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The
Telecommunication Journal of Australia

Vol 7, No. 6 *February, 1950*

MR. N. W. V. HAYES

The Telecommunication service of Australia suffered a severe loss in the sudden passing of Mr. Norman Hayes on 12th February.

Mr. Hayes had a long and distinguished career in the Engineering Branch of the Postmaster-

General's Department. After training as a Junior Engineer in South Australia he took charge of Country Equipment in that State. At later periods he was engaged on Line and Transmission work in New South Wales and the Central Administration and took a prominent part in the design and provision of the Sydney-Maitland trunk cable and its associated equipment.

Mr. Hayes afterwards became Superintending Engineer, Victoria, which position he held until his return to Central Office as Deputy Chief Engineer. At the time of his death Mr. Hayes was A/g. Asst. Director-General (Engineering Services) and Engineer-in-Chief.

Mr. Hayes was interested in many activities outside the duties of the positions he occupied. He was for some years a prominent executive of the New South Wales Branch of the Professional Officers' Association and gave valued assistance in connection with Arbitration proceedings. He served as a Councillor and President of the Victorian Division of the Australian Postal Institute. He was a foundation member of the Institute of Radio Engineers, being Chairman of the Victorian Division for some years, and also Federal President.

Mr. Hayes was greatly interested in the training activities of the Department, particularly in those connected with the training of the younger members. He took a great interest in the work of the Postal Electrical Society and also in the production of the Telecommunication Journal. He had a high regard for the work performed by the Society and regarded the Journal as a most valuable contribution to the technical literature on Telecommunication work.

During the war years Mr. Hayes was connected with much of the work in which the Post Office and Defence Forces were jointly concerned and, later, as Superintending Engineer, Victoria, took a considerable part in planning Civil Defence measures together with the provision of means of maintaining essential communications under emergent conditions. Under his guidance much essential material for the Armed Forces was produced in the Victorian Engineering Workshops.

In spite of his many activities Mr. Hayes always found time to lend a helping hand where needed and many officers of all grades benefited from his sound advice. He was a man of outstanding judgment, enthusiasm for the job in hand and above all took a human interest in all those with whom he came in contact.

MOBILE RADIO TELEPHONE SERVICES

N. S. Feltscheer

Introduction

The P.M.G.'s Department is preparing a service which offers communication between any suitably equipped vehicle moving within a prescribed area (initially within capital cities) and any telephone connected to the public network. This type of service is termed a common carrier service as distinct from the type of service, generally termed a despatch type, in which communication with vehicles is limited to a single fixed point and the information transmitted is of a specialised nature. The name follows directly from the fact that organisations which cater for the general communication needs of the public are termed common carriers.

It is the aim of this article to cover briefly the operating principles, design considerations and equipment details of a common carrier urban mobile radio telephone service. There are certain problems inherently peculiar to common carrier working as opposed to despatch working and these points will be made in the course of the discussion as they occur.

Development

Continuous communication by means of radio between moving and fixed units has been a widely practised art for many years. Public utilities and police departments have used radio to exchange information between vehicles and headquarters, and a radio telephone service between ships at sea and normal telephones has long been available. This new mobile service uses radio waves to carry the intelligence between vehicles and a fixed transmitter and receivers, and wire lines to connect the transmitter and receivers to the telephone network.

It is thus a development from a number of previous services. Also, although the advent of war probably delayed the introduction of mobile services, techniques developed for the production of war communication equipment have found application in this new sphere.

General Characteristics of the System

Frequencies used by both fixed and mobile transmitters are in the V.H.F. band of 156 Mc/s to 170 Mc/s. This band is used because propagation is effective little beyond line of sight, thus allowing the same frequencies to be used in different cities, because lower frequency bands are not available and because the physical size of an efficient aerial at these frequencies is small enough to allow of an almost inconspicuous installation on vehicles. There is also evidence that much higher frequencies will give substantially the same service as frequencies in this band, but equipment design becomes more difficult as the frequency increases. Vertical polarisation of the carrier wave is used because it simplifies the antenna installation on vehicles.

