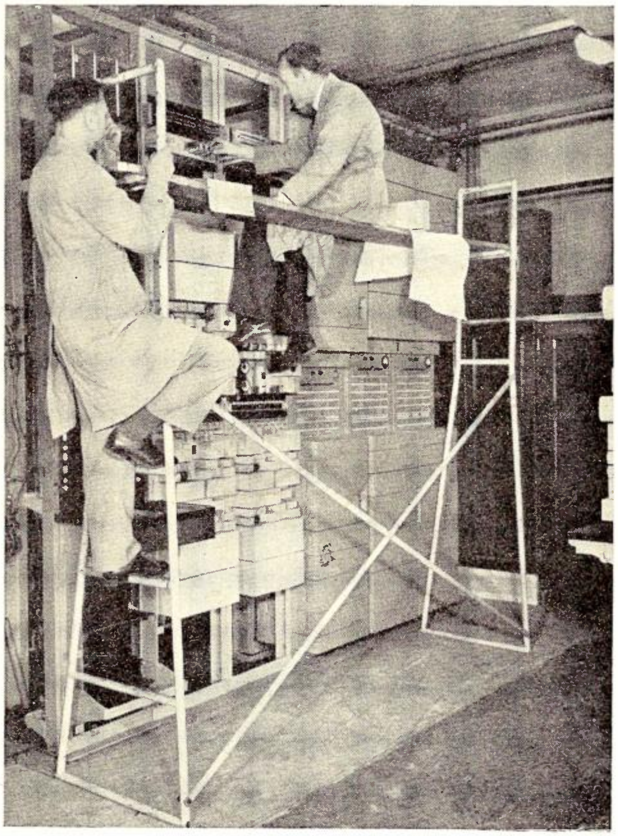

Fig. 7.—Tubular steel scaffolding in use. Platform level is adjustable.

portable scaffolding was made up, and has proved very satisfactory. It is illustrated in Fig. 7. The scaffolding is constructed of $1\frac{1}{4}''$ seamless 16 gauge tubular steel. The level of the platform or plank is adjusted by setting the position of the supporting crossbars, which take the form of short lengths of tube with a drilled tee at each end, and are capable of sliding vertically on the scaffolding end members. Holes are also drilled through the vertical members at regular intervals, and supporting pins pass through the holes in the tees and vertical members to bear the weight. The two end sections are anchored together by a pair of crossed light diagonal flat iron strips bolted at their centre. This detail ensures the vertical stability of the scaffold ends. Twisting is prevented by pairs of wooden cleats, which are attached to the underside of the platform and which fit snugly about the supporting crossbars. One of the end members is fitted with rungs for climbing. The other end is purposely left open to allow of easy access to the equipment by other officers. On removal of four bolts, the unit is ready for transport.

Rack Support Pillars: It became the practice for certain overseas equipment, particularly during the war period, to be supplied with a large number of loose units, comprising racks, panels, odd components and wiring forms. Data supplied with the equipment usually indicated a number of alternative arrangements to be obtained by different assemblies or connections.

Upon determination of the method most suitable for the job in question, the completed racks were wired up locally. This gave rise to the necessity for some ready means of supporting a large and heavy rack in such a manner that wiring and preliminary testing could be readily carried out and work performed at will on either side of the rack.

A simplified stationary version of the adjustable mobile rack support pillars already developed for use in the long line section of the Postal Workshops was produced, and proved of very great value during the work preliminary to installation.

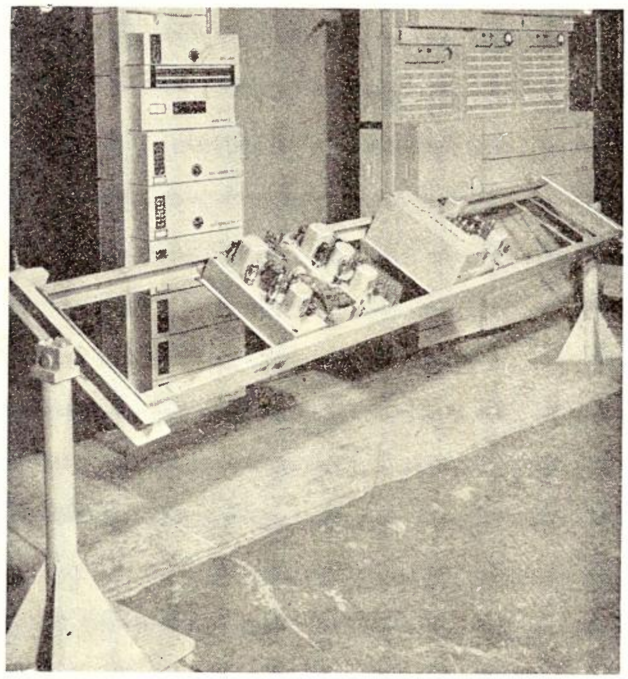

Fig. 8.—Rack support pillars—with rack in position.

Fig. 8 shows the method of supporting the rack. The supports consist of a yoke piece welded to a short steel shaft mounted in bearings at the top of a pillar. Each rack end is held in its yoke between two pins, one of which is fixed and the other adjustable. The pins engage in holes usually existing in the racks. (If the racks are supplied without the holes, this detail is readily attended to.) To ensure rigid clamping the pins are of larger diameter than the holes, and have tapered points. When mounted between a pair of pillars, the rack can be rotated on its axis as required by loosening the bearing clamp screws at both ends. The pillars are fitted with welded bases of $\frac{1}{4}''$ iron plate, 1′ 8″ square. Gussets are added for strength.

Portable Bench: The portable bench is useful at country offices, particularly where busbars and runways have to be installed, a class of work for which only a limited amount of prefabrication can be performed at the Workshops. The bench comprises a stout timber plank, each end of which is slipped through an oblong aperture in a tubular end section in which it is locked by its own weight. This type of bench has been in use for many years in the plumbing trade, and the design has been adapted to suit our requirements. Construction is of welded pipe, and, for use indoors, hinged feet have been fitted to the bench legs and prevent any damage to floors or linoleums. Fig. 9 shows a portable bench fitted with motorized drill, bar bender and vice.

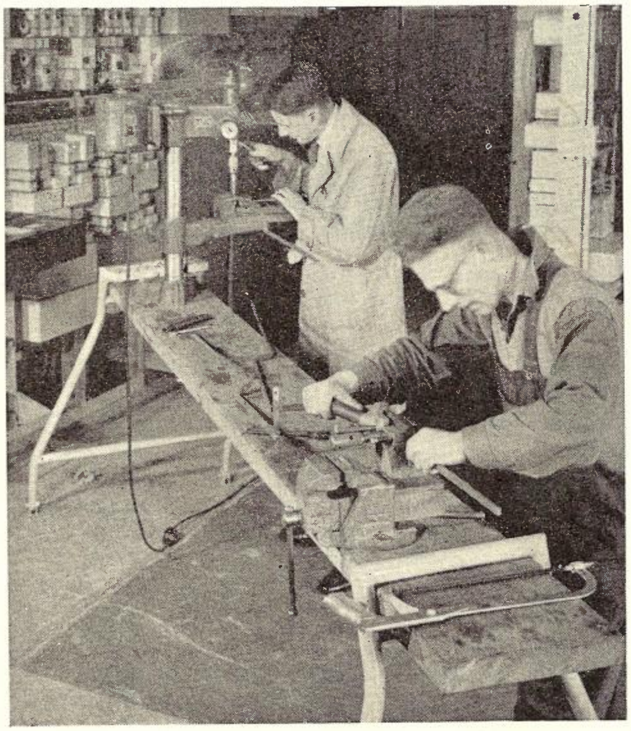

Fig. 9.—Portable bench in use. Bench is fitted with drill, bar bender and vice.

Rack Protecting Frames: The credit for the introduction of these racks is due to Communication Engineering Pty. Ltd., of Cammeray, Sydney, whose despatch methods allow for repeated use of the packing material.

The rack protecting frame comprises, in effect, a cradle formed of two tubular side sections between which the rack to be transported or handled is clamped. The paint work of the rack is protected by suitable buffer pads, usually made of felt. Racks for despatch are clamped in the cradles and lowered into specially built transportation cases, and, when unpacked, are set up in position whilst still protected by the frames, which are subsequently unbolted and fall away.

The arrangement with the Company is that the frames and transportation cases are then

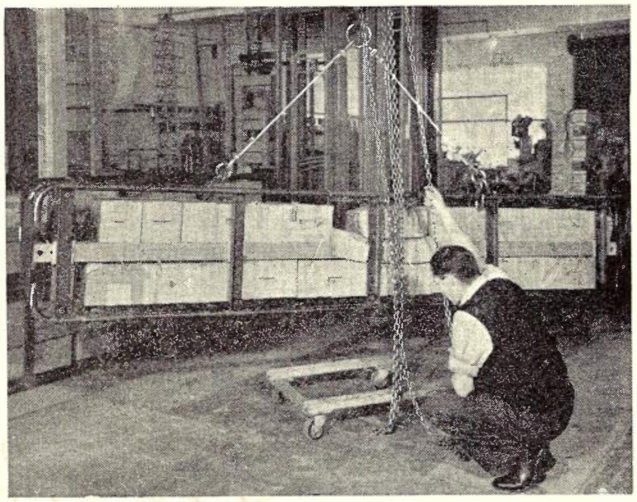

Fig. 10.—Rack protecting frames—CEP type frames and rack being lowered on to rack trolley. Note also use of sling assembly.

returned for further use. To avoid unnecessary holding of the contractor's frames, local copies were made, incorporating a very minor alteration, i.e., the closing of a gap at each end of the frame. They have proved very useful in handling all types of long line equipment racks, and doubtless the principle will be extended.

Fig. 10 shows a heavy rack of transmission equipment, clamped in a C.E.P. type frame, being lowered on to a trolley. The trolley is of simple channel iron construction, and uses industrial casters. It was made up in the Workshops, primarily for use with the frames described above; but, being fitted with casters, is useful for general purposes.

It will again be noted that steel cables and special shackle hooks are used for the hoisting operation. These attachments, which were made up after experience in handling various long line equipment loads, are safe and positive. They have more or less universal application, and overcome a considerable amount of the labour loss usually associated with the use of ropes and slings.

Mobile Tables: These tables follow the well-established principle, and quite a number of them are used at offices where any degree of equipment testing is done. Whilst the main purpose of these tables is the easy movement of testing instruments, e.g., on acceptance tests or line-up routines, they have been found serviceable for many general purposes. For example, small jobs can be set up on the tables and any preliminary work done in the most convenient position in the equipment room or shop. The table and apparatus can then be wheeled round to a fixed testing bay or to its point of installation. Mobile tables are made cheaply in the Postal Workshops from light welded angle iron. Fig. 11 shows a large and small table being set up for a testing job. On the large table is an Army type portable "1 + 4" telephone carrier terminal, whilst the small table carries an Australian Post Office type transmission measuring set.

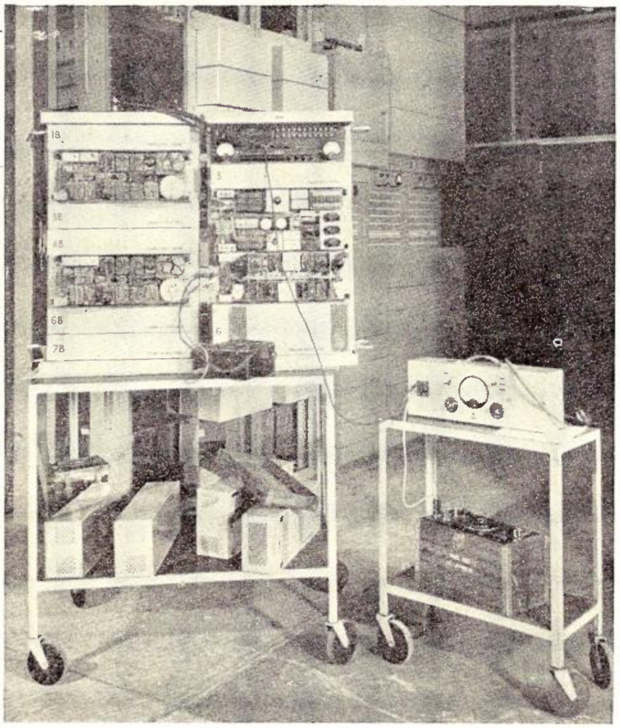

Fig. 11.—Mobile tables.

Tubular Battery Stillage: Whilst, perhaps, slightly outside the title of this article, another development which has found wide application for transmission purposes in Victoria, and may interest readers generally, is the welded steel battery stand. For a number of years, angle steel battery stands with insert wooden bearers have been used to mount open type anode batteries at repeater stations, thus obtaining improved appearance and space economy.

For motor car type batteries, stillage design can be further improved and simplified by using tubular construction. For example, at Sale, Victoria, where, pending the erection of a new building, battery room space was very limited, it was necessary on installation of a V.F. carrier telegraph system to mount three 130 V. batteries of motor car type in a 2′ space. A streamlined, three-decker, tubular steel stillage was developed which satisfactorily solved the problem. Lead-in conduits were so arranged that the wiring which passed under the floor was completely enclosed from battery stand shelf to power board. As part of the design, screwed feet were fitted to the frame support members so that adjustments could readily be made for any irregularities in the floor level. Protection from acid was given by coating with acid-proof primer and paint.

To meet a similar battery requirement at Bairnsdale, in an equally cramped room, the unit illustrated in Fig. 12 was made. It is compact and accessible, and combines mechanical strength with pleasing appearance, the enclosed type cells being mounted directly on the bars.

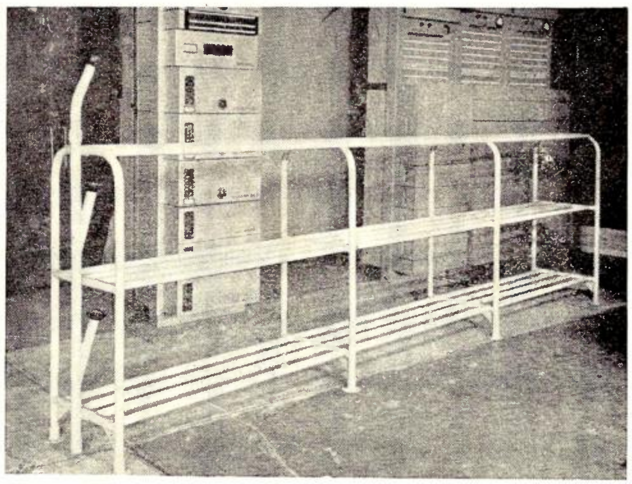

Fig. 12.—Tubular steel stillage designed for three enclosed type 130v. batteries.

Welded steel battery stands have been in use at Victorian Transmission Stations since 1938, and have proved most satisfactory, and with normal attention to the paintwork no trouble has been experienced due to acid or fumes.

Conclusion: With a constant heavy programme, it follows that Departmental installers will lean more and more towards mechanization and to the use of special tools and accessories outside those normally included in the standard construction kit.

The foregoing comments have necessarily been restricted to mechanical aids used in facilitating the job of long line equipment installation, and any digression on construction methods has been avoided; but the study of such methods, and the urge continuously to improve them, adds further interest to the installers' work.

RECEPTION OF SINGLE CURRENT TELEGRAPH SIGNALS OR IMPULSES OVER LINES SUBJECT TO LEAKAGE

E. D. Curtis

Introduction: Communication men who are concerned with telegraph circuits or long dialling lines are in general agreement that the reception of impulses or single current telegraph signals over open wire circuits subject to loss by leakage forms one of the major difficulties encountered in their work. Since economics dictate the use of omnibus circuits, sometimes of considerable length, the case is usually met for telegraph working by using morse relays provided with a means of varying the tension of the retractile spring and also for varying the distance between the armature and cores of the relay. Manipulation of these two variables permits the operator to adjust the relay to the marginal condition necessary so that the relay will respond to the particular current range of change which occurs under given conditions. An essential to satisfactory operation of the circuit under conditions when leakage is variable is the attention of a competent morse operator to keep the relay in correct adjustment. Morse relays are located on morse operating tables so that this condition is met.

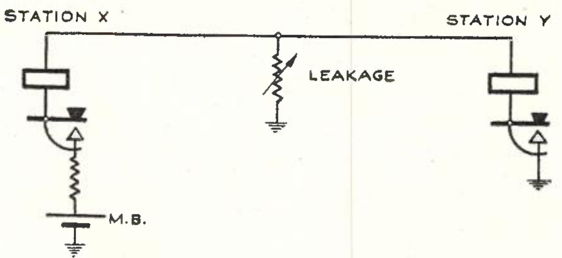

Fig. 1.

Typical Leakage Conditions: The conditions on a typical morse simplex line are shown in Fig. 1, and the resulting current conditions are given graphically in Fig. 1 (a) Curve A shows the values of total line current and curve B the leakage current in terms of current through the relay at station "X." These values are those measured with the key at station "Y" closed and opened. The curves C and D show a range of operate and release points for the relay at station "X" to meet the range of current values covered by curves A and B. From the curves it will be seen that for any given condition of leakage, the change in value of current at station "X" is given by the vertical distance between curves A and B. The relay must be adjusted to operate on this change in current, and it will be seen that the margins of the relay are reduced as the leakage increases. Furthermore, under conditions of no leakage the morse relay retractile effort would be adjusted to give the operate and release

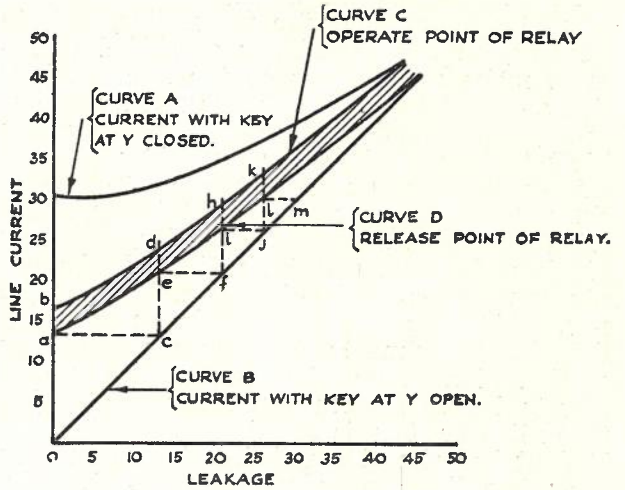

Fig. 1 (a).

points indicated by points "a" and "b." With the relay thus adjusted it would fail to respond to signals when the leakage value reached point "c," and a readjustment would be necessary at that point. Assuming that the readjustment was made to the values "d" and "e," failure would again occur when the leakage increased to point "f." Similar conditions would occur when points of leakage "j" and "m" are reached. Successive readjustment is possible until the fail point of the circuit is reached, a condition where the change in line current passing through the relay at "X" is insufficient for the operation of the relay armature. In practice it would be necessary to make adjustments before points "c," "f," "j" and "m" were reached, as signal distortion would be in evidence before the actual failure of the armature to respond to signals. The curves indicate that the fail point is reached when the change of current is of the order of 2 to 3 mA. Some difference of opinion regarding the actual fail point exists amongst operators; but it requires skilled attention to pass traffic when the change is less than the values stated and the morse relay, when adjusted for these narrow limits, is subjected to interference from inductive disturbance from other circuits on the same route. Curves of the general form of Fig. 1 (a) apply where dialling impulses are passed over lines subject to leakage.

Circuits from V.F. Channels to Simplex Line: With the introduction of V.F. telegraph carrier systems between the capital cities and major country centres, it is the usual practice to retain the portions of the closed circuit morse lines radiating from the country centre and to provide repeaters to form a junction between the single wire channel and the V.F. channel. The success of the repeaters at this junction is governed largely by the amount of leakage experienced on the open wire morse line, and, to an extent, on the availability of skilled operators to make adjustments to the morse relays which are used to receive signals from the simplex line. Where the lines radiate into country subject to heavy rainfall or conditions of high humidity the amount of lost channel time is high, with consequent delays to traffic. The opinion has been expressed that under conditions of high and variable leakage it would be advantageous to divide the circuits and repeat the traffic. While one repeater attendant may easily make the adjustments to ensure satisfactory operation of a group of repeaters at times of moderate leakage, when the fail point of the simplex line or lines is approached the repeater attendant has almost a full-time job in keeping one or two lines in correct adjustment. The problem of having sufficient skilled attention available to meet requirements in bad weather, and at the same time ensuring that the attendants have adequate employment during normal times, is of considerable magnitude.

Tube Type of Receiving Unit: In order to avoid interruptions to circuits due to varying leakage conditions, a receiving unit of a new type has been developed, which has given satisfactory results in service trials. The unit operates satisfactorily provided the current in the line changes by a predetermined minimum amount, irrespective of the actual values of the minimum and maximum current passed in causing that change. A reasonably simple combination of standard components permits a sensitivity approximately equal to the present telegraph relays in use, and the unit shows promise in removing the major portion of the difficulties now experienced with the manual adjustment of receiving relays. The unit has been developed along lines which permit its use with existing morse and V.F. plant. The general principle of the arrangement is illustrated in Fig. 2 (a). The resistance R1 is connected between negative line battery, 120 or 60 volts, and the simplex line, and a tube with a sounder in the anode circuit is arranged as shown. The capacity C1 and rectifier RX are connected across R1 in such a manner that C1 is charged, via the forward direction of RX, to the potential existing across R1. The grid of the tube is connected to the cathode via RX, so that with any value of steady current through R1 the grid and cathode are at the same potential. The actual value of the anode current is adjusted by varying the screen potential by the operation of the screen potentiometer. When the key in the simplex line is

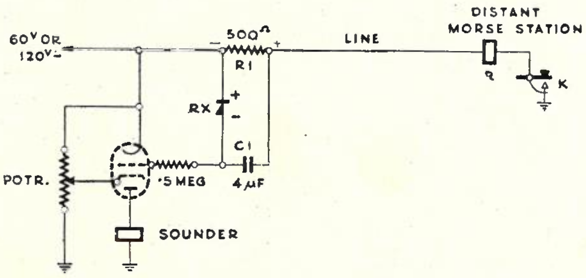

Fig. 2 (a).

opened the potential across R1 is reduced and the potential across C1 (previously equal to that across R1) tends to adjust itself to the new value across R1. This potential correcting path is via the rectifier RX in its reverse direction, and the difference of potential across C1 and R1 is developed across RX, resulting in the grid being biassed to the negative with respect to the cathode. The anode current is reduced or completely cut off, depending on the components used and the anode circuit sounder releases or spaces. The period for which this spacing condition persists is largely governed by the capacity used in C1 and by the value of the reverse direction resistance of RX. It can be controlled within wide limits by the selection of components. When the simplex line key is again closed, the potential across R1 is restored to its former value, C1 is again charged to the same value and the marking condition restored on the sounder. Fig. 2 (b) shows the working point of the tube used. With steady or marking current through R1, and with the grid and cathode at the same potential, 20 mA would pass through the anode circuit sounder. This value can, of course, be varied by the adjustment of the screen potential. The sounder is adjusted to release when the current falls to approximately 10 mA. With a tube of the characteristics indicated in the figure, satisfactory signals could be passed with a change of potential across R1 due to the opening of the morse line key, of 2 to 3 volts. Changes in excess of this value result in the tube being biassed beyond the cut-off point and do not cause any altered condition in the circuit. To summarise, the unit provides a means of keeping the receiving instrument in adjustment with the signal source over a wide range of line currents. As a typical case, a morse or similar circuit using single current relays for receiving

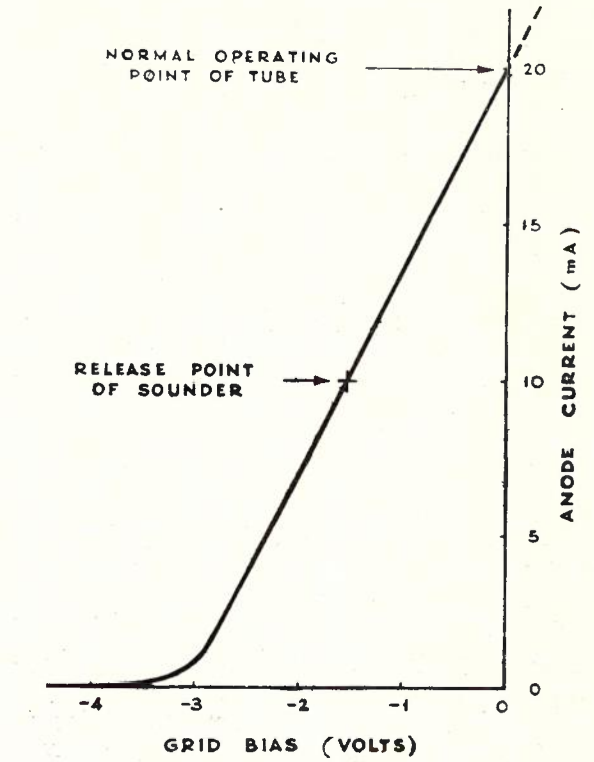

Fig. 2 (b).

and having a normal line current of 30mA would fail to respond to signals at a point where the line current increased to 40mA and the leakage conditions were such that the current through the home relay with the distant key open was reduced to only 20mA. With the unit described, the adjustment remains constant for any range of open and closed circuit conditions, provided only that there is a difference of 5mA (approximately) between the open and closed circuit values. The change in current may be from zero to 5mA, from 200 to 205mA, or any other pair of values where the difference is equal to or greater than 5mA, without altering the working conditions of the unit. This, in effect, provides the equivalent of automatic or self-adjustment down to the point of failure due to lack of sensitivity, which is approximately equal to that of the existing standard morse relays. The meeting of these conditions results in the practicability of unattended terminal units or repeaters for direct current signals.