Phase modulation (PM) giving an equivalent maximum frequency deviation of $\pm$ 15 kc/s with a maximum modulation frequency of 3 kc/s is standard. The reasons for the choice of PM are set out in the following paragraphs.

To start with, frequency modulation (FM) gives a better signal/noise ratio than amplitude modulation (AM), except for the unimportant case where the received signal is so near the noise level that neither system gives a signal/noise ratio satisfactory for a common carrier service. For a system having the characteristics stated above the superiority of FM over AM amounts to 18.8 db.

PM produces equivalent FM in which the instantaneous deviation of the carrier is directly proportional to both the magnitude and frequency of the modulation. Compared with FM then, PM produces a 6 db. per octave pre-emphasis characteristic, which, for average voices and using standard telephones, increases the signal/noise ratio by about 4 db. with respect to pure FM.

However, the major reason for using PM instead of FM is to take advantage of the frequency stability afforded by the use of crystal oscillators in the mobile transmitters. Crystal oscillators cannot be used if it is desired to generate FM directly.

As mentioned above, the use of AM instead of FM may extend the service area of despatch type services in which a very low grade of service is acceptable, but over most of the area the signal/noise ratio would be considerably worse.

The service given is essentially the same as a wire party line with selective calling of individual subscribers. A number of subscribers operate on a pair of frequencies separated by about 5 Mc/s, all receiving on one frequency and all transmitting on the other. The maximum number operating on one channel is dependent upon the traffic, and a figure of fifty has tentatively been set for Australia.

Full duplex facility as for a normal call is obtained at the fixed telephone end, but, to economise in power drain and to simplify the aerial installation, simultaneous transmission and reception at the mobile end are not provided. The aerial is normally connected to the receiver input with the transmitter de-energised and, upon the pressing of a switch located on the handset, the aerial is switched to the transmitter output and the transmitter energised. Thus the mobile user controls the conversation as he cannot hear from the other party while the "talk" button is depressed.

There are two major types of calling systems and the Department is providing fixed equipment that will operate in conjunction with either type.

One system transmits alternate pulses of two audio frequencies corresponding with the impulses from a standard telephone dial. In Australia the frequencies used are 2,200 and 2,800 c/s. Every number allotted has the same number of digits which, when added, give the same total; for example, 1171 and 1162 are two possible numbers for a system using four digits which total ten. A selector in the mobile unit adds the digits but only reaches the last contact corresponding to the common total if the particular combination for which it is set has been dialled.

The second system uses from two to four audio frequencies transmitted in succession. Tuned reeds in the mobile selector vibrate mechanically when the frequency to which they are tuned is received. If all the frequencies to which the individual reeds are tuned are received in the correct order, a circuit is completed for the bell and call lamp. As the number of audio frequencies available is several times the number which is simultaneously transmitted for any one call, a great number of different code calls are possible with this system.

Radiated power from mobile transmitters is of the order of 20 watts while base transmitters radiate about 250 watts. Because of this power difference, much greater areas are effectively covered by the base transmitters than by the mobiles. One base transmitter is sufficient to cover any Australian city, but it is necessary to place several receivers within the area to be served in order to equalise the service range for both directions of transmission.

Design Considerations

When designing a common carrier mobile radio telephone service, it must be kept in mind that the subscribers on the telephone end will expect a similar service to that which they get from other types of connections. If normal duplex working was employed, short period radio carrier drop-outs, while being undesirable, would probably not affect the progress of a call; but, with the use of press-to-talk duplex at the mobile end, even spasmodic drop-outs are likely to cause confusion to the speakers. It is essential then to ensure that there are no points within the service area where reception by or transmission from a vehicle is so weak that drop-outs will occur.

Assuming the base transmitter covers the desired area to satisfaction, the problem becomes one of ascertaining the number and positions of the fixed receivers. By considering the characteristics of the fixed receivers it is possible to deduce a minimum value of field strength which will give the minimum acceptable signal/noise ratio. The minimum field strength that will be obtained from a mobile transmitter in any particular location is dependent upon a number of factors and, to estimate this field strength, it is more convenient to consider the fixed receiver as the mobile transmitter and vice versa. As reciprocal relations obtain between transmitting and receiving aerials, no approximations are involved.