V.F. to Simplex Repeater: Although the unit has wide application in telegraph work, the primary purpose for which it was developed was to provide a satisfactory type of repeater at

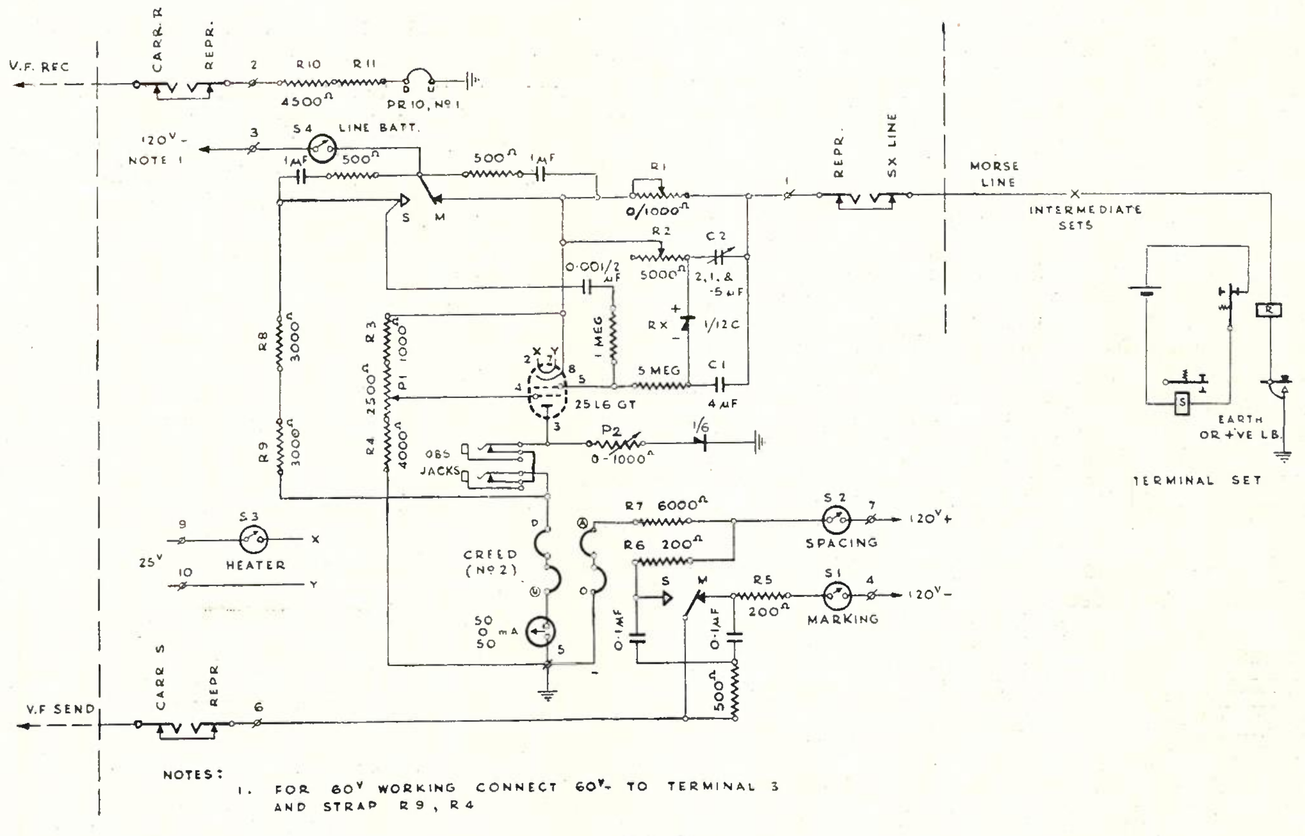

Fig. 3.

the junction of V.F. and simplex closed circuit lines. The circuit details of this repeater, incorporating the receiving unit, are given in Fig. 3. The description of the operation of this repeater and a discussion on the selection of values and types of components will illustrate the main points and limiting conditions. The normal arrangement of carrier receive relay is used, the tongue of this relay being connected directly to 60 volt or 120 volt line battery without the usual battery resistance. The marking contact is connected to the simplex line jack via the resistance R1, which, for this type of circuit, has a value of 500 ohms. The cathode of a tube type 25L6 is also connected directly to the marking contact. The grid of the tube is connected to the resistance, capacity and rectifier network. The screen potential is controlled by the potentiometer P1, connected between the marking contact and earth. The anode circuit relay may be a PR.10 No. 2 coil or a Creed No. 2 coil type with a biassing winding arranged to bias in the spacing direction by an amount compensated for by 10mA in the anode circuit winding. The tongue of the anode circuit relay feeds to the carrier send leg. The heater of the 25L6 is supplied from 25 volts and is suitable for direct connection to carrier system filament batteries or directly from 25 volt A.C. supply. The resistances R8 and R9, connected between the spacing contact of the carrier receive relay and the anode side of the anode circuit relay, provide a means of holding the anode circuit relay to marking when the carrier receive relay is to the spacing and thus prevent the signals received from the carrier being fed back over the carrier, an essential condition in repeaters of this type. The spark shunts connected between the contacts and tongue of the carrier receive relay serve a joint purpose of suppressing sparking at the contacts and preventing the anode circuit relay from lifting during the transit period of the carrier receive relay. The 0.5 megohm in series with the grid lead limits the value of grid current at times when the grid is positive with respect to the cathode. The meter in the anode circuit provides a ready means of checking the operating conditions of the unit.

The combination of resistance R2 and capacity C2 is provided to prevent capacity C1 from being charged to a potential in excess of that across R1. This condition can occur when signals are being sent from the carrier receive relay via R1 to a line which has distributed or lumped capacity. Fig. 4 (a) shows graphically the form of signal passing via R1 under these conditions; and, unless some network is provided to prevent it, C1 becomes charged to a value approaching the peak, rather than the final steady current value through R1. The

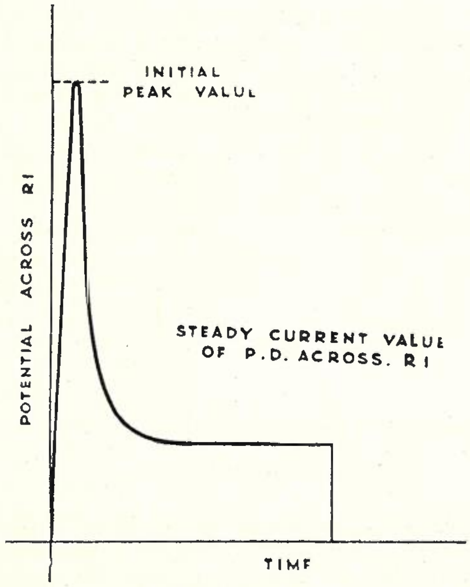

Fig. 4 (a).

values used for R2 and C2 are governed largely by the capacity of the line circuit to earth. Values of 3000 ohms and 1.5 or 2 microfarads have been adopted, and, in practice, have given satisfactory operation with such widely divergent conditions as (a) connection to a short aerial line, or, (b) direct connection to a composite circuit with its associated capacitive network.

In cases where morse intermediate sets are located near the repeater the shape of the outgoing signal may be of the form indicated in Fig. 4 (b), where, although there is the usual

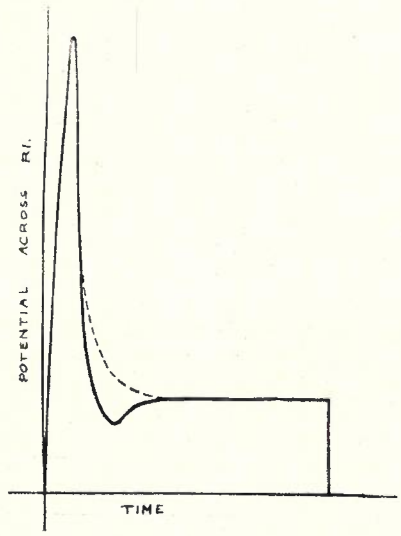

Fig. 4 (b).

capacity peak, the peak is dissipated before the signal rises to the final D.C. value. This is compensated for by providing the capacity

0.001 or 0.002 microfarads and the one megohm resistor in series between the spacing contact of the carrier receive relay and the grid of the tube. This network "swamps" the grid for the period indicated by the dotted portion in the figure, and prevents any false impulses back over the V.F. channel during the passage of signals through the repeater.

On lines which the outgoing signal is of the form shown in Fig. 4 (b), the incoming signal is of the form shown in Fig. 4 (c), and

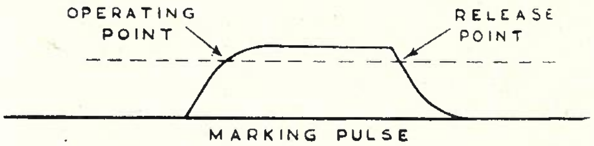

Fig. 4 (c).

it is necessary to make some compensation for the spacing bias introduced by single current working. Due to the sensitivity of the receiving unit, the operating and release points of the anode circuit relay correspond with those shown in the figure. Compensation for this loss is made by the addition of a 1/6A type of rectifier in series with a 0 to 1000 ohm variable resistance connected across the anode circuit relay. This rectifier delays the release of the anode circuit relay, i.e., the return to spacing, by an amount governed by the value of resistance connected in series with it. Variation of the resistance over its range gives the required control of signal weight between the limits of "light," or unaltered, to "heavy." This control is the only one provided for operation by the manipulative staff. Where a permanent line arrangement is connected to a repeater, no alteration to this control is necessary once the repeater is set up. The variable control is provided mainly to cater for altered signal shape resulting from altered line conditions, due to patching of lines or the inclusion of additional stations.

The jacks in the anode circuit are provided for the insertion of an observation relay in series between the receiving relay and the anode of the tube, permitting observation of through signals without disturbance to the repeater or line circuits.

Developmental Details and Selection of Components: The following details of tests made during the developmental work may prove of interest. The value of 500 ohms for resistance R1 was selected as a compromise to give sensitivity and at the same time to approximate the resistance of the usual battery station terminal. An increase in sensitivity can be obtained by increasing this value, but an increase results in a reduction in actual change in line current values due to fixed leakage conditions, and the overall gain is small.

The most suitable available tube is the 25L6, as it is designed for low anode and screen potentials and its transconductance at 60 and 120 volts is considerably higher than others of related types. In conjunction with standard relays, it provides a sensitivity approaching that obtained with the standard morse relays. Satisfactory operation, but with greatly reduced overall sensitivity is obtained with tubes of the 6V6, 6Y6 and 6L6 types, but these types are not entirely suitable when 60 volt line potentials are used.

The rectifier RX may be of the 1/12A, 1/24A or the 1/12H types. With the 1/12A or 1/24A types the capacity of C1 should be 10 to 20 microfarads for hand morse working. The 1/12H or 1/12C type, with its higher reverse resistance, permits C1 to be reduced to 4 to 6 microfarads. Tests were made, using a diode rectifier of type 25Z6 and also using the 25L6 tube as a diode with grid, screen and anode commoned. When using the diode type of rectifier the anode and cathode are shunted by a resistance of the order of 0.5 to 2 megohms, and there is some advantage, in that the reverse resistance and therefore the time of correction of the capacity C1 is readily controllable. For hand speed lines the 1/12H type appears most suitable, and has the advantage of simplicity. The capacity C1, together with the value of the resistance in the reverse direction of the rectifier, controls the time during which the spacing condition persists after the simplex line is opened. An increase in the reverse resistance of RX or in the capacity of C1 increases this period. In addition to providing the potential to cut off the anode current for sufficient time for satisfactory signalling, C1 must be able to correct its potential by discharge through RX at a rate at least equal to the potential variations across R1 due to variation in leakage from the line. This condition applies more particularly when the leakage from the line is reducing and C1 must adjust its charge potential via the reverse resistance of RX. When the leakage is increasing the potential across C1 is quickly adjusted via the forward resistance of RX. As the repeater is designed to follow reductions in line current due to leakage, it follows that it will adjust itself to an open circuit condition if this is permitted to persist for a sufficient period of time. This aspect is dealt with later.

Tests have indicated that values of 4 to 6 microfarads for C1 with rectifiers of the 1/12H type are satisfactory for hand morse signalling; but no disadvantage in operation is noticeable with higher values, and the correction period is increased. The period for which the spacing condition persists after the opening of the circuit is reduced, as the change in line current is reduced due to the smaller difference in potential across C1 and R1 under the spacing condition.

The adjustment of the values of C2 and R2, although not critical, is important in the successful operation of the repeater. If incorrect values are used for these components, C1 becomes charged to a value in excess of that across R1 when signals are passed through the unit to line and the difference in these potentials is developed across RX, causing the grid to take up a negative potential with respect to the cathode. This results in the working point of the tube being altered and also may result in the signals being passed to line being repeated back into the carrier send leg. It is essential to counteract this effect to ensure that the receiving unit remains operative during signalling out so that the distant station may break the sender. The correctness of the values for this network is readily checked by sending a series of signals through the unit. If the values are incorrect the anode current will be less than normal when marking is applied at the end of the signal train. An increase in the value of C2 or R2 removes this effect. In general, the value of R2 should not be too high, as it also serves to limit the value of current to C1 via the forward resistance of RX. This is particularly applicable when high values for the condenser C1 are used.

During the earlier trial the Siemens high-speed relay type 73G proved suitable for the anode circuit relay, using an anode current of 20mA and the relay adjusted to release at 10mA. Later tests indicated that the Creed relay No. 2 coil or the PR.10 No. 2 coil polarised relays gave satisfactory results, but with slightly reduced overall sensitivity. Although no contact trouble was evident with the single current relay, the advantages of the polarised relay in cases where double current signals are transmitted are appreciated, and it is expected that the polarised relay will prove more satisfactory from a maintenance viewpoint.

Adjustments and Operation: Compared with other types of repeater, the operating adjustments are simple. The anode circuit polarised relay is adjusted to the neutral condition and the anode current set at 20mA by adjustment of the screen potentiometer. The point at which the biassing current takes control is readily checked by reducing the anode current by operation of the potentiometer and noting the point at which the relay moves to spacing. For the Creed and PR.10 relays this value should be 10mA. When the 73G type of relay is used the retractile effort is adjusted so that the relay moves to spacing at the same value, i.e., 10mA. In making these adjustments it will be noted that there is a difference in value between the release and operate points of the relay. With the Creed No. 2 coil and the PR.10 No. 2 coil relays this value is 4 to 5mA, and with the 73G relay the value is 1.5mA. This difference in value is indicative of the sensitivity of the relay. Once these adjustments are made no further adjustment other than that necessary to compensate for tube ageing should be necessary. The value of anode current of 20mA, i.e., 10mA in excess of the release point of the anode circuit relay, is desirable to provide a margin of operation to allow for heater, anode and screen potential variations, and also to allow a margin for anode current variations caused by line crossfire or inductive disturbance. The

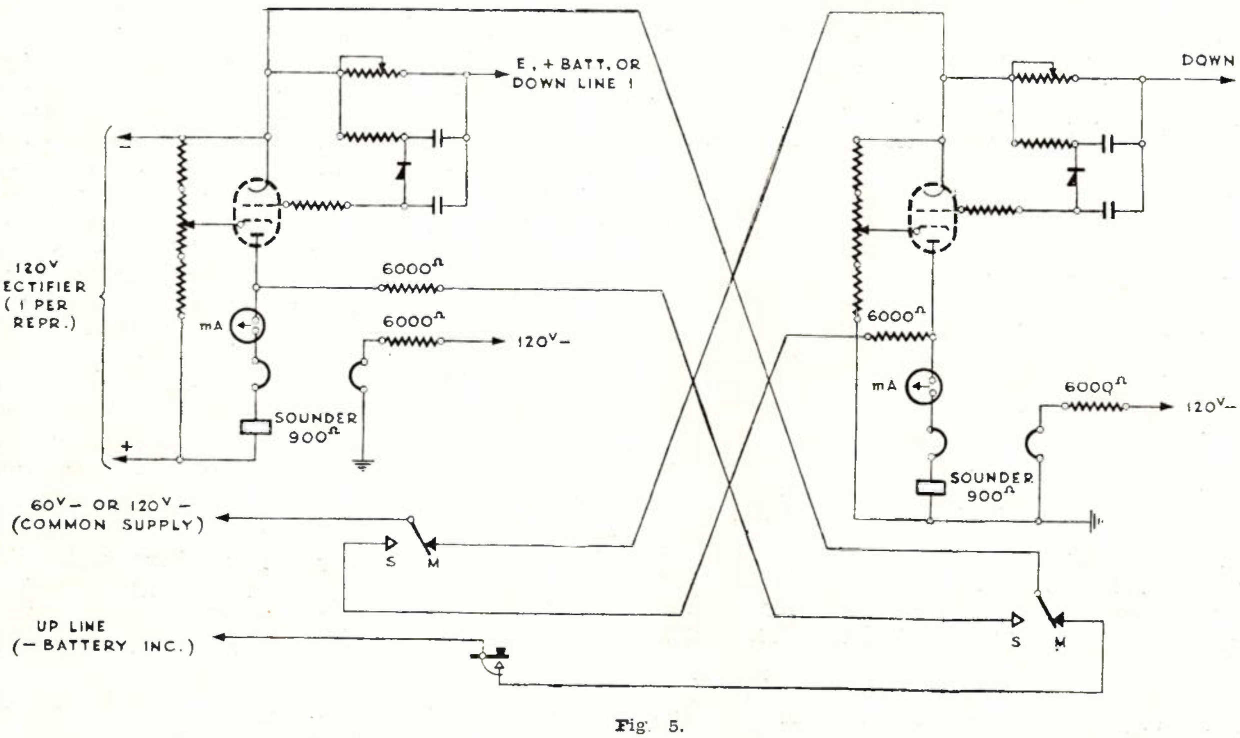

Fig. 5.

effects of crossfire and inductive disturbance can be reduced by the insertion of a filter between R1 and the line.

The receiving unit being of the type which adjusts its operating point to the line current value, the closed circuit principle of operation

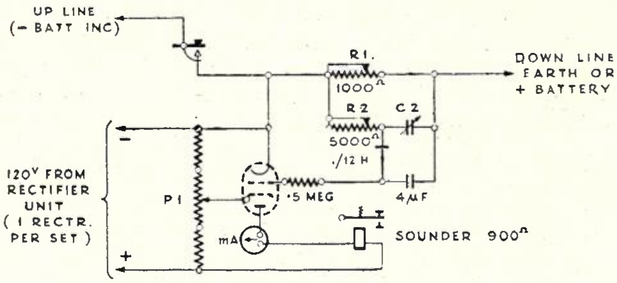

Fig. 6.

should be strictly observed. Stations on the simplex omnibus line should write against the sender to "break," and give "sec." and close the key rather than open the line when breaks are necessary. Either opening the key or writing against the sender results in the sender receiving his own signals mutilated in his receiving sounder. When leakage conditions approach the fail point of the line the period for which the reversed signals are received when the distant key is opened is comparatively short; but writing against the sender rather than opening the key gives very satisfactory break signals.

Extended trials on a working circuit indicated that when a morse station on the simplex line paused in sending and left the key open for 5 to 10 seconds, the first element of the following letter was clipped or lost at times when leakage was heavy. The effect was readily overcome by sending the usual AR or RR before proceeding after the interruption or by strictly observing the closed circuit system. Any time lost due to the clipping of the signal after an interruption was very small compared with the time which would be lost in calling in repeater stations for adjustments.

Sensitivity: The sensitivity obtainable with a single 25L6 tube is satisfactory for operation with approximately 4 to 5mA change in line current. This change in value is usually obtainable on circuits which previously extended to the Chief Telegraph Office over physical circuits, but have, by the installation of the V.F. channels, been reduced in length. Any degree of sensitivity can be obtained by adding successive stages of direct current amplification or by controlling a V.F. input and amplifying in the normal manner. The limit is, of course, the signal to noise ratio, and tests on average lines indicate that little is gained by increasing the sensitivity beyond that stated. In practice, it would be preferable to accept a value of 5mA or even 10mA as the fail point and to provide morse repeaters incorporating this receiving unit when the lower limit of change cannot be attained. A repeater of the simplex-simplex type is shown in Fig. 5. An extension of the same circuit can be made to provide for a side line repeater which may have application in some cases. The sounders in series in the anode circuits ensure that the repeater station is in constant adjustment with the terminals and the key in series with the up line permits the repeater station to be a working party on the circuit. The arrangement is suitable for complete A.C. operation, and could be arranged to be inserted in a

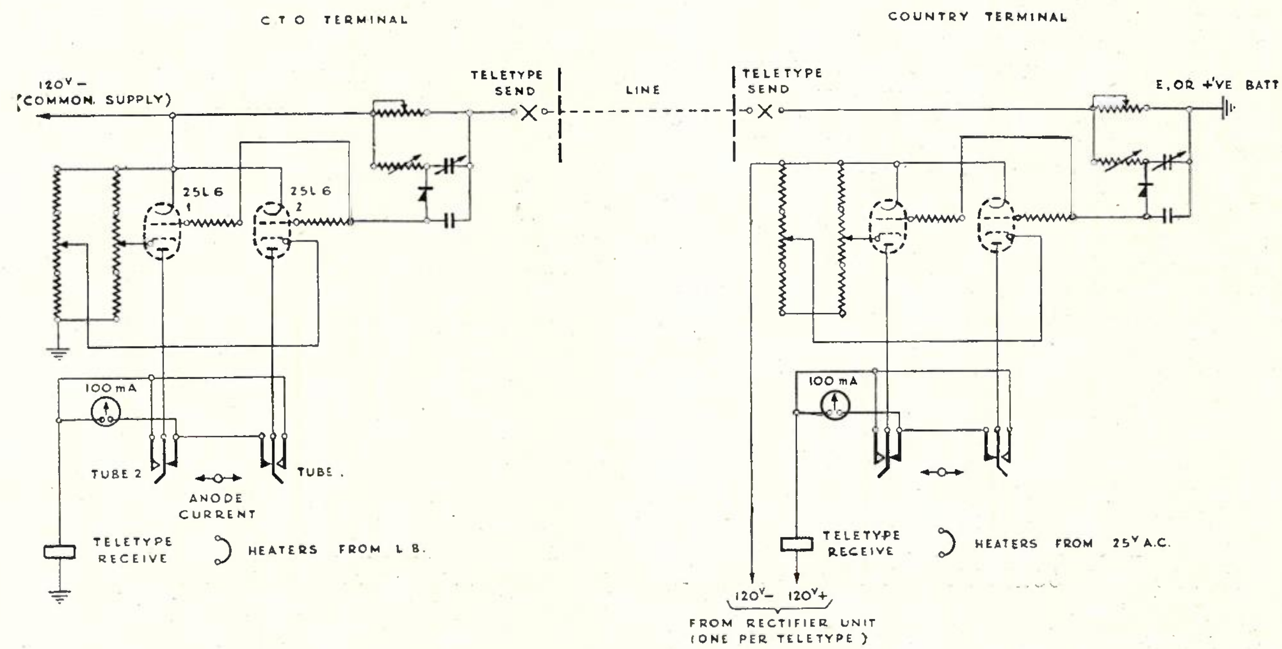

Fig 7.

circuit when the leakage warranted its inclusion. Fig. 6 shows an arrangement suitable for use as an intermediate or terminal morse set. Although the normal morse equipment is suitable for use on lines feeding into repeaters, there may be advantage in certain cases of providing this equipment to ensure that the station is in constant adjustment.