Due to shadow effects and reflections, differences in field strength of 40 db. within a few feet are quite common in city streets, and even in suburban residential areas standing wave ratios of less than 15 db. are seldom encountered. As a vehicle moves along a street the received field strength varies between the normal (no shadows or reflections) value and a value that is less than the normal by these amounts.

Raising the aerial above the level of the surrounding ground obtains an increase in signal of 6 db. every time the height is doubled. This height gain is also obtained on the side or crest of a hill facing the direction of reception, provided that the slope of the ground in front of the aerial exceeds a certain value. If at a distance D from the aerial, the ground level has fallen in height $h = 1.8\sqrt{D}$ then the full height gain of h is obtained. However, if the aerial is on top of the same hill which has a flat top, and some distance back from the crest, it is likely that no height gain will be obtained due to the fact that the curve of $h = 1.8\sqrt{D}$ now intercepts the ground immediately in front of the aerial. Fig. 1 demonstrates both these cases. As the aerial is moved down the other side of the hill, conditions quickly change and a shadow loss soon occurs. If the slope of the hill is such that the curve $h = 1.8\sqrt{D}$ intercepts the contour at some distance from the aerial, then the height gain is given approximately by the difference in height between the aerial and the point where the curve intercepts the contour. Fig. 2 demonstrates this case.

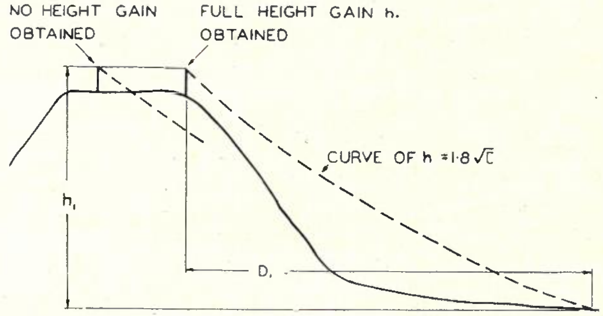


Fig. 1.—Height gain—case 1.

It is evident from this that height gains due to the locality of a mobile unit are obtained only over limited areas and for this reason are generally disregarded when estimating service areas.

Hills intervening between transmitter and receiver cause a drop in the mean signal level. The signal loss in the shadow of a hill increases with the height of the hill and with the angle that a line between the top of the hill and the receiving aerial makes with the horizontal. A hill rising 200 feet above the surrounding area and having a gradient of 1 in 10 (quite steep) on the side remote from the transmitter would produce a maximum shadow loss of 16 db. In Melbourne and its suburbs, shadow losses of greater than 10 db. are rarely encountered.

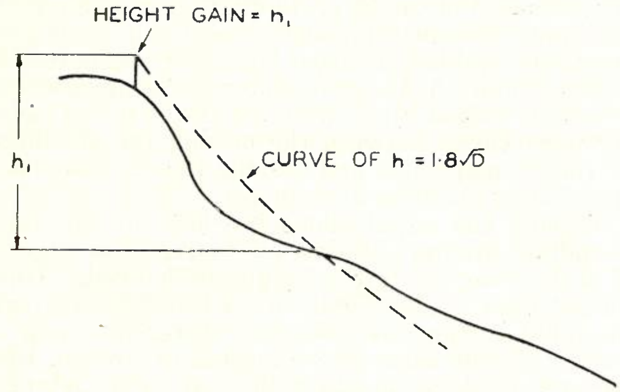


Fig. 2.—Height gain—case 2.

Allowance for the amount that the signal falls below the normal value due to local reflections and shadows is made by subtracting empirically derived figures for each situation from the normal value. Typical figures are 20 db. for average suburban business streets and 15 db. for average suburban residential streets.

The area served by a fixed receiver is considered to terminate at the first point from where a mobile transmitter will produce less than the minimum usable signal at the receiver. As the transmitter moves further away from the receiver, the field strength may rise again and give a usable signal for an appreciable distance, but because a common carrier service must give a hundred per cent. coverage, this extra service cannot be included. The individual service areas of fixed receivers are thus estimated and the receivers positioned to give sufficient overlap of service areas to allow for deterioration of equipment and for abnormal conditions.