Other Uses: A further interesting use for the unit is in providing point-to-point teletype services over single conductors subject to leakage. The usual arrangement consists of local panels and a duplex balance equipment at either end. Fig. 7 shows the details of a trial arrangement used between the C.T.O., Melbourne, and a country centre. The circuit is generally similar to that used for the repeater, but the use of two tubes in parallel allows the teletype receiving magnet to be connected directly in the anode circuit and the receiving relay to be omitted. The margins of operation are at least equal to those previously obtained with the duplexed circuit, and tests have shown that the circuit functions satisfactorily without attention when the leakage on the line is such that the change in current is 8mA. This value is approximately equal to that for the standard duplexed circuit. A similar arrangement has been tested for teleprinter circuits of the same type, the modification being the provision of one tube with a receiving relay to provide the double current signals for the teleprinter receiving magnet. Double current transmission or battery and earth transmission can be arranged by using the teleprinter send contacts; but with teletype it is necessary to use a sending relay to make use of the additional polarity.

Tests have also been made in providing branching rather than series connection of teletypes working on long underground cable circuits, and the results indicate that considerably increased margins of the operation can be obtained by this means.

EXCHANGE SERVICE TONES—CHARACTERISTICS AND TRANSMISSION CIRCUITS

P. J. Killey

The importance of transmitting satisfactory service tones in a telephone network has increased in recent years as direct dialling facilities have been extended. Originally, the tones were provided as a means of conveying information to subscribers and operators within a local network; but their use has since been extended to guide the progress of calls from distant operators in the country and other States. The tones must be suitable for satisfactory reception over the maximum or minimum attenuation likely to be encountered; and, whilst it is necessary that the frequencies employed shall be suitable for transmission over V.F. channels, they must not be of a character which will cause false operation of V.F. signalling equipment.

The standard tones are those generated by the inductor tone generator described in an earlier issue of this Journal (Vol. 3, No. 1). They are usually referred to by their fundamental frequencies and sequence of interruptions, which are as follow:—

- Dialling: $33^1/_3$ C/s continuous.
- Ringing: $133^1/_3$ C/s modulated by $16^2/_3$ C/s and interrupted to give 0.4 second tone, 0.2 second silence, 0.4 second tone, 2.0 seconds' silence.
- Busy: 400 C/s interrupted to give 0.75 second tone, 0.75 second silence.
- Number Unobtainable (N.U.): 400 C/s continuous.

Since some of these fundamental frequencies are too low for transmission over many V.F. channels, or for efficient reproduction in telephone instruments, it is apparent that their harmonics must be of more importance.

Characteristics

Busy and N.U. tones: The busy and N.U. tones have a fundamental frequency of 400 C/s, which is situated on a favourable part of the telephone transmission band, and the machine is designed accordingly to produce approximately sinusoidal wave form for these tones. The total harmonic content (consisting mainly of the 2nd and 3rd) is usually approximately 5% of the fundamental. Owing to greater sensitivity of telephone receivers and the human ear at the frequencies of 800 and 1200 C/s, compared with 400 C/s, the harmonics are audibly present in the tone as heard in a telephone, although they are not essential to satisfactory tone reception.

Dialling tone: This tone has a fundamental frequency of $33^1/_3$ C/s, but the voltage wave shape is essentially a sinusoidal impulse of 6 or 7 milliseconds' duration, occurring once during every period of 30 mS, as shown in Fig. 1A. Analysis of this wave form shows that the predominant frequency is approximately 160 C/s (corresponding with the wave duration of 6-7 mS), and all harmonics up to approximately 1300 C/s have appreciable values. A line spectrum of the components as delivered direct from the tone generator on open circuit is shown in Fig. 2. A better appreciation of the relative levels of these frequencies is obtained from Fig.

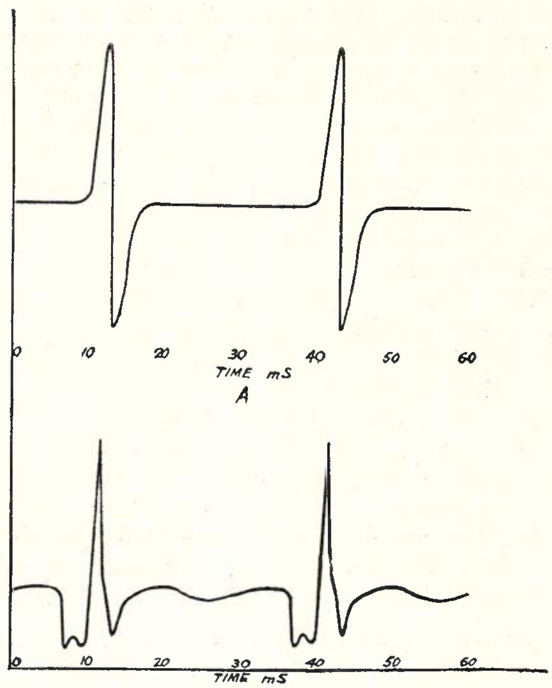

Fig. 1.—Dial tone wave form.
A. Dial tone voltage on open circuit.
B. Dial tone voltage across telephone in typical connection.

3, where the same frequency spectrum is shown on a db scale instead of a linear voltage scale.

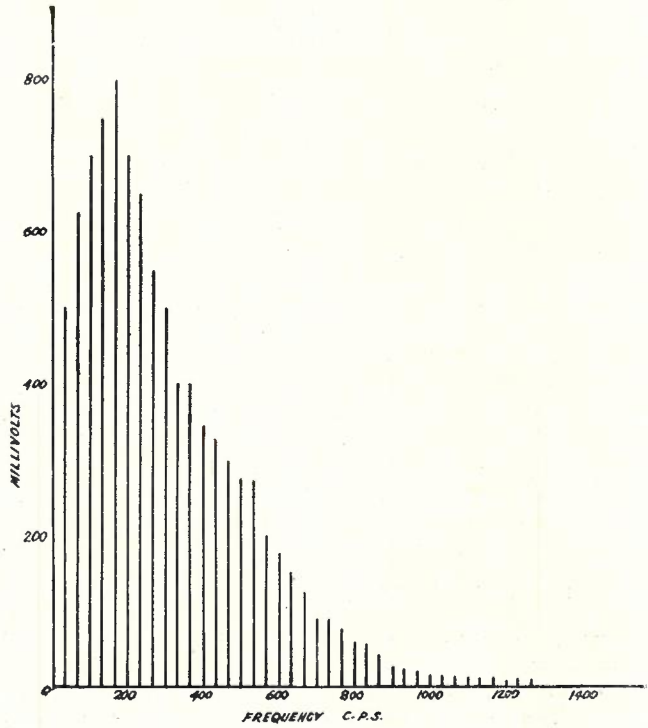

Fig. 2.—Dial tone—frequency components.

In practice, the relative volume of the higher frequencies is much greater than that shown in Fig. 3, owing to the greater sensitivity of telephone receivers and the human ear to frequencies in this range. Fig. 4 shows the spectrum of Fig. 3 weighted in accordance with the receiving electro-acoustic efficiency of a telephone 300 C.B. It will be seen that all frequencies between 200 and 800 C/s are within the limits of a 12 db range, and the fundamental frequency of $33^1/_3$ C/s is the lowest of

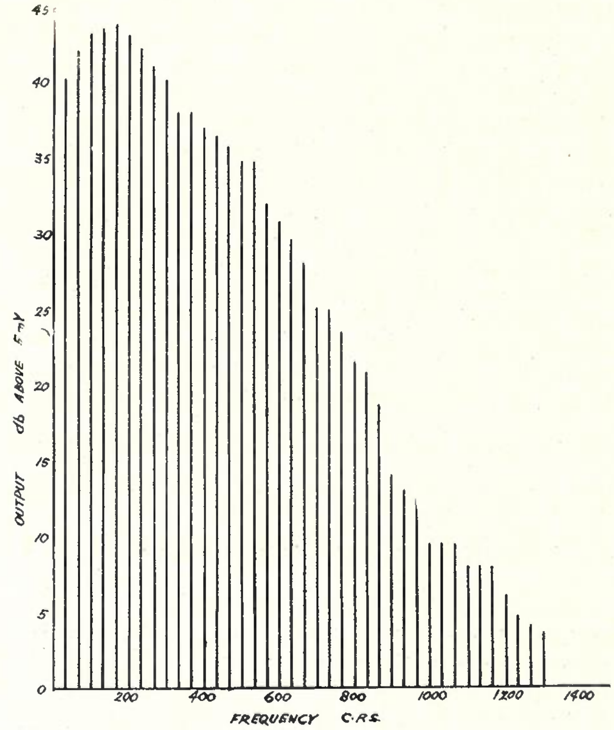

Fig. 3.—Dial tone—frequency components.

all under 1200 cycles. Fig. 4 assumes the use of a conventional receiver (Type 1L) in the telephone. This receiver has a main diaphragm resonance at approximately 1100 C/s, and accordingly raises the level considerably at the higher end of the spectrum. This effect would be less with an equalized receiver such as the type 2P.

Fig. 1B shows the wave shape of voltage measured across the telephone terminals in a typical dial tone circuit. The difference from Fig. 1A, caused by frequency and phase distortion, is considerable, owing to the large frequency range (several octaves) of the complex wave.

The wave shape of dial tone results from the configuration of the rotor of the inductor tone generator, and its richness in harmonics is an essential requirement for a tone of $33^1/_3$ C/s fundamental frequency, since a sinusoidal current of this frequency would be of little value for telephone transmission and reproduction.

Ringing tone: The ringing tone is generated by a $133^1/_3$ cycle generator of similar construction to the dial tone generator, but the field is excited by the $16^2/_3$ C/s ringing current instead of D.C. The resultant output consists of a $133^1/_3$ cycle current, amplitude modulated by the

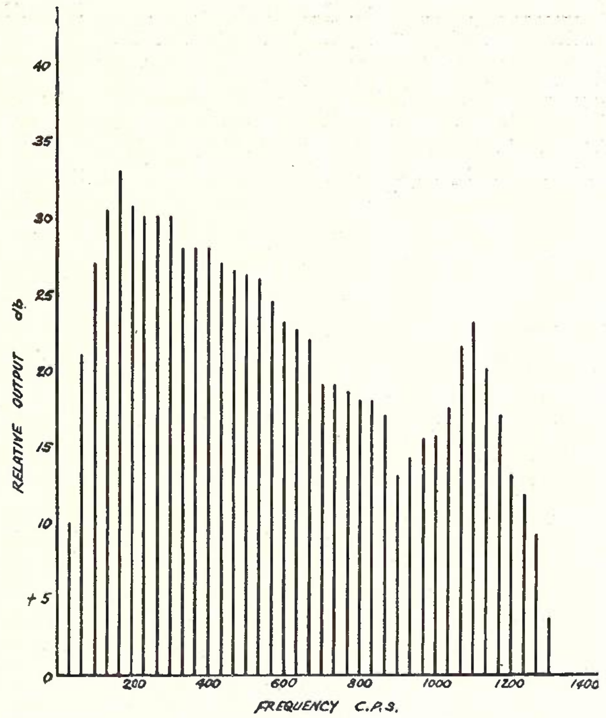

Fig. 4.—Dial Tone—weighted in accordance with receiving electro-acoustic efficiency of telephone 300 C.B.

$16^2/_3$ cycles as shown in Fig. 5C. The voltage wave form of the $133^1/_3$ cycle component, unmodulated, is shown in Fig. 5B, and an analysis of its harmonic content in Fig. 6. This wave form is obtained if the field is excited with D.C. instead of A.C.

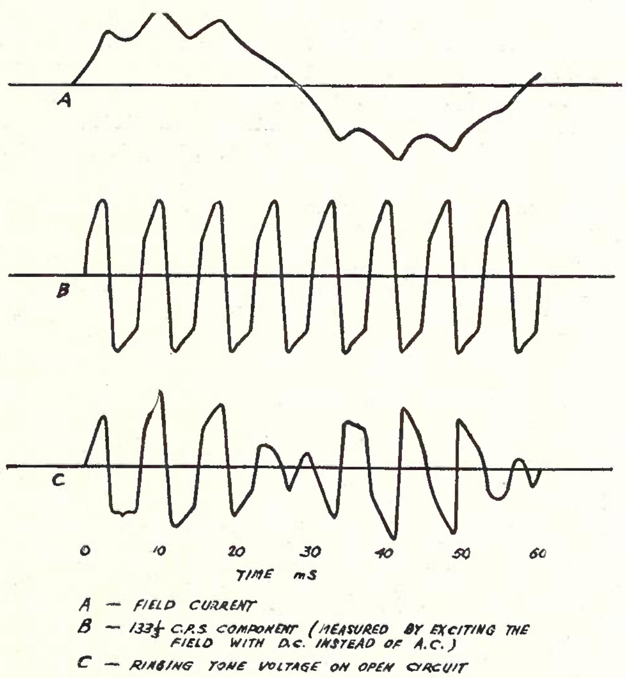

Fig. 5.—Ringing tone. Wave form.

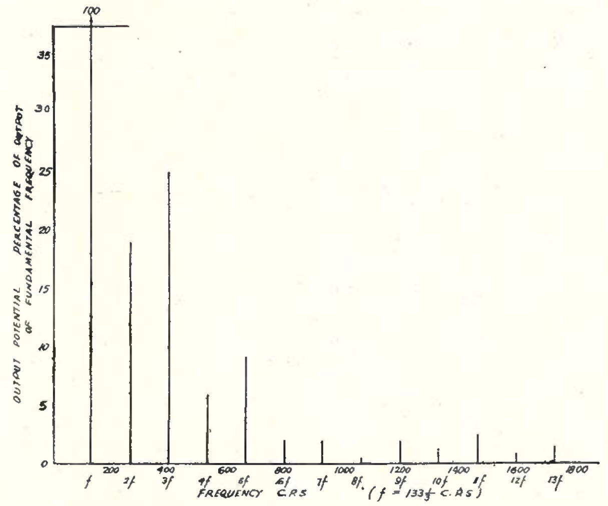

Fig. 6.—Ringing tone. Harmonics of 133 C/s component.

Fig. 7 shows the frequency components of ringing tone, which consist principally of the frequencies nf $\pm$ r, where f $= 133^1/_3$ C/s, r $= 16^2/_3$ C/s and n is integral. The frequencies f, 2f, 3f, etc. (shown in Fig. 6), which may be regarded as carrier frequencies, are not present when the field is excited with A.C. in the normal way (see Fig. 7). Absence of these frequencies is to be expected, since the machine behaves as a suppressed carrier amplitude modulator, i.e., full modulation irrespective of the magnitude of the modulating voltage.

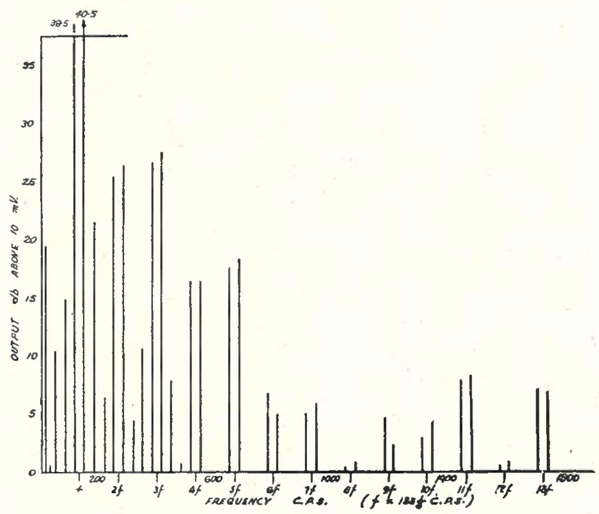

Fig. 7.—Ringing tone. Frequency components.

Other points of interest in Figs. 5, 6 and 7 are as follow:—

(a) The amplitude of each pair of modulation products in Fig. 7 is proportional to the amplitude of the corresponding carrier frequency in Fig. 6.

(b) Fig. 5A shows that the field current of $16^2/_3$ C/s has variations corresponding with the fundamental frequency of $133^1/_3$ C/s. This wave shape is due to changes of inductance and losses in accordance with the position of the rotor, and differs little with change of load.

(c) Fig. 5C shows a phase change of 180° every half-cycle of the field current at points x and y. This occurs owing to the reversal of flux in the field.

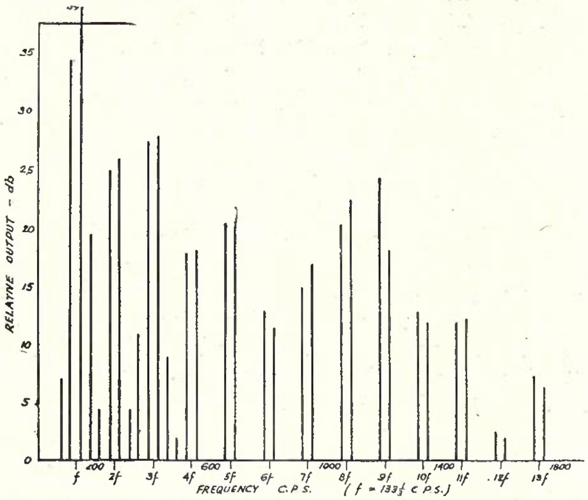

Fig. 8.—Ringing tone. Weighted in accordance with receiving electro-acoustic efficiency of telephone 300 C.B.

Fig. 8 shows the ringing tone output weighted in accordance with the electro-acoustic receiving efficiency of a telephone, which gives considerable emphasis to the higher frequencies and makes practically all of the spectrum of sufficient volume to contribute to the tone.

Transmission Circuits

2000 type circuits: Pre-2000 type automatic equipment, which is discussed in more detail in later paragraphs, contains several types of tone transmission circuit. In the design of the 2000 type equipment special consideration was given to improvement of tone transmission, and the circuit used in most cases is that shown in Fig. 9. A special tone winding (570 ohms and 1700

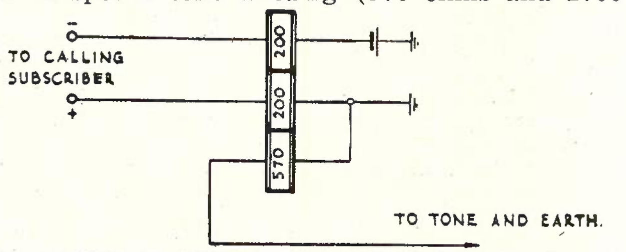

Fig. 9.—Tone transmission circuit of 2000 type equipment.

turns) is provided on the A relay of the switches, and it serves as the primary winding of a transformer in which the 200 ohms windings (each 4000 turns) connected in series are the secondary, the centre point being earthed. Advantages of this circuit compared with pre-2000 type circuits are as follow:—

(a) The circuit is balanced with respect to earth potential. This avoids excessive cross-talk interference and high loss in relay set repeaters, as described later.

(b) Use of the same circuit for all tones permits transmission of a uniform level direct from the machine without the need for transformers to adjust the level.

(c) D.C. current does not flow through the tone supply or tone distribution circuits.

The transmission efficiency of the circuit of Fig. 9 is shown in Fig. 10. The efficiency of the relay as a transformer is rather low, although this is not of great consequence, as the power required from tone generators is not high. In fact, this low efficiency has an advantage, since it permits the 570 ohms winding to be open or shorted without substantial alteration to the impedance of the other windings. During the first train of dial impulses the tone winding of the A relay in the first group selector is closed by the dial tone generator, which has an impedance of only 10 ohms or less, depending on the size of the machine; whereas, for other switches receiving subsequent trains of impulses this winding is open. Any substantial alteration in the impedance of the 200 ohms windings would cause a change in the impulsing characteristics of the relay. Although the efficiency of the relay is low, its response versus frequency is flat over the significant frequency

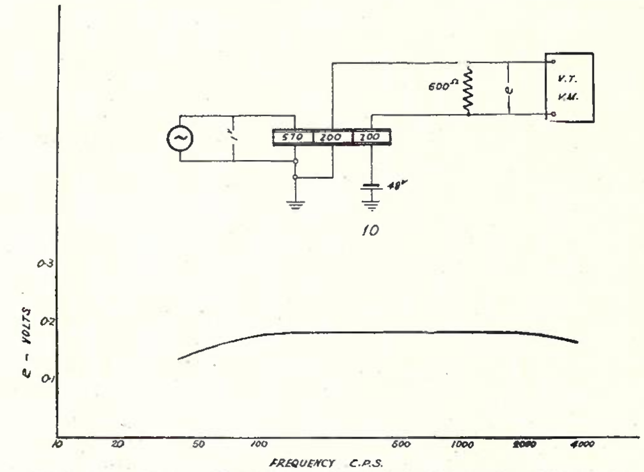

Fig. 10.—Tone relay 3000 type transmission efficiency.

range, provided the input voltage is constant, which condition applies in practice owing to the low impedance of the tone generator compared with that of the 570 ohms winding.

No great latitude is permissible in the voltage which must be applied to the circuit of Fig. 9 to ensure reception of a satisfactory tone volume under all conditions, since the line attenuation between the transmission circuit and the receiving telephone may have any value between zero and approximately 25 db in the cases of busy, ringing or N.U. tones. Dial tone is subject to less attenuation, since it is always received from a subscriber's own exchange or the parent exchange. A tone volume which is not excessively loud on local calls, but has sufficient volume on the longer connections, is obtained when 1.5-2.0 volts is applied to the 570 ohms winding. Under these conditions, the power transmitted to a 600 ohm line would be approximately 7 db below 1 mW. Inductor tone generators are designed to deliver an output voltage of this order, with means of adjusting for higher or lower values by variation of the field current.

Pre-2000 type circuits: Some of the more commonly used tone transmission circuits of pre-2000 type equipment are shown in Fig. 11.

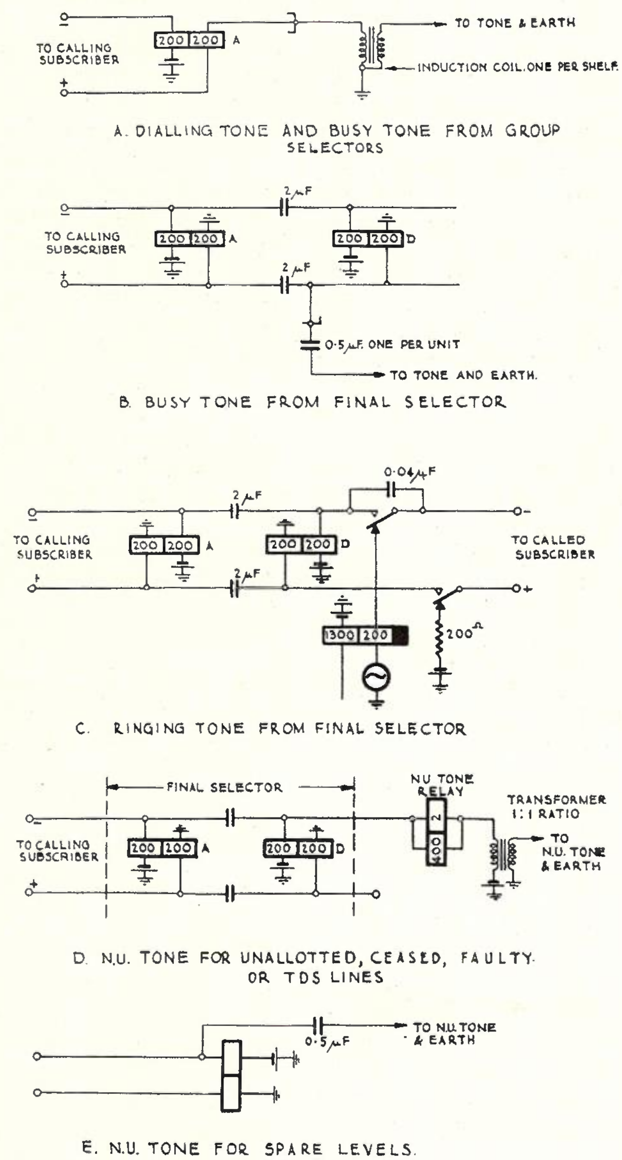

Fig. 11.—Tone transmission circuits of pre-2000 type equipment.