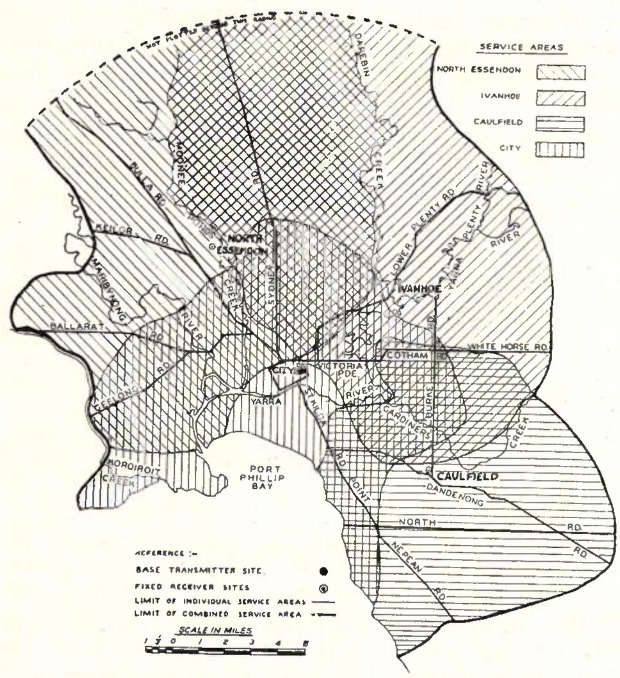


Fig. 3.—Limits of receiver service areas, Melbourne.

Fig. 3 shows the positions of the base transmitter and fixed receivers of the Melbourne experimental system with individual receiver service areas marked. These service areas are as actually measured and show close agreement with estimated areas. The base transmitter service area is not plotted but it extends beyond that of the combined receiver areas in all directions.

Equipment Details

Basically, there are five major units in a complete installation of equipment in a vehicle; transmitter, receiver and selective call mechanism which may be situated remotely from driver or passengers in any convenient space (generally the luggage compartment in passenger vehicles), control unit with handset situated on or under the dash, and the aerial which mounts on the roof of the vehicle. See Fig. 4.

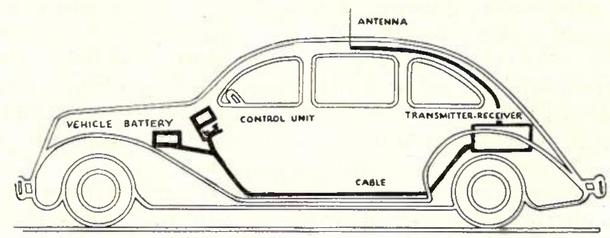


Fig. 4.—Layout of vehicle equipment.

The physical appearance of mobile equipment varies considerably according to manufacturers' ideas. Construction of the remote equipment ranges from a single integral chassis on to which is built transmitter, receiver and selective call

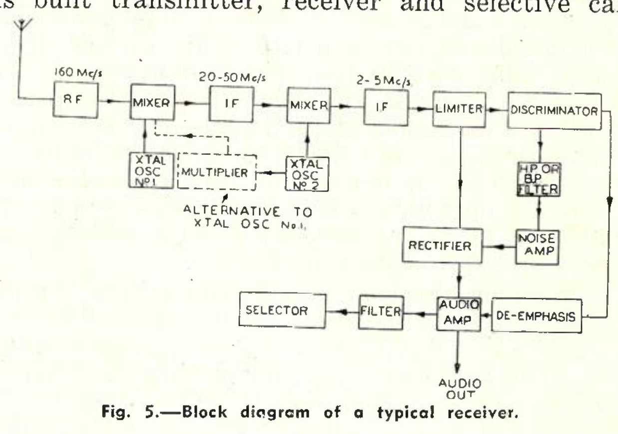


Fig. 5.—Block diagram of a typical receiver.