The main disadvantages of these earlier circuits are listed below. Several of these arose from the need to transmit tones such as dial and overflow busy from switches not originally designed for tone transmission:—

(a) They are all unbalanced with respect to earth potential.

(b) The tone level transmitted to line for a given tone voltage fed to the switch varies considerably between the different circuits.

(c) Common components such as condensers and shelf transformers, connected in the distribution circuits to provide for D.C. return or level adjustment, cause variation of the tone voltage at the switches as the load varies.

(d) It is not practicable to use the standard ringing tone with Fig. 11C, in which case it has become usual practice to utilize the harmonics of the ringing current when a standard inductor tone generator is in use.

The disadvantage of unbalanced transmission circuits is greatest when transmission is over a junction line with a relay set repeater in circuit. A typical condition is shown in Fig. 12. One

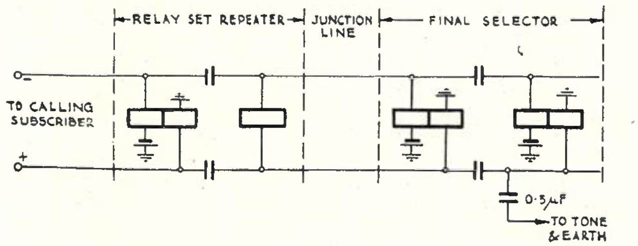

Fig. 12.—Tone transmission from pre-2000 final selector via junction line and repeater.

side of the tone circuit is connected to the + line at the final selector via a negative reactance. The other side (earth) is connected to both lines from the centre point of the relays which have positive reactance. The relay set repeater is a balanced network, in which the centre point of the A relay is earthed. It is apparent that tone current will flow to earth at the repeater and the currents in the two wires of the junction line will be unbalanced. In addition to crosstalk interference which can result from this condition the insertion loss of the repeater can be much greater than its normal value of approximately 1 db, which assumes balanced conditions.

Transformers and condensers in the tone distribution circuits to pre-2000 type switches were originally designed to suit the level provided by interrupter type tone generators. The inductor type generator is designed to deliver a suitable voltage direct to 2000 type switches, and the maximum output of the machine is insufficient for some of the pre-2000 type circuits unless replacement transformers are provided. The output of some of these circuits relative to the output of the 2000 type circuit for the same tone voltage supplied to all is as follows. Owing to their different impedances as viewed from the line, the relative efficiencies are not fixed, but vary with line impedance variations; also, the type of relays (Strowger or 3000 type) affects the efficiency:—

Fig. 11A	—23 to —32 db*
Fig. 11B	+ 4 to + 5 db
Fig. 11D	+ 9 to +14 db
Fig. 11E	+ 5 to +10 db

* 20 db of this loss occurs in the induction coil.

Tone transmission over carrier circuits: Frequencies below approximately 200 C/s are not transmitted over carrier circuits, and it is of interest to consider the effect of this frequency limitation on the transmission of dial and ringing tones, which have fundamental frequencies below this value. Figs. 4 and 8 show that the amount of the effective spectrum which is eliminated is not large, and indicate that the effect should not be great. The loss of volume as heard in a telephone is 2-3 db, and the difference in tone is detectable, although not appreciable.

Disadvantage of continuous tones: Continuous tones such as dial and busy can cause difficulty in operating some equipment, such as voice frequency signalling apparatus. The voice immunity arrangements of the 2 V.F. signalling receiver include a broadly tuned guard circuit passing a band centred on 340 C/s. The rectified potential obtained from this guard circuit opposes any potential which may be received in the circuits which are tuned to receive the signalling frequencies of 600 and 750 C/s. False operation of the receiver by the harmonics of the service tones is prevented in this way, but a tone of suitable frequency, such as N.U. tone, which is continuous, can prevent any further response to the normal V.F. signals, and so hold the receiver in a "locked-out" condition. Steps taken to overcome this difficulty have been to interrupt the N.U. tone for a half-second in every six seconds, or carefully adjust the N.U. tone levels from all exchanges so that they are insufficient to override the V.F. signals.

Possible changes in standard tones: Some features of the standard tones used at present are such that it may be desirable to effect some changes in the future. "Overflow" busy appears to confuse some subscribers, who, upon receipt of the tone, assume that the number is busy, only to find later that the called party was not engaged at the time of calling. This, of course, is avoided if the caller takes care to listen between each train of impulses. Possibly the ringing tone would be completely free from confusion with other tones and would give more confidence to the caller if it was a reproduction of the tone of a bell.

The use of recorded voice, particularly for "Number Unobtainable" and "Number Engaged," has been considered often, and trials have been conducted. Although it gives definite information, it has disadvantages. At first, subscribers answer it, and even after becoming accustomed they will listen longer than to a tone, which conveys its intelligence to operators and experienced subscribers in a fraction of a second. Also, many of the older tone transmission circuits may require extensive alteration before being suitable for recorded voice transmission.

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TELECOMMUNICATIONS IN JAPAN*

R. W. Boswell, M.Sc.

1. Japanese Board of Communications

Introduction: As in most British countries, the Japanese telephone and telegraph services are a government monopoly, controlled by a Board of Communications. The only exceptions are two trunk cables owned and operated by the International Telecommunication Company. This Company, which handles overseas communications, is ostensibly a privately-owned Corporation; but the Government, through the Board of Communications, owns half the stock and controls the management.

The President of the Board is a Minister in the Cabinet appointed by the Emperor, but is not necessarily a politician. The rest of the Board consists of a Vice-President and eleven Bureaux directors, all of whom are appointed by the Emperor on the nomination of the President. Japan is divided into ten operating districts, and the senior personnel on the district staffs are selected by the Bureaux heads after approxal by the Secretariat—the bureau of the Board controlling personnel.

It is most probable that originally the Board was organized with the British Post Office as a pattern; but in recent years it has increased its functions along similar lines to the Australian P.M.G.'s Department, in that it controls, in addition to the normal postal and telephone services, the technical side of radio broadcasting, and has a controlling interest in the private company responsible for international communications. The Board has associated with it a Secretariat, six Bureaux controlling Staff, Telecommunication, Electrical Engineering, Postal services, Radio communication and Postal Savings Bank and Insurance, as well as the Electrotechnical Laboratory and two training schools.

The major weakness in the organization is apparent from a study of the numbers of employees in each class. The first three contain a total of 490, while the fourth and fifth have 117,358. This grouping of responsibility naturally imposes a tremendous load on the higher officials and is reflected in the very low efficiency of the fourth and fifth class employees, due to lack of adequate supervision and planning. In the succeeding paragraphs the functions of the more important bureaux will be discussed in greater detail.

2. Bureau of Telecommunications

This branch is responsible for the traffic and rates aspect of the telephone and telegraph services. In 1940 there were about one million exchange lines and half a million P.B.X. extensions connected to 103 automatic exchanges, 86 common battery and about 6000 small magneto exchanges. The total annual local calls were approximately 6000 million, and the trunk calls 450 million. The high calling rate and the large percentage of P.B.X. connections is due to the fact that the majority of telephones are fitted in business premises. Even those in private homes carry a heavy load, as a telephone, like many other conveniences in Japan, is regarded as being for community rather than for private use.

The system of telephone charges is most complex, the installation fee, annual charge and call fee depending on the size of the local network to which the subscriber is connected. These networks are grouped into twelve classes, with a corresponding set of twelve tariffs. Trunk calls are charged on circuit distance rather than air line, and special priority is given on the payment of double or treble fee. No reduced night tariffs are given. The P.B.X. services are subscriber-owned or hired from an independent company—Nippon Telephone Equipment Company—and each trunk between the Central Office and the switchboard is considered as a private line service. Judging by the large number of P.B.X. phones installed—half a million—this policy must be very successful. While the rental charges and unit fees are reasonable, i.e., £6 and twopence respectively, the installation charge is almost prohibitive to the ordinary citizen. This charge varies from £24 to £90 according to the size of the exchange area, but the telephone thereon becomes the property of the subscriber. Trunk call charges are comparable with Australian rates—a 700-mile conversation costing about six shillings. A normal inland telegram in Japanese characters may be sent for about two shillings, but a fifteen-word English message would cost four shillings.

Personnel: The personnel is divided into classes which correspond almost exactly with the Australian Public Service divisions, except that office workers are grouped with technicians in the fourth class. A very rigid distinction is made between classes one, two and three, which contain university trained engineers and administrators; class four, in which are found the technicians and clerks of high school standard, and class five, who are manual workers recruited from primary schools. The training is organized to produce an efficient employee within a class, but not to provide an entree from one class to another. The official classification is given below:—

*This article relates the experiences of the author while a member of the Australian Scientific Mission in Japan which was sponsored by the Secondary Industries Division of the Ministry of Post-War Reconstruction.

Class 1—Persons who deal directly with the Emperor or Prime Minister, i.e., President.
Class 2—Vice-President and heads of Bureaux.
Class 3—Section heads, administrators, engineers.
Class 4—Office personnel and technicians.
Class 5—Manual workers, operators, linesmen.

In classes two and three there are a total of 490 males, of which 380 are engineers; while in classes four and five, of a total of 49,000 males and 68,000 females, 20,000 males and 4500 females are in the engineering branch. At the moment, it is impossible to give definite figures on wages, as these are continually rising and being supplemented by various bonuses in an attempt to overtake the rising cost of living.

The trunk operating procedure used is very inefficient. The desired information is obtained from the calling subscriber, who then hangs up. The docket is placed by the central distributing desk in the circuit group box, from where it is carried manually to the correct operating position. The operator sets up the connection and calls back the originating party. No automatic trunk exchanges have been installed, and no "on demand" services are operating. Figures were not available on the details of pre-war traffic; but in the central trunk exchange at Nagoya, 128 positions with 388 operators handled approximately 10,000 calls on a total of 415 lines each day.

This branch suffers greatly from the Japanese superstition regarding numbers. Any increasing number—1237, for instance—is lucky, since it betokens prosperity, while a decreasing number is, of course, unlucky, and unwanted. Further, the Japanese for four, "shi," also means death, and so is avoided by all. The actual disposal of these unlucky numbers was not discovered.

3. Bureau of Electrical Engineering

General: This bureau is responsible for providing all engineering facilities necessary for the maintenance and extension of the normal telephone and telegraph services. The two main sections—city and country telephones—are individually responsible for installing and maintaining all equipment and line plant within their separate areas. This division of responsibility for line plant is most noticeable—the city construction being markedly inferior to the country work. It may also explain the fact that trunk repeater stations are invariably located on the outskirts of the city. This practice may be economical and desirable at large terminals, but it is persisted with even in small towns, where some concentration of telephone plant would seem logical. One of the few places in which the repeater station was in the city was at Hiroshima. Through this station passed about 90% of the telephone and telegraph circuits to Kyushu, Korea, Manchuria and China, so the effect of the atomic bomb on Japanese overseas and inter-island communications may be imagined.

As most of the destruction in Japan was caused by incendiary bombs, the losses of subscribers' instruments were very heavy; but the exchanges, which were normally housed in concrete buildings, escaped damage in many instances. The maintenance on the remaining plant is, however, quite inadequate. For instance, the percentage of lost calls in a bombed city such as Tokio is about 35 per cent.; and even in towns such as Nara, which was completely untouched, the rate varies from 7-10 per cent. Nevertheless, Japanese engineers claim that, before the war, their automatic equipment was up to Western standards. The provision of trunk lines has been most generous, but this is offset by inefficient operating and switching procedure. As no four-wire switching is used, through circuits are provided between all major cities. These cities are located about 100 miles apart on the main route extending through the main island, Honshu, so a very uneconomical use of line plant results.

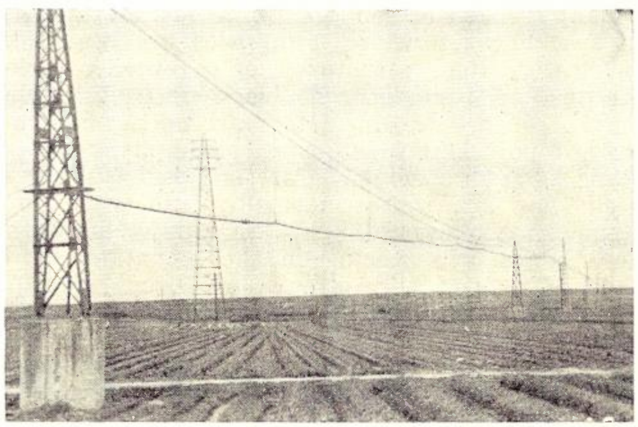


Fig. 1.—Aerial cable line through paddy fields near Nara.

Outside Plant: The main factors conditioning the design of outside plant are the topography of a country, the climate, the distances and number of circuits involved. In the case of Japan, the island of Honshu consists of a very mountainous backbone, with a narrow, flat coastal strip and a series of valleys penetrating the mountains. The arable ground is all irrigated, either by canals or ditches on the coastal strip and the beds of the valleys, or by a series of walled terraces on the mountain sides. The climate varies from semi-tropical conditions during the summer to heavy snow in the winter, with the additional natural hazard of earthquakes. So far as distances are concerned, Japan approximates closely to England. The general pattern of development adopted was a duplicated cable route traversing the length of the island, underground in the city, but often run aerially through farming areas, and fed with lateral open wire routes running through the mountains. The tendency now is to underground all trunk cables, using gas pressure as additional protection in the sections through the paddy fields. The open wire construction is, in general, very solid—in some cases all poles have transverse stays, with every eighth fitted also with longitudinal stays. The poles are

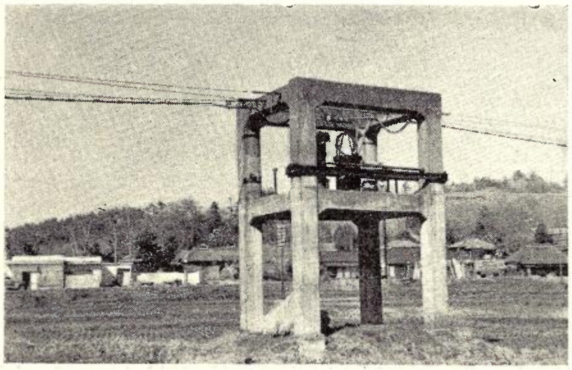


Fig. 2.—Aerial cable loading point.

usually wooden or solid reinforced concrete; but, in special cases where high poles are required, fabricated steel structures or a wooden pole strapped to a single or double wooden stub pole may be used. The insulators are of the double-skirted porcelain type, using steel pins with a standard 12" spacing. Carrier spacing is not used, nor are routes normally transposed for frequencies above 30 kC/s—the major problem here being pole spacing in the mountains. In the cities, open wire circuits are used for outlying subscribers, but the standard of construction is much lower than in the case of the trunk lines. In particular, the safety standard relating to telephone and power lines appeared to be very lax.

The trunk cable development followed conventional lines, the original loaded cable circuits now being replaced by unloaded cable carrier circuits. The carrier cables are, in general, of a composite type—a central core of carrier quads being surrounded by smaller diameter loaded quads. These latter are used 2- or 4-wire on short haul trunks up to about 100 miles, and the carrier circuits for longer distances. The go and return circuits were originally contained under the one sheath, but later construction employs the conventional two cables. In the earlier cables, the go and return pairs were separated into two cables at points of high level difference, i.e., for about 5 km on either side of a repeater station. Modern Japanese carrier cables are of a very loose construction—the mutual capacity being 0.050 μF/mile, compared with the British standard of 0.057 μF/mile—otherwise their specifications are very similar to our own.

One coaxial cable, which also contains unloaded quads, has been laid between Tokio and Ashioka—about 80 miles. The terminal equipment has not been installed, but is designed to provide 216 circuits using the 0-1.0 Mc/s band, with a television circuit in the 1.0 to 4.0 Mc/s band. Originally, trial repeater lengths of three types of coaxial cable were to be installed—the first using disc insulators and fabricated by a continuous method by the Furakawa Company, the second using a silk thread supported centre conductor made by the Fujikura Company, and the third, in which the centre conductor was supported by a series of split ceramic cylinders, constructed by the Sumitomo Works. Unfortunately, the disc cable proved difficult to manufacture, the Fujikura Works were bombed out, so that any future production will probably be by the Sumitomo Company.

During the war, material shortages produced a series of unusual types of cable. Tin and aluminium were substituted for lead in cable sheaths, and aluminium for copper in the conductors. At present, tin is sometimes used as a substitute for antimony in the lead sheaths—Japan following the American practice of always using antimony-lead sheaths. An attempt was even made to use aluminium conductors in carrier cables. Although the D.C. resistance was 67 per cent. greater, the A.C. resistance at 50 kC/s was only increased by 32 per cent. Joining the conductors proved the major practical difficulty, and the project was dropped.

The main point of criticism of the cable plant is the multiplicity of types. Apparently little thought has been given to standardization, but it may be expected that shortcomings in the Japanese economy will cause some rationalization.

Inside Plant: After the earthquake of 1923, the telephone plant was completely re-equipped with the equipment available at that time. Since then, the plant has been extended without being further modernized. Two main types of automatic equipment are used—Strowger, and Siemens-Halske step-by-step. The original exchanges were manufactured in America, England and Germany, and installed by the Company's engineers, and therefore are exactly similar to exchange equipment elsewhere in the world. In the late twenties, Japan commenced local manufacture of automatic switches, and the necessary tools were imported from overseas. The Strowger tools were later replaced by tools of Japanese manufacture, in which all dimensions and screws had been converted to the metric system; otherwise the switches are identical with the original imported switches.

In layout, frame construction, protection, cabling and power supply, all exchanges are quite conventional.

The Board of Communications' circuit engineers have now designed a system termed Teishinko or "T" type, which they claim combines the best features of both the above systems and which they intend to introduce as the standard system throughout Japan. To date, two exchanges—one in Nara and one in Tokio—have been installed, using the "T" type circuits and S. & H. switches. The Tokio Exchange, in the Kogimachi district, was housed in the bombproof shelter shown in Fig. 3, and was designed to provide "last stand" facilities in the event of invasion.

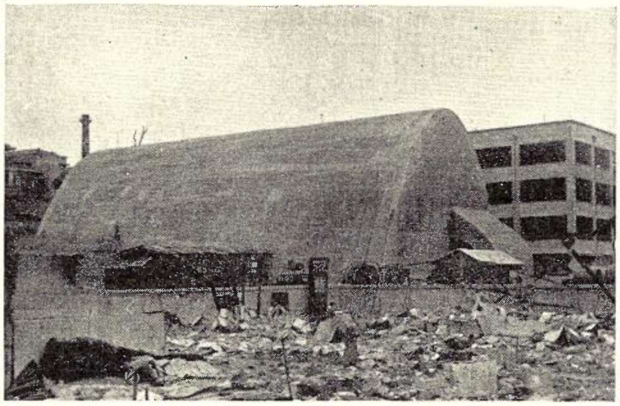


Fig. 3.—Kogimachi "last stand" exchange.

Subscribers' equipment presented no new features, but a large proportion possessed handsets—this is possibly due to the competition from the privately-owned P.B.X. units. These handsets possessed no anti-sidetone circuits.

The carrier equipment is all of Japanese design and construction, but conformed to normal Western practices in circuits and layout. The cable equipment which provides most of the long distance trunks is a 6-channel go and return system, each using the lower sidebands of 7, 11, 15, 19, 23 and 27 kC/s. The earlier models used push-pull repeaters and valve modulators, but the later equipment is fitted with feedback amplifiers and copper-oxide modulators. No voltage regulators or automatic level controls are fitted, so that their performance is rather unstable. Both 1000 cycle and 2300 cycle ringers are used. This basic six-channel group is group modulated to the bands 30-60 kC/s and 60-90 kC/s to provide a six-channel open wire carrier system for use above the Japanese equivalent of the W.E. Type "C" three-channel system. A description of this system is published in the Nippon Electrical Communication Engineering Journal of January, 1941.

Due to lack of staff and material, and bombing, the condition of the engineering plant is appalling. The only form of heating in many exchanges is provided by open wood or coke braziers, around which a major portion of the staff spend their time warming their hands, making tea or preparing food, so the condition of the switches, after several months in such an atmosphere, can be imagined. The main frames, in particular, are in a bad condition, partly due to the Japanese custom of using the horizontal tag strips as ladders (Allied circuits are always placed on the top of the frame), partly due to the practice of leaving dead jumpers in the frame, but mainly due to the fact that, owing to the shortage of solder, new connections are merely twisted joints. Most batteries have reached the end of their useful life, and the commutators on machines invariably show wear of up to $\frac{1}{4}$ inch. On the carrier side, the repeater stations, owing to their location in the country, have escaped bomb damage, and, further, the static character of

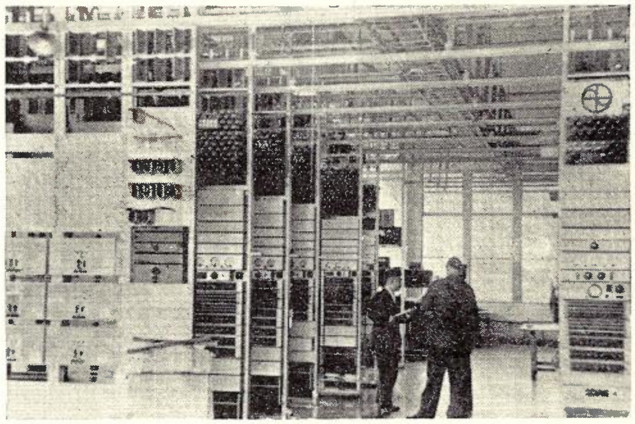


Fig. 4.—Repeater station showing 6-channel carrier and V.F. repeaters

the equipment has made maintenance much easier. The main shortage here has been repeater tubes, due to lack of coal gas for vacuum tube production. The maintenance of the military lines and those few necessary for Japan's minimum economy even now strains the resources of the Board of Communication, so it may be assumed that the complete rehabilitation of the Japanese communication system will probably take at least ten years.

4. Bureau of Radio Communications

One of the main functions of this bureau is the provision of technical and administrative services to the Broadcasting Corporation of Japan. This Corporation has about 5000 shareholders, but pays no dividends. Shareholders obtain some prestige and some little influence on policy by virtue of their investment; but the Government, through its appointment of the President and Board of Directors, very effectively controls the organization. The Corporation is supported financially by licence fees, which cost approximately 12/- per year. Of this total income of about £5,000,000, only 50 per cent. is spent on broadcasting service.

Ostensibly in the interests of economy, the technical plan called for high power stations and cheap low sensitivity receivers. This policy, incidentally, enabled Japan to blanket the Phillipines and China with her programmes, while at the same time restricting the Japanese to listening to their own local stations. Radio was one of Japan's major propaganda weapons, and steps were taken to ensure that all citizens were reached by the broadcasts. All schools were completely wired for radio instruction, and such broadcast lessons formed part of the primary school instruction. Before the war, Japan possessed about 7,000,000 home receivers. These were in four models, depending on the local field strength, and varied in sensitivity from 0.1-10 millivolts/metre.

An interesting technical detail is the use of radio relay stations for programme transmission. This was forced on the Corporation because of the lack of automatic level controls and equalizers on the programme lines, and the constant hazards imposed by snow, cyclones and earthquakes.

5. Japanese Industry

Natural Resources: The raw materials required in quantity by the communication industry include copper, lead, iron, tin, zinc, silver, paper, rubber, mica and oil, as well as those strategic metals such as nickel, cobalt and molybdenum, which are necessary in small quantities for certain iron alloys. Of these materials, Japan possessed in adequate supply in her home islands only iron, silver, copper and paper. By her conquests in China, Manchuria, Korea and Formosa, she obtained iron, zinc and some tin, but it was still necessary to import practically all her requirements in lead, tin, nickel, cobalt, rubber, oil and mica.

By 1942, however, the products of the Dutch East Indies, Burma and Malaya had reduced the deficiencies to lead, mica, nickel and cobalt. With respect to lead, the industry was in direct competition with the munitions industry, and this metal was therefore used very sparingly. The lack of mica stimulated research into ceramic insulators, while the metallurgists searched for substitutes for nickel and particularly cobalt, for use in magnetic steel.

On the credit side, Japan had exploited the deposits of alunite in Korea and her own hydroelectric power to produce aluminium in huge quantities. This metal and the looted tin was therefore pressed into many unorthodox applications. However, it will be seen from the above that Japan's present position is unenviable—her bombed factories will certainly not be able to produce sufficient exportable goods to enable her to buy the raw materials she requires for the re-establishment of her minimum economy.

Effect of the War: The effect of the war on the Japanese communications industry is best considered in two separate phases. The first covers the period up till the end of 1943, when Japan, with her merchant marine still intact, was reaping a rich harvest from her conquered territories. Tin and rubber from Malaya were in free supply, and huge stock-piles of these two materials were built up, so that, even now, considerable quantities still exist in Japan.

In the second phase, which extended until the end of the war, the Japanese merchant fleet was reduced practically to zero, and the industrial cities were exposed to intense bombing. It is probable, by this time, that Japan had collected sufficient raw materials to satisfy her industry for at least three years of war, and the shipping losses reacted rather on her export of the manufactured articles to her island bases. The bombing, however, not only destroyed industrial plants, but forced the manufacturers to accelerate the dispersal of their factories. This policy of dispersal was initiated in about 1943, when many country plants housing non-essential industries, such as rayon manufacture, were taken over for war purposes. By 1945 the bombing had reached such proportions that the dispersal organization broke down completely. Precision machine tools and valuable jigs and dies were uprooted from the remaining factories and despatched—usually without proper packing—to small, outlying villages and towns, where they lay for months exposed to the weather and the depredations of the local inhabitants. Since the surrender the Japanese factories have been endeavouring to collect this dispersed equipment; but in general it is found on reinstallation to be completely useless. In fact, it is possible that damage due to dispersal was greater than that due to bombing.

Industrial Families: By the beginning of this century, Japan's cottage craftsmen had been gathered into a large number of Western style factories, where they were fast learning modern mass production methods. However, the three essential services required by these manufacturers—supplies of raw materials, transportation of the finished articles abroad and finance—had fallen into the hands of the "fifteen families." These families, or, rather, clans, were usually groups who had built up their wealth during the Tokegawa regime, which preceded the restoration of the Emperor in 1868. They wielded their powers to such an extent that by 1941 they controlled about 75% of Japanese industry.

Of the "fifteen," the three main groups were the Mitsubishi, Mitsui and Sumitomo. Mitsubishi started as one of the original shipping companies and gravitated naturally to heavy industry so that, eventually, through a series of holding companies they controlled the major portion of Japan's shipping, steel and coal, and machine tool industries. Mitsui, originally moneylenders and silk merchants, have large interests in banking, textile and chemical industries, while Sumitomo control the non-ferrous mining and electrical undertakings.

The latter group had its origin in the island of Shikoku, where the Sumitomo family possessed large copper mines. Copper was one of the few exports permitted by the Tokegawa, and so the Sumitomo family built up large financial reserves. As the electrical industry was dependent on their mines for copper, this industry quickly fell under the control of the family. In 1941, of the twenty main suppliers to the Board of Communications, nine were directly controlled by Sumitomo. This control is exerted through eighteen holding companies—banks, insurance companies, real estate companies and the like—over a total of about 240 individual undertakings. The Sumitomo capital involved is of the order of £30,000,000.

At the present time, these autocratic institutions are being investigated, and, by dissolving the holding companies, Japanese industry is being reduced back to the original independent companies.

Communication Industry: From an inspection of the Japanese factory equipment and their installed telephone equipment, it is very obvious that the two Western nations which had the greatest influence were the U.S.A. and Germany. Of the three main telephone manufacturers, Nippon Electric had overseas affiliations with Western Electric in U.S.A. and was part of the Sumitomo group. Fuji Electric manufactured Siemens-Halske type equipment in Japan from tools supplied by Germany, but apparently was not controlled by the three main families. Oki Electric, which was also part of the Sumitomo group and was 60% destroyed by bombing, manufactured, in the main, subscribers' instruments and manual switchboards.

In the cable making industry, there were again three main companies which followed American practices in insulating and stranding, and used German equipment for sheathing and impregnating. Of these companies, Fujikura, which was completely destroyed, was an independent company both in regard to finance and manufacturing practices, the other two—Sumitomo and Furakawa—being part of the Sumitomo group and having patents arrangements with Western Electric in U.S.A.

Industrial Practice: In the following paragraphs are described certain Japanese personnel practices, which indicate the manner in which Western ideas have been perverted to conform to the traditional Japanese social structure. For instance, in most electrical firms the engineers are usually university trained, but their standing depends on the particular university from which they graduated. In fact, certain Imperial Universities have formed cliques which control the appointments and promotions of engineers within certain companies in the industry. An American or English graduate would be at a severe disadvantage in securing employment, first, because he is not a graduate of an Imperial University, and secondly, because his total education would normally extend over only 16 years instead of the normal 17 years for a Japanese graduate. Such graduates, because of their slightly shortened schooling are, in fact, classed as being of technical school standard. Within the clique itself, the traditional Japanese reverence for authority is very apparent. Any employee, irrespective of rank, may only submit a proposal to his immediate superior and without further discussion abide by that person's decision. Neither can the officer deal directly with others in parallel sections of the organization; such interchange of ideas must proceed up the ladder to the co-ordinating head, then down to the other officer concerned. The division between white collar workers, clerks and engineers, and manual workers such as tradesmen and labourers, is rigidly maintained. There is no promotion of staff from the ranks of the manual workers to those of the white collar workers; and, even with the artisans, seniority rights are just as complex and rigid as within the white collar workers.

The general Japanese method of payment is to provide a monthly wage, but to supplement it by a semi-annual bonus, which will depend on the prosperity of the particular company and of the efficiency or influence of the employee. An efficient or well-connected employee may receive up to eight months' salary as a bonus, while an inefficient or unpopular officer, in a time of depression, may only receive two months' bonus. In effect, the employers withhold approximately one-half of their employees' salary and distribute it as they see fit.

The Japanese Government has now awakened to the fact that certain social services are necessary in a democratic State, and have therefore instituted a system of child endowment, whereby the employer must increase the wage of a worker by approximately 10% for each child he supports. This enlightened scheme, of course, simply means that employees with children find it most difficult to get work, the young, unmarried, and possibly more efficient, men, being available to industry at a lower wage.

In general, labour is becoming aware of its depressed condition in Japan, and Trade Unions are being organized. These, however, are on an industry basis, rather than a craft basis, and include both artisans and white collar workers. There is a great danger, therefore, that these Unions will be run by the professional employees, and may degenerate into company unions. To date, there have been very few strikes in industry; but the Japanese have evolved what appears to be a new technique, but which would be only applicable to their country. The strikers do not cease work, but take over the factory and run it through their own representatives, the management thereby losing considerable face. This intolerable state of affairs naturally could only persist for a very short time, and these strikes have normally been settled in a few days.

Another interesting sidelight on Japanese industrial methods was provided by one telephone factory, which is in general superior to the average Japanese establishment. It was noted that the machine equipment was excellent and the workers, when actually on the job, most industrious, but the factory management seemed incapable of keeping more than about 50 per cent. of the operatives actually with work at hand. This inefficient management is perhaps understandable when it is realized that this factory possesses no central filing system. All papers, letters, schedules, etc., are held on individual employees' private files, and when a change in staff occurs the new occupant of a position must commence from nothing to build up his own filing system. Before the war, an American director was retained as adviser to the management. This man succeeded in building up a normal Western filing system. On his internment, however, his files were distributed among those people interested and the remainder burned. It was stated that six months later the production in the factory had dropped to one-third.

May Day, in 1946, was a public holiday throughout Japan, and it is estimated that about a quarter-million marched past the Emperor's Palace in Tokio. From personal observation, they appeared to be well-disciplined and very happy, and seemed more intent on having a pleasant holiday than on exploiting the political significance of the day. Due to the long oppression of the labour movement, it was necessary for most of the marchers to read the words of their revolutionary songs from scraps of paper, and for some unknown reason these songs were set to old hymn tunes. The above remarks have obviously not been collected from official publications but from personal contacts and observations. Wherever possible, opinions expressed by the Japanese were checked and were found to be true.

6. Research and Development

Introduction: It is of interest to compare the manner in which Australia and Japan have treated the problem of obtaining communication equipment suitable to their particular needs. Australian engineers, because of the small number of technical people available and because of the traditional ties with England and U.S.A., have confined themselves to making sufficient local experiments to enable them to specify precisely the type of equipment they required from overseas. In this way, modern equipment modified to suit the local conditions was obtained for the Commonwealth. Japan, on the other hand, after obtaining the tools for mass production from overseas, commenced large-scale manufacture and relied on her own scientists and engineers for any further development. Those men, whose only link with the scientific developments of the Western world was through textbooks written in a foreign tongue, naturally proved sterile of new ideas, and so she came to rely on ideas brought back by her touring scientists from U.S.A. and Europe. They, in a tour of several years abroad, had first to overcome a severe language barrier before attempting to assess the technical value of some new technique or equipment. They naturally brought back much information which they erroneously considered was of fundamental value, and by virtue of their position and prestige incorporated it in the plant at the expense of other more useful equipment. According to social custom, of course, their conclusions were inherently correct.

As a result, development on the basic plant has been most uneven—the carrier telephone equipment is excellent, but the circuits so provided cannot be used effectively owing to obsolete trunkboards and traffic handling methods; the work of Yagi and his school on aerials was very thorough, but there is no corresponding development in transmitters and receivers; the Japanese string oscillographs, based on the Westinghouse model, are well constructed, but are used for work which obviously could be done quicker and cheaper by a cathode ray oscillograph. The search for substitute materials often developed into a line of original research; and, in fact, the painstaking search through several hundred possible solutions is a problem particularly suited to the Japanese mind—the work of Honda and Nishima on nickel-free magnetic alloys being a classical example of this kind of work.

In general, then, it will be seen that Japan has relied on its associations, commercial or personal, with the Western world for any new developments in technique or equipment. However, there are in Japan three main groups of scientists who have made some contribution to technical development. The first group are those in the Universities, who, in general, concentrated on fundamental problems. The second group is found in the industrial or governmental laboratories, and their function here has been the improvement of the technique within their particular industry or department. The third group, which has no counterpart in the Western world, is a collection of about 500 physicists and chemists, which was inaugurated by an Imperial grant, and which is known as RIKEN, i.e., the initials of the Institute for Chemical and Physic Research. Nowadays, however, RIKEN, which supports thirty laboratories, derives 90 per cent. of its income from royalties or consultation fees. This group has concentrated on producing new, patentable processes in chemical and heavy industries, but also supports men like Nishima, who pursued a programme of pure, fundamental atomic physics.

In the communication field little work is done at the Universities, and most of the fundamental research is undertaken by the Electrotechnical Laboratory, which is controlled by the Board of Communications. This laboratory has a very broad field, covering the maintenance of Japanese fundamental electrical standards and testing and development work in both communication and power engineering. The organization within the industrial firms is similar to that occurring in England or America. Nippon Electric, for instance, has a fundamental research laboratory at Ikuta, and the developments of this laboratory, after passing through a pilot plant at Tamagawa, are manufactured in their various factories scattered throughout Japan.

The research and development work generally, however, is hampered by four factors:—

(a) A high degree of specialization among technical men causes much overlapping work and a very insular attitude towards the particular research in hand. Associated developments in other fields are often quite unknown to the research worker.

(b) The presence of a rigid system of channels by which associated research developments are co-ordinated only through the director of a company or laboratory.

(c) The continuance of research in industrial and particularly governmental laboratories beyond the point where it should have been apparent that the results were impracticable.

(d) The apparent lack of scientific intuition among Japanese scientists causes most of their work to progress along empirical lines, i.e., the search through a series of permutations and combinations until the correct solution is found. Although this method in some few rare cases has produced unexpected results, it is very wasteful of men and labour.

Below will be discussed those raw materials and equipments which appeared to be new developments. In many cases it will be observed that, although they are new, they are not necessarily applicable to the Western plant.

Magnetic Materials: Honda and Nishima, following on a line of research established by Sir James Ewing in Japan, 1911, have developed, mainly by empirical methods, a series of new magnetic alloys such as MK and KS steel and Sendust powder, all of which were known before the war. During the war their work was directed to find substitutes for cobalt in magnetic alloys. This work has already been described in a report by Thurlby, of the Australian Scientific Mission. The most interesting development is probably their oxide powder, which can be pressed into any desired form, and, although possessing a specific gravity of about 3, has the magnetic properties of Alnico. This material has been tried in relays and receiver magnets, but has been rejected owing to its brittleness. The Sendust powder is used extensively for filter and loading coils, and while its characteristics are as good as the normal permalloy dust, it is inferior to molybdenum iron dust.

Insulating Materials: Steatite is used extensively for radio frequency insulators, and as a result of the traditional skill of the Japanese in ceramic work, a very high-grade product is produced. The steatite is derived from a very pure and uniform Manchurian talc, mixed with barium carbonate in the proportion 45/55. The powder is pressed to shape and baked at 800°C. It is then machined as desired and given a final firing at 1300°C. The shrinkage is of the order of 15-20 per cent.

Owing to the shortage of mica in Japan during the war, much attention was paid to the development of titanium-oxide ceramics for use as a dielectric. As well as the common miniature disc and tube condensers, large units of about 1000 micromicrofarad capacity and 15 kV test voltage were produced, apparently for use as coupling and bypass condensers. A sample with the above characteristics carried a current of 20 amps at 2.5 mC/s for a temperature rise of 50°C. The condenser itself was in the form of a disc about $4\frac{1}{2}''$ in diameter and $\frac{1}{2}''$ thick, with the terminals in the centre of each silvered face. The composition of the disc is a ceramic formed of titanium oxide with a calcium oxide binder—the dielectric constant being of the order of 95.

"T" Type Automatic System: In 1936 the Japanese Board of Communications began circuit design work on a step-by-step automatic system known as the Teishinko ("T") dial system. In 1940, a 2000-line experimental office employing the "T" type circuits but standard Siemens and Halske switches, was installed at Nara. Later, two further offices were completed. The local equipment manufacturers were also invited to design a switch which would combine the best features of known bimotional switches and at the same time exploit the new features in the "T" circuits. To date, three acceptable hand-made switches have been produced by Nippon Electric. In this switch, with minor variations, the multiple is copied from Strowger, the wiper assembly a duplicate of the 2000 type, and the mounting arrangement, size, shape, mechanical action and relays, virtual copies of the Siemens and Halske switch.

The main design aim was the reduction of the number of relays used in the exchange. This was achieved by:—

(a) Concentrating many of the normal connector functions such as the supply of transmission and ringing current in the second or third selector—termed the transmission selector—i.e., at a point where the minimum number of switches is employed.

(b) Transferring to the "off normal" switches many contacts normally relay-actuated.

(c) A loop impulse circuit is used up to the transmission selector, but thereafter impulses are transmitted to succeeding selectors and connectors through the A wire and earth—no slow-release relays being used in these latter switches. A further feature is that, in the case of the called subscriber being busy, the selectors succeeding the transmission selector, and the connector, are immediately released, the transmission selector and preceding switches releasing when the calling subscriber restores his phone.

In general, the design aim has been met; the number of relays is reduced to one-half, but the number of contacts is virtually unchanged. It might be expected, then, that the initial cost of such an exchange may be reduced below normal, but maintenance cost would be the same.

Orikasa, the designer of the "T" circuits, has also produced an automatic party-line system. A group of up to ten subscribers is connected through a locally fitted rotary switch over a single exchange line to a distant automatic exchange. These subscribers are obtained by dialling an extra digit above that allotted to the exchange line—the rotary switch stepping in synchronism with a relay in the exchange to select the wanted number. As his circuit stands, these subscribers have access to the exchange but not to each other.

Phase Modulation: Dr. G. Yoshida, of the Electrotechnical Laboratory, has embarked on a ten-year programme of research on the phase characteristics of electro-magnetic waves. One of his developments is called a "polyphase displacement" method of modulation, which has been applied to radio and line telegraphy and facsimile transmission. In the simple case of a two-channel telegraph system, the signals are transmitted by shifting the phase of the carrier in multiples of 90°. For instance, a mark on each channel is represented by a shift of 90°, a space on channel one and a mark on two by a shift of 180°, a mark on channel one and a space on two by 270°, and a space on each by zero phase shift. However, the demodulation of a phase modulated carrier requires the incoming signal to be mixed with the output of an oscillator which is in phase synchronism with the transmitted carrier. This phase synchronism has always proved very difficult to attain in practice, and phase modulated telegraph systems have in general been abandoned. Yoshida, however, overcomes the problem by taking some of the incoming signal and multiplying its frequency four times. This, of course, increases each of the phase shifts by a factor of four and so brings them to multiples of 360°, thus producing an unmodulated wave of four times the original frequency. After demultiplication to one-quarter this frequency, a wave is obtained which is exactly the same frequency as the sending oscillator, and, of course, in phase synchronism with it. This wave is then used to demodulate the incoming signal. In the Laboratory a system handling 12 signals each 30° apart is under test.

Yoshida has also produced a wide band frequency demultiplier which converts a range of frequencies 50-8000 c.p.s. to 25-4000 c.p.s., using only static equipment such as copper-oxide rectifier networks and filters. This is, in effect, a frequency compandor; but, unfortunately, he has not yet solved the problem of re-expanding this band.

General: Two other items which, although not matters of research, are of interest to communication engineers, are the development of a special slide rule by the Hemmi Company, and the production of a most complete handbook on telecommunications by a group of engineers associated with the Board of Communications.

The slide rule, which bears the Serial No. 2446, is a further development of the Hemmi Type 153, which it replaces. It is a single-sided rule, and provides the normal facilities for multiplication, division, squares, cubes and logs., but the A and B scales have been replaced by a C and D folded scale. These scales are folded about $\sqrt{10}$, and by this device it is possible to eliminate almost entirely end changing of the slider. For instance, when multiplying 2 by 8 on the C and D scales, it will be noted that 8 would be off the rule on the C scale, but the answer can be read off the CF and DF scales, where 8 is in approximately the centre of the rule. The sine and tangent scales are engraved on the reverse side of the slide: but by continuing the scale on the centre of the rule a 20″ length is obtained for these functions. By reversing the slide, the sine and tangent scales may be used with the CF and DF scales to give the hypotenuse and angles of a right-angle triangle, knowing the two other sides, with one adjustment of the slide and two of the cursor. The accuracy is considerably greater than that obtained on the 153 rule. This rule should be of great value in converting vectors from the $R + JX$ form to the $R \angle \theta$.

The handbook of telecommunication engineering was prepared by a group of communication engineers working in co-operation with the Board of Communications, during the period of

1935-44. This book contains over 3000 pages and gives most complete treatises on mathematics, physics, chemistry, electrical, civil, mechanical and metallurgical engineering, as well as specialized communication subjects such as telephony, line construction, long line equipment, radio equipment design, radio propagation, navigation aids and ultra-high-frequency technique. The book was published in 1944, and gives a very complete summary of all overseas papers and handbooks up until 1941, together with a statement of Japanese technique in the art.

PLAN AND DOCUMENT REPRODUCTION

R. Finlayson

The successful conduct of any technical organisation depends to a large degree on the effective distribution of technical information to the many locations where it may be required for design, manufacture, construction or maintenance purposes. Whatever the need, it is essential that the information, in correct form, be readily available. Much of this information is prepared in drawing form, and copies of the original drawings are distributed to the required locations.

Data in text form is also frequently required to be distributed, and whilst the preparation of the necessary copies may often be arranged by medium of the typewriter or other machine printing processes, further means must be available to meet all demands.

The purpose of this article is to discuss the plan reproduction processes available in the P.M.G.'s Department, and to briefly describe the methods employed.

It is important at the outset to state that the production of good copies, no matter what process be adopted, is directly dependent upon good quality original subjects. Many devices are resorted to in order to prepare sub-quality originals for better reproduction; but there is a limit to what can be done in this regard. Generally speaking, the state of the original dictates the quality of the reproduction.

Various processes are available, each having characteristics which make it suitable for particular application; and in order to determine the most effective process for the work in hand the following should be considered:—

1. The class and condition of the original from which copies are required.
2. Whether reproduction will be to the same scale or to an altered scale.
3. The number of copies.
4. The purpose for which copies are required.

The class of originals normally handled may be:—

(a) Drawings prepared on a transparent base such as tracing linen, which are required to be copied to the same scale.

(b) Drawings and data in text form usually contained in bound volumes, printed on an opaque base, and which may be required to be copied to the same, smaller or larger scale.

The purpose for which copies are required must be considered in order to determine if copies are for direct distribution or are to be used for further reproduction. If reproduction is to be effected to an altered scale, photographic methods must be employed; and the type of reproduction can be such as to give either normal photographic copy or copy on transparent base from which further copies may be produced.

Processes: The more commonly used processes are:—

Blueprint.	Kodalith.
Dyeline print.	Linotone.
Helio print.	Multilith.
Sepia negative.	Normal photo. negative.
True-to-scale.	
Photostat.	

The Blueprint, Dyeline, Helio, Photostat and Multilith methods are essentially used for direct distribution purposes, whilst the Sepia negative, Kodalith and Linotone processes are used for the preparation of transparent copies from which further prints may be taken.

The "True-to-scale" and Photo. negative processes may be used for either purpose.

The abovementioned processes may be divided broadly into two categories, namely, those which may be carried out in normal daylight and those requiring dark room facilities.

Daylight processes: Blueprint, Dyeline, Helio, Sepia and True-to-scale.

Dark room required: Photostat, Kodalith, Linotone, normal Photo. negatives and photographically produced Multilith plates.

Daylight processes: These are somewhat similar to each other, with the exception of the "True-to-scale," for which there is more than one process. Variation exists in the type of chemical used and the colour of the finished article.

Blueprint, Dyeline, Helio and Sepia processes each require a chemically coated paper or linen, which is placed in direct contact with the original tracing and subjected to light rays which act on the sensitised coating causing chemical changes.

Blueprint (white line on blue background): Paper or linen is coated with a light-sensitive Ferro Prussiate solution. The tracing to be copied is placed in direct contact with the sensitized paper and subjected to intense light rays for the required period of time, after which it is developed in water; and, in more modern practice, placed in a further chemical bath, such as Perborate of Soda, which intensifies the blue background and bleaches the white characters.

Briefly, the chemical action of the process is as follows:—Main chemicals in the solution are ferric salts and ferricyanide of potassium. The action of light causes the ferric salts to be reduced to a ferrous state and to combine with the ferricyanide of potassium, which produces the blue colour. This solution, when subjected to light, is insoluble, and when the print is immersed in water this portion turns blue, while the soluble ferric salts on which light has not acted, due to the opaque characters of the tracing, remain unchanged and leave a white line.

Dyeline (black line on white background): The paper for the popular Dyeline print is sensitized by chemicals of the Diazo group. The print is produced by, firstly, applying light to the paper, which is held in close contact with the original tracing in a manner similar to the blueprint method. Unlike the blueprint, however, no water bath is employed, but in this case the application of a further chemical is necessary. This has the effect of dyeing the line on the print—hence the term "Dyeline." This further chemical is usually applied by means of a series of rollers, one of which is partly immersed in the chemical solution and on revolving, deposits a fine film of solution on the already exposed paper, thus developing the necessary characters which have been rendered sensitive to this further chemical.

It will again be seen that the opaque portions of the original tracing screen the sensitized paper from the action of the light, thus leaving them sensitive to the action of the second chemical. This type of print has many advantages over the blueprint from the production point of view, as it is almost a dry process and prints may be handled immediately they are developed. The installation of washing troughs and drying apparatus is not necessary, thus floor space is considerably reduced, whilst production is greatly increased. The near-dry nature of the process is also an advantage in that much less distortion occurs than in the case of the wet processes, which cause a print to expand and contract.

Helio (black line on white background): The advent of Dyeline prints has reduced the demand for Helio prints to a minimum, although it is still sometimes preferred, mainly in architectural circles, for colour-rendered prints. The paper in this instance is coated with a Ferro-Gallic chemical solution and printed in the same manner as a blueprint. Two types of paper are available—(a) water bath, which contains Gallic acid in the sensitizing solution and which is merely developed in water; and, (b) acid bath, which requires the print to be developed in a dilute Gallic acid solution. As in the case of a blueprint, no further fixing treatment is required. A definite disadvantage of this type of paper is its tendency to become brittle with age, with resultant damage from folding and handling.

Sepia Negative (white line on brown background): The Sepia negative or Vandyke, as it is commonly known overseas, no doubt derives its name from its colour, for it is a thin paper print with translucent characters on a brown background. It is used for making copies of original drawings from which further copies may be taken. Copies from sepias are generally taken on blueprint paper, and give a blue line on a white background. The main sensitizing element for this type of paper is a solution of silver and iron salts, and prints are produced with the same equipment and in the same manner as a blueprint, except that sepias require to be fixed in "Hypo."

They are the medium which this Department employs for reproduction of standard drawings for despatch to the various States and overseas, and are also favoured in many instances by overseas companies for the provision of drawings of Telecommunication equipment supplied to this Department.

It might be mentioned at this stage that sepias are not welcomed by those in charge of print rooms, as they are very slow to produce, and the further reproduction from them is also a slow process. It is hoped that a more speedy and efficient process will be available in the near future.

True-to-Scale: Whilst the processes previously described do not provide true-to-scale copies due to distortion caused by the wetting of the paper, they are satisfactory for general purposes.

If actual true-to-scale copies are required it is essential that a dry or near-dry process be employed.

The process normally known as "True-to-scale" is one which requires closely controlled atmospheric conditions and employs a chemically loaded gelatine pad on which an exposed but undeveloped blueprint is impressed. Chemical reactions cause the image from the blueprint to be transferred to the gelatine pad. This pad is inked, and copies are taken off by impressing the copy paper on to the pad.

A Continental product known as Acuté is again available after absence from the local market during war years. It provides an excellent medium for True-to-scale copying, having a tough transparent paper base, and is produced by the near-dry Dyeline process. Characters may be erased by the normal "rubber," and it is admirable for keeping current records of circuit maps, underground plant, aerial lines, etc., thus preserving the original and generally costly tracings from continuous handling and resultant damage. By such means original tracings need only be brought up to date at periodic intervals and further Acuté working copies made from the amended plans.

PLANT USED FOR DAYLIGHT PRINTING PROCESSES: The following description is of plant used in a Departmental print room, and is not intended to cover the wide field available in industry generally:—

Printing Machine: The term "printing machine," as commonly used, is somewhat of a misnomer, and is really better described by the makers' description, "Electric Copying Machine." Whilst the sunlight is a most effective light source for plan copying, it will no doubt be appreciated that in some localities the absence of sunlight for a considerable period of the year presents a great obstacle to consistent production of prints.

The artificial light source is built into the copying machine for continuous operation, thus obviating the necessity of using cut sheets as are employed for sun printing, and allowing tracings of any length to be copied. There are various types of machine in use, but they all provide similar basic elements, namely:—

(a) Light source.
(b) Heat-resisting glass contact panel, either flat or curved.
(c) Conveyor belts to carry the tracing and sensitized paper past the light.
(d) Means of changing speed of operation.

A typical machine is illustrated in Fig. 1.

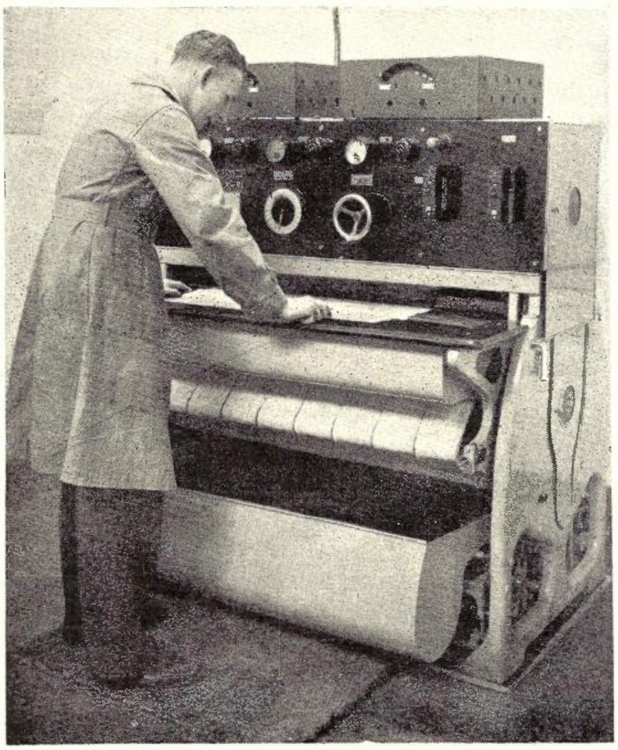


Fig 1.—Typical electric copying machine.

The light source is usually a carbon arc, which traverses a double-cut drive shaft, giving full light cover to the printing frame. The older machines used one lamp only, but two lamps moving over a shorter traverse are now fitted. Most recent practice of some manufacturers is to employ mercury vapour tubes for lighting. It is of interest to mention that a much worn and obsolete type of single-carbon arc machine was converted to mercury vapour working for the Central Office Drafting Section, and is giving complete satisfaction. The system of lighting is shown in Fig. 2. Since this

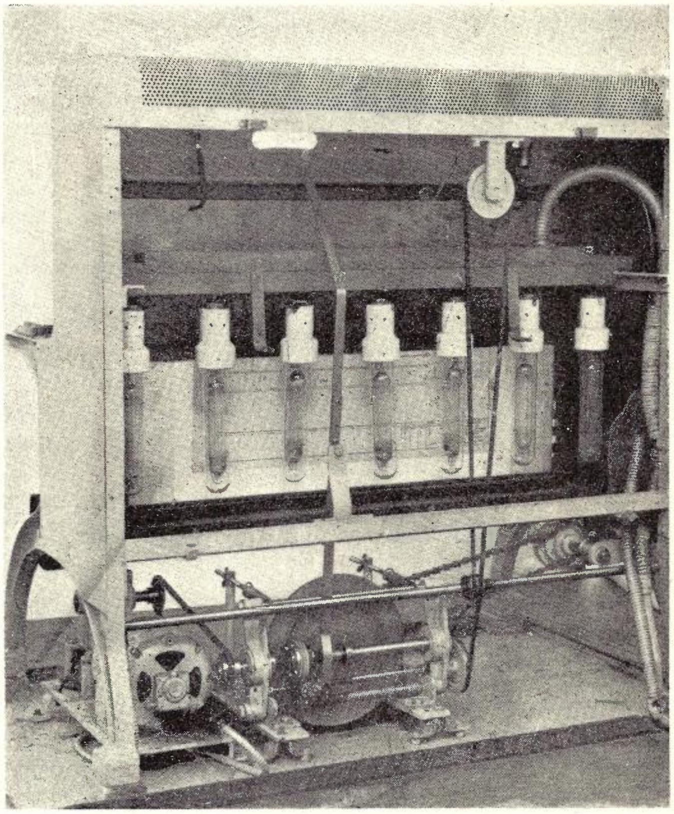


Fig. 2.—Back of converted printing machine, showing mercury vapour lighting.

conversion, machines employing mercury vapour tubes have been offered on the Australian market and have been purchased for Brisbane and Adelaide offices. The stationary glass panel allows light to pass and provides a firm base over which canvas conveyor belts are stretched. The tracing and sensitized paper are held in firm contact between the belts and the glass, and travel past the light source simultaneously. Sharpness of characters is dependent upon good contact between tracing and printing paper, and any "slip" between the two causes a blurred image on the finished print.

Modern machines employ a curved contact glass in order to provide a greater area for exposure to the light. Suitable "feed-in" provision is made, and there is a trough to receive the exposed paper and the tracing after having passed through the machine. Various methods are employed for changing speed of operation, which is necessary to cater for various types and conditions of originals. The latest types of machine use a synchro-mesh gear box with convenient hand-wheel control.

In the opinion of the writer, the ideal type of machine is that produced by some American manufacturers, which has a stationary strip light, generally a high-pressure mercury vapour quartz tube, around which a glass drum rotates. By this means damage to tracings is reduced to a minimum, as the tracing is held firmly between canvas bands and the glass drum, which revolves simultaneously. The tracing, therefore, is not required to move across a stationary glass surface as is the case with most machines used in this country.

Dyeline Developing Machine: Various types are in use, but each consists basically of feed rollers, a coating roller and a trough containing developing solution. Parts should preferably be of stainless steel or other anti-corrosive substance, as the developing solutions are extremely corrosive. A typical developing machine is illustrated in Fig. 3.

Other Equipment: Additional equipment normally consists of troughs large enough to accommodate the largest normal blueprint handled,

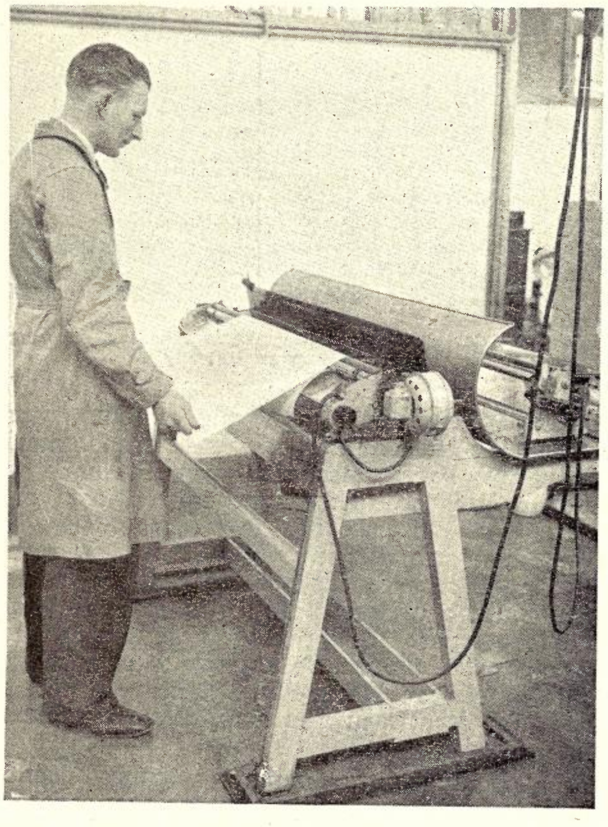


Fig. 3.—Dyeline developing machine.

together with drying and trimming facilities. In some cases a drying machine consisting of a conveyor belt which carries the wet print over a heating element is provided, whilst air drying is often employed. Trimming appears to be a matter of individual choice, and all means, from razor blades to guillotines, are used. Copies up to 40 inches wide can be produced on Departmentally-owned equipment; but greater widths can be handled by some commercial organisations.

PROCESSES REQUIRING DARK ROOM:

Photostat.
Linotone.
Kodalith.
Normal photo. negatives.
Multilith (photographic plates).

Photostat: The Photostat machine, which is mainly used for copying extracts from journals, documents and other data on opaque base, consists basically of a subject holder, an optical system consisting of a lens and prism, a container for sensitized paper, and some form of lighting. This machine may be operated in daylight or artificial light, and is fitted with light-proof facilities for containing the light-sensitive paper. Unlike most photographic processes which employ celluloid or glass negatives, the photo-sensitive solution is coated on opaque paper base, on to which the image is directly transferred. It is a fast Bromide paper, with high contrast properties.

The normal subject to be copied is black on white, and the first copy, taken by projection of the image from the subject, through the optical system, to the sensitized paper, is "negative" in colour, i.e., white on black. When "positive" copies are required it is necessary to recopy from the negative, the result being a black line on a white background. Whether "negative" or "positive" in colour, the form of the characters is always true, i.e., characters are not reversed as in a normal photographic negative. The introduction of the prism in the optical system brings about this result. The best copies from Photostat working are obtained from originals with "line" characteristics rather than half-tone.

Colour filters may be introduced, but a variation of filters is uncommon, hence, copying of multi-coloured originals cannot be regarded as entirely satisfactory.

There is automatic focussing for self-size copy; but a ground glass screen is provided for focussing if enlargement or reduction is required. Such enlargement or reduction is possible within the optical and physical limits of the particular machine. Machines are available to provide full-sheet copy of sizes 24" x 18", 18" x 14" and 14" x 11". The development of the Photostat image is carried out in a dark room by normal photographic development methods.

Linotone: Linotone, a translucent Bromide paper, possessing deep contrast characteristics, is now used extensively for "reprint" purposes, and is a distinct aid to any Drafting Section. Copy is taken on Linotone by contact from transparent or translucent originals, or by projection from film copy of opaque originals. Such copy may be utilised in a manner similar to a normal tracing for the production of further prints by Dyeline or Blueprint methods.

Kodalith: Kodalith is a photographically sensitized linen, and, when processed, has the appearance of a normal linen tracing. Copy on Kodalith is produced in the same manner as Linotone, but is superior, in that developing solutions do not penetrate the fibres of the linen, hence it is an excellent medium for true-to-scale reproduction. Like Linotone, the Kodalith print provides an excellent medium for producing further Dyeline or Blueprint copies, and will withstand a great deal of handling without damage.

Kodalith is extremely useful when several master drawings are required, each varying in some slight degree, as is often the case. One drawing only need be prepared, and from this Kodalith copies are taken with any unwanted details blocked out. By adding, with normal drafting methods, any amendments required, a number of drawings, the equivalent of normal tracings, may be produced with a minimum of drafting work.

It is often necessary to prepare drawings to a large scale for clarity of presentation and accuracy of detail. Large-size prints from such drawings are frequently a distinct disadvantage to those requiring to use them. By the use of Kodalith, drawings may be reduced in size to legible dimensions, the resultant prints being much more convenient to handle and the cost of the prints greatly reduced. This material is not sold in Australia, but is imported direct by the P.M.G.'s Department.

General Photography: It is not proposed to deal at length with normal photographic processes, although photographic work performed in the P.M.G.'s Department embraces a wide field and is used extensively in the illustration of equipment, buildings, sites, laboratory processes, publicity and many other purposes. It is sufficient to mention that any type of photographic work can be and actually is undertaken successfully.

One item of equipment, however, which deserves special mention is the vacuum contact printing box. The apparatus consists of a box containing the necessary lighting, a plate glass contact panel and a vacuum sealing rubber blanket, which is actuated by a vacuum pump. The derived vacuum ensures perfect contact between the subject to be copied and the sensitized paper or linen, thus providing clean-cut or "sharp" characters on the print. Exposure and development are performed by normal methods.

The box installed in the Central Office Drafting Section is a much-used item of equipment. The apparatus which is illustrated in Fig. 4 is capable of contact printing maps, plans, etc., up to a size of 44 inches by 32 inches.

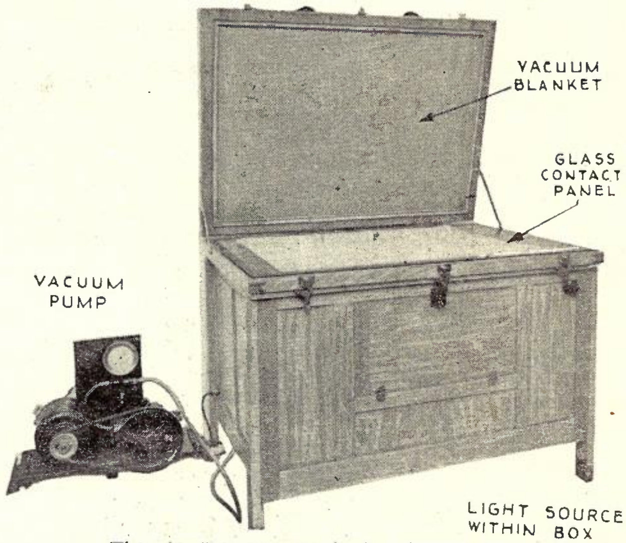


Fig. 4.—Vacuum contact printing box.

Glazer: The glazing of photo. prints can constitute a definite "bottleneck" in production. The introduction of a Glazing machine, as illustrated in Fig. 5, is the best known means of eliminating this trouble, and machines of this type have been installed in the larger Drafting Sections to good effect.

Multilith: The "Multilith" process of printing has been used for some time in this Department, principally for the printing of the Course of Technical Instruction books, and is the most economical process available if large numbers of copies are required. The actual printing of the copies is an offset litho. process; but the preparation of the master copy calls for a good deal of skill and mastering of a technique peculiar to this type of work.

The original image is put down on a grained metal plate 15" x 10", zinc or aluminium being generally used. The size of the plate limits the image to an area of approximately $13\frac{3}{4}$" x $9\frac{3}{4}$". Two methods are employed—either direct image working or a photographic process.

Direct image working: In direct image working, the image to be placed on the metal printing plate may be typewritten text, handwritten text or sketches, circuits, freehand drawings, etc. The metal plate is chemically treated before the image is put down, to ensure cleanliness of the plate and to increase its sensitivity to grease. The typewritten text is directly typed on the plate through a sheet of specially prepared greasy carbon paper or a greasy carbon typewriter ribbon. The handwritten text and sketches are placed on the plate by brushes and pens, using a greasy lithographic ink or crayon.

Extreme care is necessary in handling the plates. If an apparently clean finger, for example, is pressed on the plate, the resultant greasy finger print, although normally invisible, will be printed, as well as the other image on the plate. On account of the greasy content of pencil leads, pencils cannot be used on plates, construction and guide lines being drawn in red ochre.

Fig. 5.—Glazing machine.

Photographically prepared plates: Grained zinc plates are used for this method of preparation. The process involves the making of a photo-negative of subject matter and the transfer of the image on to a sensitized zinc plate. The sensitizing solution is composed of Albumen and Ammonium Bichromate, and is applied while the plate is revolving on a "whirler," thus ensuring even distribution of the solution.

The negative is placed in direct contact with the sensitized plate in a vacuum frame, good contact being essential. Carbon arc lighting is employed, and the plate is exposed for the required length of time. After exposure, a chemically treated developing ink is applied, and the plate developed under water. "Background" ink is thus removed, leaving the required characters only. The production of half-tone images requires the use of photographic screens, and calls for a more highly developed technique than is the case for line work.

Printing Process: After the greasy image has been placed on the plate, either directly or by the photographic process, the plate is further chemically treated to ensure the retention of the image on the plate under the suction effect when ink is being applied to the plate during the printing operation.

The metal plate is placed around a cylinder on the Multilith printing machine, where an inked roller and a water saturated roller make contact with the plate. The principle of Multilith printing may be stated as "water and grease will not mix." As the water roller passes over the plate all parts of the plate without a greasy image will be moistened, but the greasy image will remain dry. The inked roller passing over the plate, however, will deposit ink (which has a greasy content) on the greasy image but will not ink the water moistened parts of the plate. The cylinder on which the plate is fastened is in direct contact with a rubber covered cylinder, and the inked image on the plate is transferred to the rubber covered cylinder. A sheet of paper now passes between the rubber covered cylinder and another metal cylinder, and the inked impression from the rubber covered cylinder appears on the paper.

Paper 14" x 10" is the largest size that can be used with the Multilith. After use the plates may be covered with a film of Gum Arabic, stored indefinitely, and used for further printing as required. Multi-colour printing is possible with the Multilith.

Conclusion: It might be stated that a great deal of attention has been paid to the reproduction of data for Departmental requirements in recent years, and consequently Drafting Sections in the larger States are now able to produce copies from almost any type of original in an economical manner. The skill of the operatives has a direct bearing on the quality of the work produced, and is a prime factor in the successful functioning of a Plan Printing and Photographic Section. This is particularly evident when improvized equipment has to be utilized, as has been the case in recent years.

In order that the reader may more readily recognize the various products previously mentioned, a brief summary is appended herewith:—

Contact Printing Processes
(Using Electric Copying Machine)

Type of Print	Description	Original from which Copy is Made
Blue print.	White line on blue ground.	Tracing or other transparent base medium.
Dyeline print.	Black line on white background (paper and opaque or transparent linen).	Tracing or other transparent base medium.
Helio print.	Black line on white background (paper or linen).	Tracing or other transparent base medium.
Sepia negative.	White line on brown background (thin paper).	Tracing or other transparent base medium.
Sepia positive.	Brown line on white background (thin paper).	Sepia negative.
Reversed blue print.	Blue line on white background (paper).	Sepia negative.

Photo. Copy Processes

Type of Print	Description	Original from which Copy is Made
Photostat negative.	White line on black background (paper).	Printed matter or drawings of any description.
Photostat positive.	Black line on white background (paper).	Photostat negative and some coloured originals such as a blue print.
Linotone negative.	White line on black background (thin paper).	Tracing or other transparent base medium.
Linotone positive.	Black line on white background (thin paper).	Film negative (if by projection), Linotone negative or similar original (if by contact).
Kodalith.	Similar to Linotone, but on transparent linen base. The positive resembles a normal linen tracing.	

ANSWERS TO EXAMINATION PAPERS

The answers to examination papers are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and give information which a candidate should have to enable him to give answers which would secure high marks.

EXAMINATION No. 2582—SENIOR TECHNICIAN—TELEGRAPHS

R. D. Kerr

Q. 4.—Draw the schematic circuit of a long distance teleprinter set as used to extend a carrier channel to two local teleprinter subscribers. Describe the operation of the set and state what observation facilities would be required. The circuits of the observation facilities need not be shown.

A.—The circuit is given in the Journal for Feb., '44, p. 378, as Fig. 1, Q. 4, Examn. No. 2377.

The teleprinter long distance "three relay" set is used to connect local teleprinter circuits to a carrier telegraph channel.

(1) In the idle condition—

(a) The teleprinter local send loops are marking (open circuit at transmitter contacts).

(b) The receive relay of the long distance set is marking under the control of the carrier receive circuit.

(c) The send and home record relays of the long distance set are marking under the control of the 15mA current flowing through the U-D windings of these relays in series.

(d) The subscribers' teleprinters' receive magnets are held to marking, under the control of the 25mA marking current flowing through each signal shaping network (2000w shunted by 2 mf.) and limiting resistance, the negative battery being fed via the mark contact and tongue of the receive relay and the mark contact and tongue of the home record relay, to the local receive lines.

(2) When a teleprinter subscriber operates his teleprinter, the keyboard transmitter earths the local send line to signal space and leaves it open to signal mark. When the transmitter contacts earth the line, the current flows through the D circle and U circle windings of send and home record relays, in series, and through the signal shaping and limiting resistance of the sending local loop. This current is adjusted to 30mA, and when flowing, its preponderance over the 15mA marking bias current operates these relays to space.

The contacts of the send relay repeat the space signal on to the static modulator of the carrier telegraph channel and thence to the distant terminal. The contacts of the home record relay repeat the space signal back to the local teleprinters' receive magnets, and, in this way, give a home record at the sending machine, and a copy of the sent signals on the other local machine.

(3) When the distant terminal signals, a series of spacing and marking signals will be received over the carrier telegraph channel and will be repeated by the receive relay, which in its turn will repeat these signals to the two local teleprinter receive lines and magnets in parallel.

(4) Should one station be sending, the operation of the keyboard of any other terminal will cause the signals from the latter to interact with the signals of the former, and will mutilate the printing on all machines in the circuit. The sending operator can in this way recognize a "break" signal from another station.

(5) Observation arrangements provided at the long distance relay set give the following test facilities:—

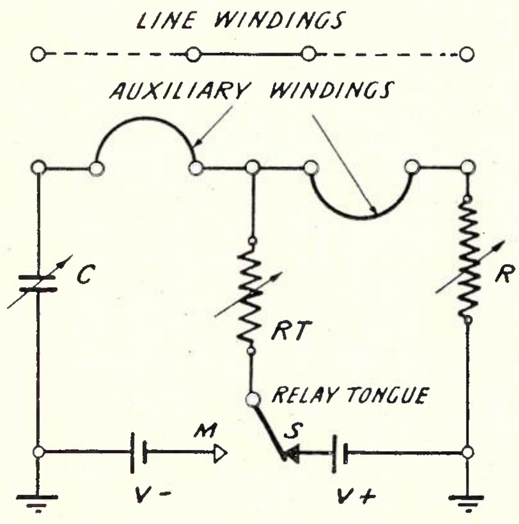
(a) **Monitoring:** By placing the contacts and magnet of an observation teleprinter, each with suitable current limiting resistances, in parallel with the local subscribers' send and receive lines so that the observation machine functions, in effect, as a third subscriber's machine.

(b) **Write Long Distance:** By connecting the observation teleprinter contacts and magnet directly to the long distance channel so that the channel may be tested clear of the long distance relay set. In this condition the marking (— battery) and spacing (+ battery) potentials are connected directly to the transmitter contacts of the observation teleprinter.

(c) **Write Locally:** When testing into the local "line" jacks, the observation teleprinter contacts and magnet and local teleprinter loop under test are connected to a point-to-point relay set incorporated in the observation equipment. The local loops and associated subscribers' machines may be tested individually and clear of the long distance relay set.

Q. 5.—Explain why a Gulstad relay is used on a long physical line, using sketches to describe its operation under working conditions.

A.—The signals sent over a long telegraph line become distorted due to the resistance, capacity, inductance and leakage of the line and the apparatus added to it. Due to these factors, a signal of short duration may not build up sufficiently to operate the receive relay and would thus be lost. The Gulstad relay provides a local circuit which, in effect, anticipates the line signals and tends to operate the relay should the received signal fail to build up to its full value, thus minimizing the effect of the electrical



Q. 5, Fig. 1.

inertia of the circuit and the mechanical inertia of the relay tongue.

In this way with the Gulstad relay an increased speed of working can be obtained from a given line.

The connections of a polarized differential telegraph relay with Gulstad (auxiliary) windings are as shown in Fig. 1.

The main windings of the relay D-U and D circle-U circle are connected in the line circuit (e.g., as the relay in a conventional differential duplex circuit) whilst the auxiliary windings are connected in a local circuit to the tongue of the relay. When there is no line current in the coils, the relay tongue vibrates in the following manner:—When battery is switched on and the relay tongue is on the space contact, condenser C charges in from + battery through resistance RT and winding AA. The current through the AA winding tends to keep the relay tongue on the spacing contact. As the condenser becomes charged, the current through the AA winding decreases and the current through the OO winding and resistance R takes control of the relay, and its polarity is such as to cause the relay tongue to commence to move to the mark contact.

When the relay tongue leaves the space contact, the condenser C discharges through the AA and OO windings in series, thereby assisting the steady current in moving the relay tongue across the gap. When the tongue reaches the mark contact, the condenser C is again charged through the AA winding of the relay and since the polarity of the marking battery is the reverse of that on the space contact, the AA winding now tends to keep the relay tongue on the marking contact. As condenser C again charges the OO winding again takes control, moving the tongue back to space. Thus a continuous vibration takes place, its period being determined by the values of C, RT and R. The currents in the AA and OO windings are kept to such values that their magnetic effect is less than that of the line windings when energized so that the latter have control over the relay. The rate of vibration of the auxiliary circuit is made equal to the speed of the incoming signals.

When the received dots are so attenuated that they would not be normally received, the AA and OO windings take control of the relay and interpolate them. With received dashes since the line current builds up to full value in the longer signal, the line windings take control of the relay. However, in all relay transits in either direction, the auxiliary circuit will speed up the operation of the relay and hold the tongue on its contact, thus reducing contact bounce.

The currents in the various windings are shown graphically in Fig. 2 of Q.7, reproduced in the Journal for February, 1944, p. 380.

Whilst the line current is marking, the current through the AA winding tends to keep the relay marking at the commencement of the signal. The current through the OO winding tends to make the relay space and in the steady condition (at the end of the signal) the line currents and OO winding currents are in opposition. It can thus be seen that the success of the arrangement depends on keeping the OO winding current lower than the line winding current, otherwise incoming signals will be broken up by the auxiliary circuit.

Q. 6.—Make a list of the electrical testing and measuring instruments and equipment which you consider are necessary in a Telegraph Maintenance Section workshop. Briefly discuss the use of each item listed.

A.—The electrical testing instruments required in a Telegraph Maintenance Workshop are as follow:—

(i) a general purpose voltmeter, milliammeter, ohmeter, etc., such as an "Avometer";
(ii) detectors No. 4;
(iii) a bridge megger;
(iv) a buzzer test set;
(v) a teleprinter test set (Telegraph tester);
(vi) a Murray multiplex test set;
(vii) a Wheatstone test set (where Wheatstone equipment is used);
(viii) reversal generator;
(ix) relay test set.

Purpose and Description of Instruments and Equipment: (a) (i) The avometer or similar instrument is a combination voltmeter, ammeter, milliammeter and ohmeter with the following full-scale readings:—

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

Separate instruments would, of course, be satisfactory.

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

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

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

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

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

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

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

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

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

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

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

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

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

Q. 7.—Discuss the properties of the various metals used in the manufacture of telegraph instruments and equipment, indicating the machining properties of the metals to which reference is made.

A.—Iron: Iron is a soft metal varying in colour from very light to dark grey. Its specific gravity is from 7-8. Pure iron is rarely used for general engineering work but in combination with various other elements to form steel and special alloys.

Soft Iron: Soft iron is chemically pure iron and is used for the cores of electro-magnet coils. It is chosen for this work since it possesses little magnetic retentivity. Pure iron machines poorly since it is so soft that it tears badly. Also, after machining, it needs annealing if it is to be used in magnetic fields since working it hardens it and results in greatly increased retentivity.

Cast Iron: Cast iron consists of iron with from 2½ to 4½% carbon and small percentages of silicon, manganese, sulphur and phosphorus. Part of the carbon (approximately 1½%) is alloyed with the iron, whilst the remainder is pure graphite. Since cast iron is cheap, melts at a relatively low temperature (1200° C.) and is very fluid in the molten condition, it is widely used for castings. It machines very readily but cannot be used to take shock or tension loads since it is brittle and relatively weak under these conditions.

Steel: Steel consists of iron with varying percentages of carbon up to 1½% in combination with the iron. Mild steels contain from .15% to .3% carbon, medium carbon steels .3% to .8% and high carbon steels .8% to 1.5%. The mild and medium carbon steels are used for a wide range of components of machine telegraph equipment, being pressed out of sheet or machined from round or strip sections, and for small forgings. To improve the hardness of these components they may be case-hardened, which, in effect, gives a high carbon steel skin about the mild steel component. High carbon steel is used for springs and components which must be relatively elastic for shock loads. The hardness of steel increases with its carbon content.

Steel may be machined readily, after annealing, whilst the steel parts after machining may be hardened and tempered to reduce brittleness.

Great care must be taken with the heat treating of steel since prolonged over-heating results in permanent alteration of the chemical nature of the components, making it useless.

Copper: Copper is a soft red metal which, in its pure form, is an extremely good conductor of electricity. As such it is widely used for the electrical conductors of telegraph equipment. Copper conductors are generally cold drawn with resultant hardnesses and tensile strengths up to twice that of soft copper. Cold worked copper loses its hardness immediately on heating to redness. Due to its softness and ductility, copper is difficult to machine.

Brass: Brass is an alloy of copper and zinc, the proportions being approximately two to one. Slight variations in proportions make suitable brasses for casting, rolling into sheets and drawing into wire. Hard brasses possess a tensile strength comparable with mild steel. The colour varies from yellow to reddish-yellow, depending on the proportion of copper. Since the copper-zinc alloy under ordinary conditions is soft and ductile and consequently tends to drag when machining, a small quantity of lead (1 to 2%) is often added, which improves the machining qualities, the turnings breaking up into small pieces.

Phosphor Bronze: Copper-tin alloys (bronzes) with phosphorus added are widely used for castings, bearings, bushes and small pressed components in telegraph equipment. A typical alloy for bearings contains 11% tin and .3% phosphorus with the copper.

The bronzes, although fairly hard, can be machined readily, the chips coming off in small pieces. The metal is reddish-yellow in appearance. The hardness and strength of the bronzes is increased some 50% with cold working, but may be softened by quenching from a little below red heat.

Aluminium: Aluminium is a white metal of specific gravity 2.68, as compared with 7.8 for steel. This lightness makes it excellent for a wide range of work, particularly in saving weight in the major castings of telegraph equipment. Pure aluminium is very soft and weak and thus the pure metal is not widely used but is alloyed with copper and zinc. A typical casting alloy contains 12½ to 14½% zinc with 2½ to 3% copper, with increased tensile strength over the pure metal.

Pure aluminium, because of its softness and ductility, machines poorly but can be drawn and spun for small pressed components, whilst the casting alloys machine easily and cleanly.

Lead-Tin: Pure lead is a very soft bluish-grey metal, whilst pure tin is a soft silvery white metal. These metals in alloy are widely used as soft solders in the electrical wiring of telegraph equipment. The most commonly used alloy is 50% tin and 50% lead.

Q. 8.—Describe how you would "run-in" a quadruple multiplex set, assuming that you were at the "corrected" station. Briefly explain the reason for each operation performed.

A.—To run-in a quadruple multiplex set at the corrected station, the following procedure applies:—

(1) After the daily check of the machine equipment, relays and brushes, the set should be run locally to check the mechanical and electrical performance of all the terminal equipment.

(2) The long distance circuit (carrier or physical) should be checked by sending and receiving 50 cycle reversals on the channel, observing and arranging for the removal of bias if present.

(3) The correcting station sends space on all channels (i.e., correction signal only) so that the corrected station's distributor may run into synchronism with the distant station. The vibrator at the corrected station should be adjusted to run slightly faster than that at the correcting station and as the correction signal is received on all channels in turn, it is seen to beat approximately 20 times on any one receive segment.

(4) The correcting station sends thirds on W channel, thus permitting the corrected station to orient (the extra correction segment should not be in circuit). Since the receive segments of the distributor are half the length of the sent signals, they may be moved to a limited extent with respect to the sent signals without errors occurring in the received copy. Orientation consists of moving the receive segments to find these limits and setting them to the midpoint, which will give the optimum tolerance of distortion of sent signals.

(5) The corrected station sends thirds on W channel back to the correcting station.

(6) The correcting station then sends thirds on W and erase on Z channel simultaneously and the corrected station orients again, noting any change in orient from the first position. Should the change be appreciable, the extra correction segment should be switched in and the orient again checked and compared with the original orient. The receive ring should be placed at the optimum position between the original limits of orient and those obtained with the extra segment switched in at the corrected station and the erase sent on Z channel by the correcting station. This procedure is necessary since, due to the characteristic distortion of long distance circuits (particularly carrier telegraph channels), the distortion of the correction and other signals varies with the preceding signal combination.

(7) The corrected and correcting stations should exchange trial tapes on all channels and on receiving these correctly should hand the set over to traffic.

Q. 9.—Describe the methods employed to suppress radio interference from a teleprinter 7C. and show, by means of sketches, how the various components are connected in circuit.

A.—Radio interference from teleprinters is caused by the interruption of—

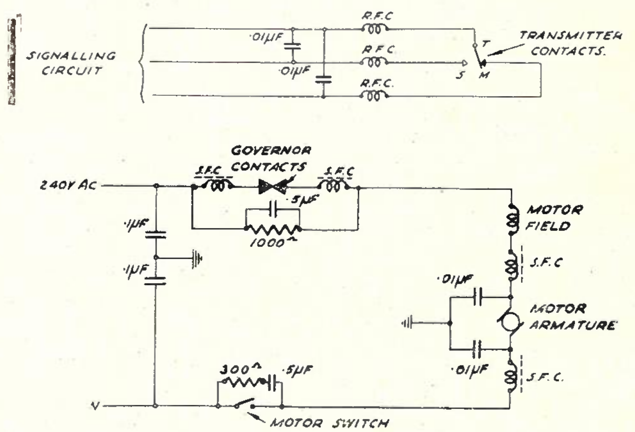
(a) the line signalling current at the transmitter contacts;

(b) the power supply to the motor at its commutator and brushes;

(c) the power supply to the motor at the motor governor contacts and governor brushes.

The general method of suppression is to connect small radio frequency chokes in series with the circuit to the interfering contacts and small condensers in shunt across them, or from the circuit to ground.

The impedance of the choke in series with the circuit attenuates the radio frequency components of the transients when the contacts make and break, whilst the condensers provide a shunt path for these components. This prevents the interfering frequencies from passing along the wiring of the telegraph equipment and radiating to radio receiving equipment. Since even short unsuppressed wiring leads in the teleprinter may radiate radio interference, it is necessary that all the suppressor components be mounted as close as possible to their associated contacts. Fig. 1 shows the suppressor components and their position in the circuit.



Q. 9, Fig. 1.

The coils RFC are commercial radio frequency chokes having inductances in the order of 5-10mH.

The coils SFC are wound with some 75 turns 26 S.W.G. D.S.C. copper wire on a sirufer (iron dust) former. The large wire is necessary due to the relatively large currents flowing in the motor circuit, whilst the sirufer former increases the effective inductance of the coil with consequent increase in the efficacy of the interference suppression. The .1 mf. condensers connected directly across the power circuit into the machine act as a general by-pass for any interference passing the individual suppression circuits and the minor interference due to the occasional operation of the mechanical motor stop switch.

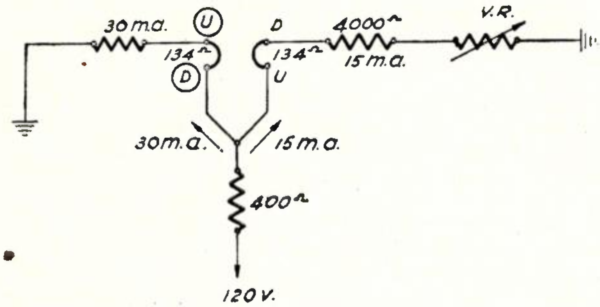
Q. 10.—In the circuit shown, the resistance values are such that 30 milliamps flows through the line winding of the relay, whilst 15 milliamps flows through the bias winding. When the variable resistance VR is adjusted to give this current value through the bias winding, calculate—

(a) its resistance;

(b) its wattage dissipation; and

(c) the potential drop across its terminals.

The internal resistance of the battery should be neglected.



Q. 10, Fig. 1.

A.—Since battery feed to both arms of circuit is via 400 ω, resistor, current flow through it is 30 + 15 = 45 m.a.

(1) Voltage Drop across 400 ω resistor

$$= \frac{45}{1000} \times 400 \text{ volts}$$
$$= 18 \text{ volts.}$$

Voltage Drop across 134 ω D-U winding

$$= \frac{15}{1000} \times 134 \text{ volts}$$
$$= 2.01 \text{ volts.}$$

Voltage Drop across 4000 ω resistor

$$= \frac{15 \times 4000}{1000} \text{ volts}$$
$$= 60 \text{ volts.}$$

Voltage Drop across VR resistor

$$= \frac{15 \times VR}{1000} \text{ volts}$$
$$= .015 \text{ VR volts.}$$

Total voltage across circuit is given by sum of voltages across the series components.

$$\text{i.e., } 18 + 2.01 + 60 + .015 \text{ VR} = 120$$
$$\therefore .015 \text{ VR} = 39.99$$
$$\text{VR} = \frac{39.99}{.015} = 2666\ \omega.$$

(2) Wattage dissipation of VR is given by I^2R.

$$= \frac{15}{1000} \times \frac{15}{1000} \times 2666 = .6 \text{ watts.}$$

(3) Potential drop across VR.
In Section (1) above, total voltage across circuit is

$$18 + 2.01 + 60 + .015 \text{ VR} = 120 \text{ volts}$$
$$\text{i.e., } .015 \text{ VR} = 39.99 \text{ volts}$$
$$\text{i.e., voltage drop across VR} = I \times VR = .015 \text{ VR}$$
$$= 39.99 \text{ volts.}$$

EXAMINATION No. 2585 — SENIOR TECHNICIAN (BROADCASTING) — PAPER No. 2, SECTION A

F. O. Viol and N. S. Smith.

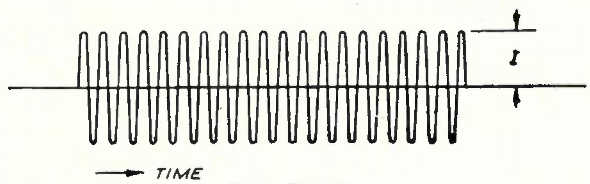
Q. 1.—What is meant by—

(a) Amplitude modulation of a carrier wave.

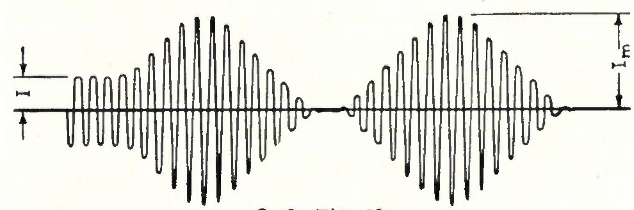
(b) Modulation capability of a transmitter.

Describe a method of measuring the percentage modulation of a B/C transmitter. A radio transmitter is delivering 10 kW of unmodulated power to a transmission line of 600 ohms impedance. What will be the peak voltage across the transmission line when the transmitter is modulated to a depth of 100% with a pure sine-wave?

A.—(a) Amplitude modulation is the term given to a method of imparting to a radio-frequency carrier wave the intelligence it is desired to transmit. The name is derived from the fact that the instantaneous amplitude of the carrier wave varies in accordance with the intensity or level of the modulating wave. If the carrier is modulated by a pure audio-frequency tone (sinusoidal wave) then the amplitude variations will occur at a rate equal to the frequency of the modulating tone. Fig. 1a represents a carrier wave of amplitude I.; Fig. 1b represents the same carrier modulated by a pure tone. The effect of amplitude modulation is apparent.



Q. 1, Fig. 1a.



Q. 1, Fig. 1b.

(b) It can be shown that the result of amplitude modulation is the production of a carrier wave and two side-bands, and that all the intelligence is carried by the side bands. Therefore, the more power that is in them the more effective will be the transmission. Maximum power occurs in the side-bands when the modulating wave causes the amplitude of the carrier to vary between zero and twice its normal value. (This condition is known as 100% modulation.) The modulation capability of a transmitter is the degree with which the transmitter can be modulated without the introduction of excessive distortion.

A convenient method of measuring the modulation percentage of a B/C transmitter is by observing the rise in line current or circulating current in the modulated-amplifier stage, assuming that the load is non-reactive. This method is reasonably accurate provided a sensitive meter with a good open scale is used.

The method is fundamentally derived from the relationship between unmodulated current, modulated current and percentage modulation. The relative expression is:—

$$K/100 = \sqrt{2 (I^2_m/I^2) - 2}$$

where K = percentage modulation

I_m = value of modulated current

I = value of unmodulated current.

If a number of values be allotted to K (100, 75, 50, 25, etc.), and the right-hand side of expression solved for I_m/I, a graph may be drawn relating percentage modulation (K) to the ratio I_m/I. The current I for a particular transmitter will be known, and the ratio I_m/I readily converted to values of I_m on the graph. Thus the procedure would be simply to note the value of modulated current and read from the graph the percentage modulation for that current value. It would be wise to check the unmodulated current value first to see if it is normal. Fig. 1a illustrates this form of graph.

P = 10 Kw unmodulated

Z = 600 ohms

K = 100% (modulation depth).

Find peak voltage across the transmission line—

$P = E^2/Z$, therefore $E = \sqrt{PZ}$.

This is the unmodulated r.m.s. value, and peak value will be—

$E(\text{peak}) = \sqrt{2} \times 2 \times \sqrt{PZ}$.

Substituting values—

$E = 1.414 \times 2 \times \sqrt{10000 \times 600} = 6930$ volts.

Q. 2.—State the principle of operation of the following types of microphones:—

(a) Velocity.

(b) Moving coil.

(c) Cardioid.

What are the particular advantages of each type, and under what circumstances would each type be normally used?

A.—When a sound wave passes by a velocity microphone the resulting force acting on the ribbon is proportional to the difference in sound pressure on the two sides and is also proportional to frequency. As the ribbon is suspended in a transverse magnetic field the movement causes a voltage to be induced in it which is proportional to the velocity of the ribbon. Since a difference of sound pressure is required to produce the movement, then sound waves from the side of the microphone will not produce a voltage in the ribbon. The microphone, therefore, is bi-directional in its characteristics. The ribbon acts as both the conductor of current and the diaphragm and is of such a low impedance that an audio-frequency transformer is fitted in the microphone to match the ribbon to an impedance of 50 ohms for the pre-amplifier.

The diaphragm of a moving coil microphone is enclosed. When a sound wave strikes the diaphragm a difference of pressure will occur between the two sides and a movement will result; inward if the pressure is greater on the outside, and outwards if it is less. The movement is proportional to pressure.

The coil is suspended in a transverse magnetic field, hence the movement will induce a voltage in the turns of wire. This voltage is proportional to the velocity of the diaphragm.

Sound waves from a source directly in front of the diaphragm will produce the greatest voltage, and from the rear the voltage will be at a minimum. The moving coil microphone is therefore unidirectional.

One type of cardioid microphone uses both a velocity and a moving-coil microphone mounted in a common housing. They are so connected that for sound waves from a source in front of the microphones the induced voltages are additive. For sound waves which come from a point at the rear of the microphone the voltages are out of phase and tend to cancel one another, which results in the directional characteristic.

Advantages:

(a) **Velocity microphone.**—The velocity microphone is bi-directional, and so is useful for interviews, where both sides can be used simultaneously; for play production, where use can be made of the sides to obtain special effects, and for musical items, such as a singer with piano accompaniment.

(b) **Moving coil.**—It is unidirectional and robust, which makes it useful for the description of sporting events. One type, when fitted with an acoustic baffle, is used for studio announcers.

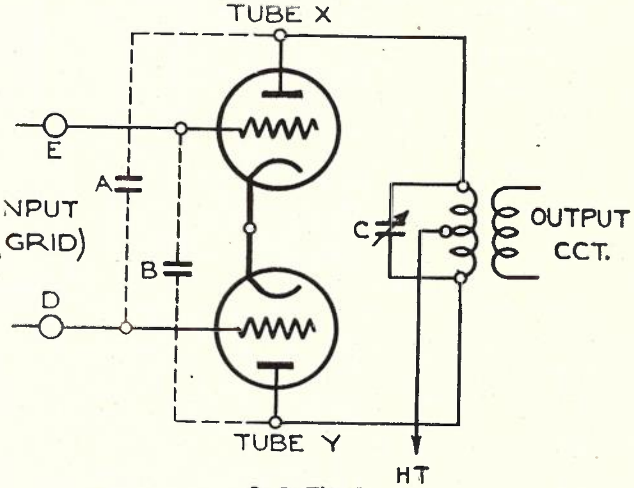
(c) **Cardioid.**—A switch is usually fitted so that each unit may be used singly or the two can be used together to give the cardioid pattern. This permits greater flexibility, and not only can it be used as indicated under (a) and (b) above, but it has greatest use for orchestral or choral work, where wide coverage is required.

Q. 3.—Why is it necessary to neutralize a radio-frequency amplifier? Show by means of a circuit diagram and describe the principle of operation of a neutralizing circuit for—

(a) Push-pull amplifier.

(b) An amplifier using a single tube.

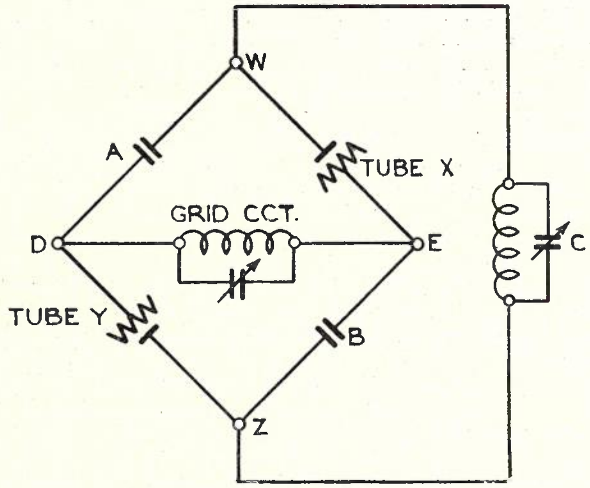
A.—It is necessary to neutralize a radio-frequency amplifier in order to reduce to negligible proportions the effect of internal capacitive coupling between the grid and anode electrodes. This coupling being capacitive has a reactance which decreases with frequency, and at radio-frequencies enough energy may be transferred from anode to grid to make the tube oscillate, especially in the case of triodes. This oscillation results in instability, distortion, etc., in the amplifier. Sometimes a tube is under-run to minimize this effect, but the efficiency is thereby impaired.



Q. 3, Fig. 1.

Fig. 1 shows the essential portion of a neutralized push-pull amplifier, A and B being the neutralizing condensers. The circuit may be rearranged as in Fig. 2, where X and Y are the tube anode/grid internal capacitances, and A and B the neutralizing condensers.

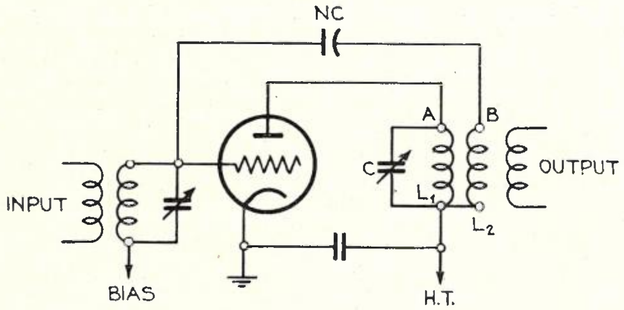
Under proper balance conditions the capacities A = Y = B = X, and a voltage generated across WZ by the anode coil will so divide around the circuit



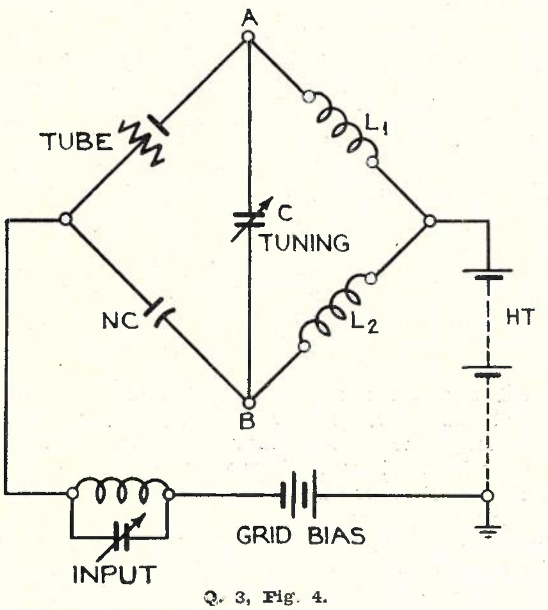
Q. 3, Fig. 2.

that no potential difference will exist across the points DE, i.e., the grid circuit. Thus there will be no feed-back from anode to grid. It is essential that the circuit be symmetrical and balanced externally for the neutralizing to be properly effective.

Fig. 3 shows one of several circuits applicable to single tubes, Fig. 4 being the equivalent circuit. This is known as the "neutrodyne" method.



Q. 3, Fig. 3.



Q. 3, Fig. 4.

In this circuit, L2 functions to generate a balance voltage and the neutralizing condenser NC is adjusted to equal the anode/grid capacitance of the tube. Under this condition, and providing L1 and L2 are balanced, the circuit is balanced and potentials at A and B are always equal and opposite.

It will be seen from the above brief descriptions that neutralizing consists of arranging the circuits in a Wheatstone bridge form, with the output circuit across one pair of terminals, and the input circuit across the other pair.

Q. 4.—What is the unit in which the signal intensity of an electro-magnetic wave is expressed?

Give an outline of a method for measuring the field intensity of a signal radiated from a broadcasting station, and state the precautions you would adopt in making the measurements.

A.—The fundamental unit for measuring field intensity is the volt/metre, and a field possesses this intensity when a potential difference of one volt is produced between the ends of a vertical aerial one metre long in the field. This unit is too large for practical purposes, and the sub-multiples millivolt/metre (mV/m), and microvolt/metre (μV/m) are in general use.

One method of making field strength measurements is to match the received signal with a signal from a calibrated local oscillator tuned to the same frequency as the station being measured. A sensitive meter suitably connected in the receiver circuit is used as an indicator, and the local oscillator is adjusted until the reading on this meter is the same as that of the station.

Main items of equipment are:—

- Loop aerial;
- Radio receiver;
- Local oscillator;
- Meters, switches, attenuators, etc.

A loop aerial is used since its constants may readily be determined and its effective height calculated from the formula:—

$$H = 2\pi NA/\lambda$$

where N is number of turns of loop
A is area of loop in sq. metres
H is effective height of loop in metres
λ is wave length in metres.

A loop aerial also possesses the advantage of directional pick-up, enabling it to be rotated to a minimum pick-up position, which occurs when the plane of the loop is perpendicular to the direction of propagation of the signal.

Technique: The desired signal is tuned in on the receiver, the tuning controls and the loop being adjusted carefully for maximum deflection on the meter, which value is noted. The loop is then oriented for minimum signal (or zero signal under most conditions), and the local oscillator switched on. The oscillator controls are then adjusted to give the same reading on the meter as the station being measured. A quick recheck is made of the station strength, and finally the readings of the local oscillator noted. (The oscillator voltage is injected into the electrical centre of the loop.) The voltage injected into the loop is then computed, unless the F.S. set is direct-reading, as is the practice with present instruments.

Let this voltage be E_0 volts—then the field strength is E_0/H units per metre.

Precautions to be observed:

(a) Avoid proximity of overhead telephone or power lines. (Minimum distance, about 50 yds.)

(b) Avoid making measurements close to the B/C station or aerial system.

(c) Keep clear of large buildings, especially if they are steel-framed.

(d) It is sometimes difficult to obtain a satisfactory null near steep hillsides or in deep valleys.

(e) The effect of trees is not very definite, but it is advisable to keep clear of them.

Note: The reader is referred to Paper 4, paragraph 6 of Radio I. Course of Technical Instruction.

SECTION B

Q. 5.—Describe in detail how you would measure—

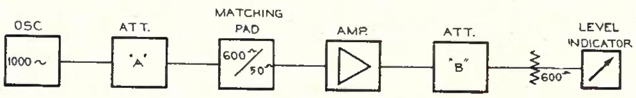
(a) The overload point of a microphone amplifier.

(b) The frequency response of a line amplifier.

(c) The overall frequency response and carrier noise of a 10 kW radio transmitter.

Give the set-up of the apparatus and the precautions you would take in making the measurements.

A.—(a) The apparatus required and method of connection to test the overload point of a microphone amplifier are shown in Fig. 1. It is assumed that the input is 50 ohms and the output 600 ohms.



Q. 5, Fig. 1.

Procedure: With attenuator "B" at zero, adjust the output level to 1 mW by means of attenuator "A."

Decrease attenuator "A" in 1 db steps, and at each step increase attenuator "B" by 1 db. The output level should return to 1 mW after this latter step until overload point is reached, when the output level will read less. In other words, there is linearity between input and output levels until overload point is reached.

The overload point for the amplifier is expressed in db above 1 mW, and is the reading of attenuator "B."

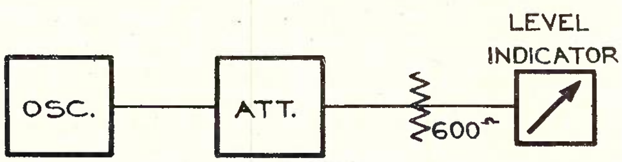
It is usual to plot input versus output level; the resultant graph will be linear until overload point is reached.

(b) The frequency response of a line amplifier is measured in two parts as follows:—

(i) calibration of measuring equipment;

(ii) frequency response test.

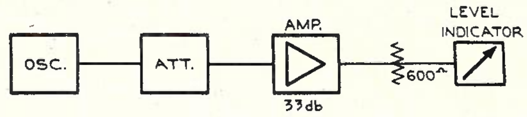
(i) The equipment is connected as shown in Fig. 2, and the level adjusted to 1 mW by means of the



Q. 5, Fig. 2.

attenuator, with the oscillator set at 1000 C/s. The oscillator is now varied over the frequency range 30 to 10,000 C/s and the meter reading is maintained at 1 mW by means of the attenuator. The frequency and attenuator setting are recorded at frequent points.

(ii) The equipment is now connected as shown in Fig. 3. The output of the amplifier is adjusted to

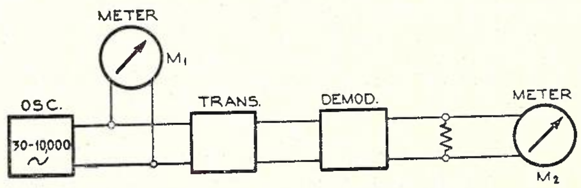


Q. 5, Fig. 3.

1 mW, which is appreciably lower than the overload point, and the oscillator is varied over the frequency range 30-10,000 C/s. The meter reading is maintained at 1 mW by means of the attenuator, and the frequency and attenuator settings are recorded at the same points as in (i). The corrections obtained from test 1 are now applied, and the resultant is the frequency response of the amplifier.

Note: Should it be known that the oscillator and level indicator are linear over the required frequency range, step 1 may be omitted.

(c) (i) The overall frequency response of a radio broadcast transmitter may be measured as indicated in Fig. 4. The equipment required is as follows:—



Q. 5, Fig. 4.

(a) Variable oscillator capable of adjustment to any frequency from 30 to 10,000 C/s, and with its output impedance matched to the input impedance of the radio transmitter speech amplifier.

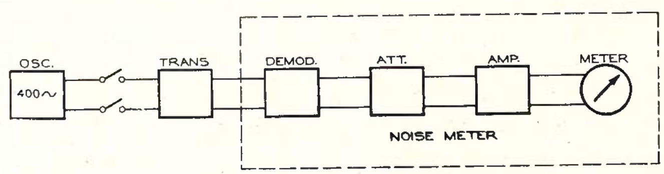
(b) Level indicator connected across output of the oscillator to indicate the level sent in to the transmitter.

(c) Demodulator coupled to the transmitter output and with a flat audio frequency response from 30 to 10,000 C/s.

(d) Level indicator calibrated in decibels connected to output of demodulator.

The oscillator is set at 1000 C/s and the output adjusted until the transmitter is modulated 40%. The input level to the transmitter, as indicated by the meter M.1, is noted. The meter M.2 is adjusted to read zero. The oscillator frequency is then set at 30 C/s and the output adjusted till the same reading is indicated on the meter M.1 as before. The output level on M.2 is then read, and the difference in db between this and the previous reading is the response at 30 C/s. This procedure is repeated at suitable frequencies in the range 30 to 10,000 C/s, i.e., 50, 75, 100, 200, 500, 700, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10,000.

(c) (ii) The carrier noise of a 10 kW radio transmitter can be determined by measuring the voltage across a suitable demodulator when no modulating voltage is applied to the input of the transmitter.



Q. 5, Fig. 5.

The noise is generally expressed in decibels below 100% modulation, and may be measured with an oscillator and noise measuring set, as indicated in Fig. 5.

The noise meter consists essentially of a demodulator, which is coupled to the output of the transmitter and which is connected through an attenuator and amplifier to a vacuum tube voltmeter. The audio frequency response of the demodulator attenuator and amplifier should be flat from 30 to 10,000 C/s.

To measure noise, the output of the 400 C/s oscillator is fed into the transmitter and the level adjusted until the transmitter is modulated 40%. The amplifier of the noise measuring set is then adjusted until full scale deflection is indicated on the vacuum tube voltmeter. The modulating tone is then removed from the input of the transmitter and the attenuator is reduced until the same meter reading is obtained as before. This meter reading is a measure of the noise or residual modulation produced in the transmitter, and the noise level (in db below 40% modulation) is given by the number of decibels by which the attenuator has been reduced. As the measurement was made with the transmitter modulated 40%, the value of the transmitter noise with reference to 100% modulation is obtained by adding —8 db to the result obtained.

Q. 6.—Explain the action of a superheterodyne receiver. What is meant by image ratio, selectivity, sensitivity, second-channel interference, and how would you measure them?

Indicate briefly the tests you would apply to a good quality receiver used for the relaying of overseas programmes.

A.—A superheterodyne receiver functions on the principle that the desired signal is converted to a signal of lower frequency and then amplified at this new frequency in a high-gain amplifier, termed the Intermediate Frequency Amplifier (I.F. Amp.).

Since the I.F. Amplifier operates at a fixed frequency, it can be designed to have high gain, high selectivity, good band-width, and these characteristics will be constant over the frequency range of the receiver.

Most receivers operating in the band 550 kC/s to 30 mC/s have an I.F. of the order of 450 kC/s.

Fig. 1 is a simplified dagram of a superheterodyne receiver.

R.F. Stage: This stage amplifies the desired signal at the signal frequency, and serves mainly to improve sensitivity, selectivity, image frequency rejection, signal-to-noise ratio and to minimize reradiation from the local oscillator.

Frequency converter: This receives the signal from the R.F. amplifier and also a signal from the local oscillator. These two signals are combined and of the products of mixing the difference frequency is selected by the tuned output circuit for amplification in the I.F. Amplifier. The I.F. carries the same modulation as was present on the original signal.

Oscillator: This furnishes to the converter stage a signal which always differs from the desired signal by the I.F., and is in most cases higher than the signal. Ganging the oscillator tuning condenser with the normal tuning condenser simplifies this procedure. Thus, in a receiver having an I.F. of 455 kC/s and a range of 550 to 30,000 kC/s, the oscillator range will be 1005-30,455 kC/s.

I.F. Amplifier: This is a high-gain amplifier, usually two or three stages, which provides most of the gain and selectivity of the receiver. It is also easy to provide variable selectivity in this stage, since it operates at a fixed frequency.

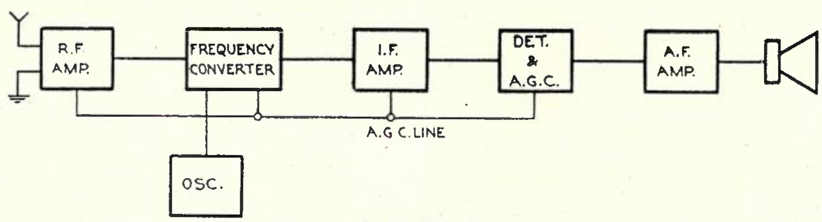
2nd Detector: This stage usually employs a double diode tube, one diode to rectify the signal, the other to supply automatic gain-control voltage. This stage is followed by an audio frequency amplifier capable of furnishing the required power output.

Definitions: (a) Image ratio.—This is the ratio of the amount of signal at the image frequency to the amount at the desired frequency to give the same output from the receiver. (Image frequency is the desired frequency plus twice the Intermediate Frequency.)

(b) Selectivity.—This is the ability of a radio receiver to discriminate against unwanted signals.

(c) Sensitivity.—This sensitivity of a receiver is expressed as the least value of input signal which will furnish a standard output with a given signal-to-noise ratio.

(d) Second-channel interference.—This is the interference resulting from the inability of a receiver to discriminate against a signal at the image frequency (see definition (a)).



Q. 6, Fig. 1.

Measuring the above: A standard signal-generator, dummy aerial, receiver and output indicator or power meter are connected as in Fig. 2.

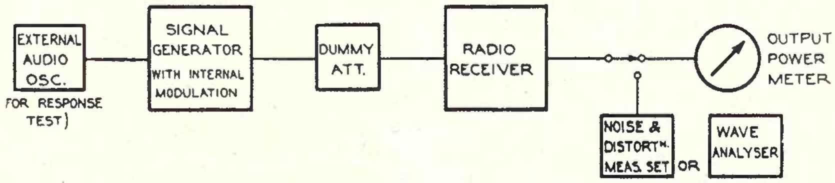
Image ratio: The receiver is tuned to the signal frequency at which measurement is to be made, and the signal generator and receiver adjusted for a convenient output. The S.G. output is noted and it is then tuned to the image frequency (as defined above) and the output adjusted until the receiver output is as before. The image ratio is then—

$$\frac{\text{Amount of signal at desired frequency}}{\text{Amount of signal at image frequency}}$$

Selectivity: Connect as before, and adjust for standard output. The signal generator frequency is then varied in 10 kC/s steps above and below the test frequency, being adjusted each time to give the same output from the receiver. The generator output is noted for each frequency, and the results are plotted in the form of a graph of frequency versus the ratio—

$$\frac{\text{Output at frequencies off resonance}}{\text{Output at resonant frequency}}$$

Sensitivity: Connect as above, and adjust the receiver controls for maximum gain, rendering the A.G.C. inoperative. Tune signal generator and receiver to the required frequency with the S.G. modulated to a depth of 30% by the internal modulating frequency. The S.G. output and the receiver audio frequency control are then adjusted until standard output is obtained with the desired signal-to-noise ratio. This latter is measured by noting the difference in output with modulation switched on and off.



Q. 6, Fig. 2.

Second-channel interference: See test for image ratio.

Tests required on a good-quality receiver:

(a) Sensitivity.
(b) Selectivity.
(c) Image ratio.
(d) Frequency response.
(e) A.G.C. effectiveness.
(f) Signal-to-noise ratio.
(g) Harmonic distortion.
(h) Power capability.
(i) Oscillator drift.
(j) Maximum undistorted power output.

Q. 7. (a) Given a choice of high-vacuum and mercury-vapour types of rectifying tubes, which type would you use to supply the anode potential of a high-power B/C transmitter using class B modulation in the final stage? Give reasons for your answer.

(b) Give a circuit diagram of a 3-phase full-wave rectifier, including the filter circuit.

(c) If the output of a rectifier is 160 kW and the efficiency 90% what will be the current taken from the supply mains at a power factor of 0.85 (neglecting filament heating) if the voltage between phases is 400V rms.?

A.—(a) Mercury-vapour type of rectifying tubes would be selected because of their good regulation under the variable load conditions such as would be imposed by the given transmitter. The voltage drop across this type of tube remains at about 15 volts over a wide range of load currents.

(b)

3-Phase Full-Wave Rectifier

T_1 = Delta-star 3-phase high-tension transformer;
T_2–T_5 = Filament transformers for rectifiers;
V_1–V_6 = Mercury-vapour rectifying tubes;
L_1, L_2 = Filter chokes;
C_1, C_2 = Filter condensers.

(c) Output, 160 kW; efficiency, 90%; power factor, 0.85; phase voltage, 400Vr.m.s. Find line current:—

Actual output = 160 x 100/90 = **1600/9 kW.**

Power in a 3-phase circuit, P = 3 E I Cos θ

where P = power in watts
E = Line voltage
I = Line current
Cos θ = Power factor.

Line voltage is 3 times the phase voltage, therefore line voltage equals—

$400 \times 3 = E.$

Transposing the formula for I—

$I = P/(3\ E\ \cos\theta)$

$I = 16 \times (10^6/9) \times 3 \times 400 \times 0.85$

$I = 16 \times 10^4/918 =$ **174.3 amps.**

Q. 8.—Describe briefly the equipment required and procedure to be adopted in making a disc recording of an overseas broadcast for rebroadcasting purposes.

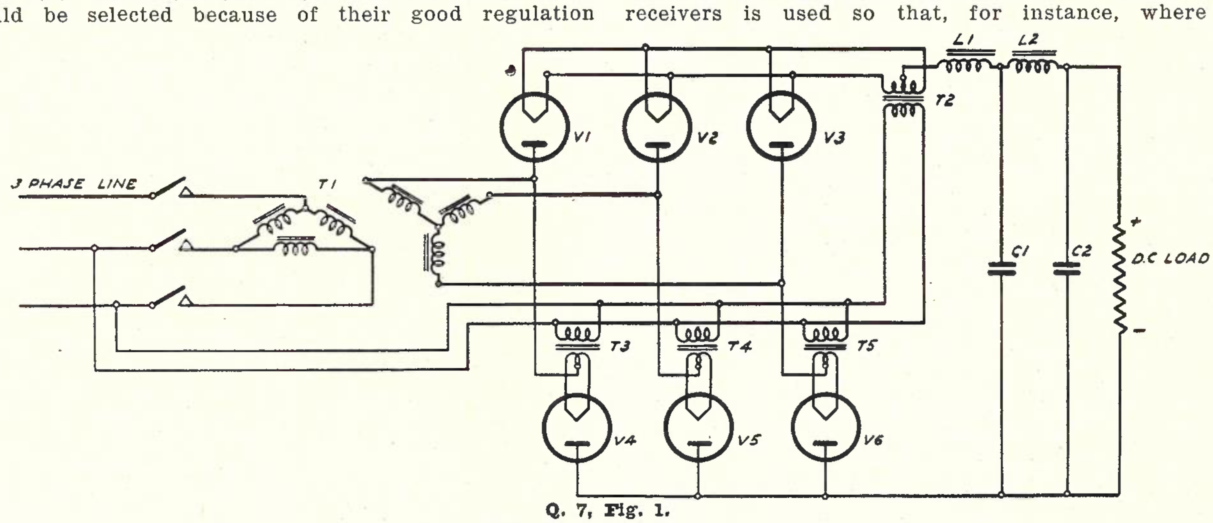
State any special requirements you consider necessary in equipment at—

(a) Receiving point;

(b) Recording centre.

A.—The equipment required to make a recording of an overseas broadcast is, primarily, in two groups, as follows:—

(a) **Receiving centre:** A number of communication receivers is used so that, for instance, where the



Q. 7, Fig. 1.

B.B.C. transmits a programme on more than one frequency, each can be observed continuously and a choice made of the best output for use at the recording centre.

(b) **Recording centre:** An equalized programme channel is used between the two centres, and the line amplifier restores the programme level to 6 mW. In the recording room the equipment usually consists of a gain control, an automatic recording equalizer for use when recording at 33⅓ r.p.m. on a 16 inch disc, and the recording amplifier, which operates the recording heads fitted to the recording machines.

Level indicators are used to maintain the programme at a satisfactory level at various points.

Procedure (assuming a B.B.C. item is to be recorded): At the receiving centre, the receivers are tuned to the frequencies of the transmitters, use being made of rhombic aerials directed on London. This is done some time before the actual broadcast, so that the most satisfactory output can be fed to the recording centre. The operator at this centre is notified of the channel on which the programme is being fed.

At the receiving centre, the programme is monitored, and at the same time the recording machines are tested by making test cuts on the machines. This is to ensure that the machines, discs and recording sapphires are satisfactory.

When the starting announcement is heard, the recording commences, and continues until the specified item concludes, after which the discs are played back as a final check.

The special requirements at the receiving centre are as follow:—

1. Provision of a switching panel so that any receiver can be connected to any aerial.

2. Adequate monitoring facilities, both headphone and loudspeaker.

3. A number of communication receivers with the following facilities and requirements—

3. 1—Frequency range at least 6 to 20 mC/s.
3. 2—Reliable performance to operate 24 hours per day throughout the year.
3. 3—Input circuit suitable for balanced or unbalanced aerials.
3. 4—High sensitivity, at least 1 μV per metre.
3. 5—High tuning accuracy.
3. 6—Good stability after warming-up period.
3. 7—Satisfactory A.V.C. characteristics with suppression between signals.
3. 8—Variable selectivity.
3. 9—Low noise level.
3.10—Satisfactory image frequency ratio.
3.11—R.F. control.
3.12—A.F. control.
3.13—Tuning meter.
3.14—Band switching.
3.15—Simple tuning.
3.16—Satisfactory audio frequency response.
3.17—Adequate power output.
3.18—Headphone and loudspeaker monitoring.
3.19—Diversity receiving equipment is useful for this type of reception.

The special requirements at the recording centre are:—

1. Dual recording machines, to permit continuous recording at 78 or 33⅓ r.p.m.

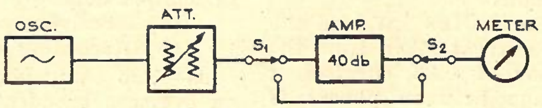
2. Must record "inside to out" or "outside to in."

3. Must be able to record on discs up to 17¼ inches in diameter.

4. Must be simple to operate, yet reliable.

5. Adequate monitoring facilities.

6. Switching panel to control the automatic equalizer and to enable satisfactory changeovers to be made from one machine to the other.



Q. 5, Fig. 1, Section B, Paper 1.

ERRATA

The above drawing should have appeared as Fig. 1, Q. 5, page 120, of the October, 1946, issue, in lieu of the drawing shown.

The Ruskin Press
123 Latrobe Street
Melbourne