mechanism, to three separate units, one for each of these items. Electronically, there is more standardisation. Fig. 5 shows a block diagram of a typical receiver. Double frequency conversion with a high first intermediate frequency is employed to obtain a good image rejection, while most of the receiver gain is produced by the low second intermediate frequency amplifier and limiter stages. Some receivers use only one crystal controlled oscillator and derive the heterodyning voltage for the first mixer from a multiplier as shown in dotted outline. All receivers employ a noise silencing circuit called the squelch circuit, which disables the audio amplifier when no signal is present. Two sources of operating voltage are generally employed in this circuit, one derived from the first or second limiter grid current, and the other from the discriminator output through a high pass or band pass filter circuit which passes frequencies of the order of 10 kc/s or higher. With no signal present, the noise voltage from the limiter grid acts in opposition to the voltage produced by the high frequency noise components after they are amplified and rectified, and the audio amplifier remains inoperative. In the presence of a signal, the limiter grid current increases but the noise components in the output decrease and a nett voltage results which lifts the bias on the audio amplifier. The de-emphasis network has a falling response of 6 db. per octave to compensate for the effects of phase modulation. Operating voltages for the selector pass through band pass filters to the selector which prepares the bell ringing circuit.

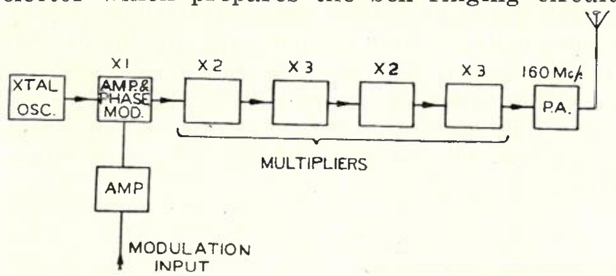


Fig. 6.—Typical transmitter arrangements.

Fig. 6 is a typical transmitter arrangement. The crystal oscillator is followed by an amplifier which also introduces the phase deviations after which the signal is multiplied to its final frequency by a series of harmonic multipliers. Total multiplication factors of from 36 to 96 are common. It is necessary to use this amount of multiplication to avoid the production of the excessive distortion which is characteristic of phase modulators when too large a deviation is produced. The power amplifier stage is almost invariably one or two beam power tubes which are specially suitable because of their stability without neutralisation.

Power for these units is supplied by the vehicle battery. The most popular method of deriving high tension is by a vibrator for the receiver and a rotary converter for the transmitter. In the latest equipment which features tubes with low drain, quick heating filaments in the transmitter, the battery drain is around 25 to 35 watts in the receiving condition, and depending on the power output, from 180 to 300 watts when transmitting.

As stated previously, a common aerial is used. It is for most vehicles a vertical quarter wavelength rod of flexible steel wire for which a ground plane is provided by the steel top of the vehicle.

The control unit generally has a switch to control the power to the equipment, a volume control, a warning light which glows when the equipment is in operation, a call lamp and perhaps a reset button. The call lamp continues to glow when the bell has ceased ringing and is extinguished by the operation of the reset button when

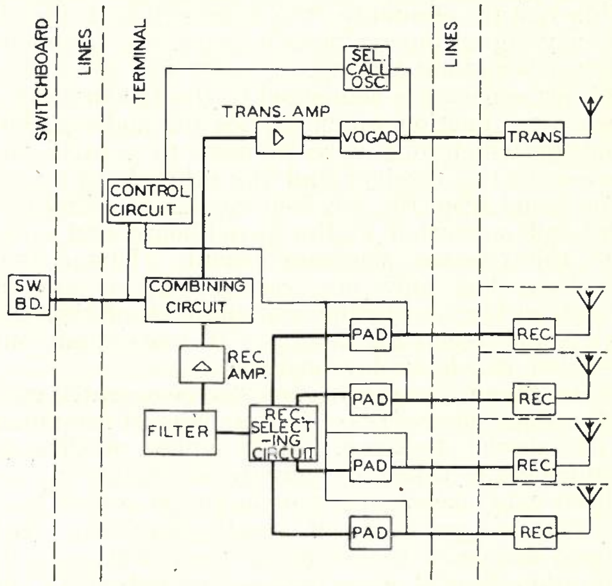


Fig. 7.—Control terminal

provided, or by the operation of the switch hook when the handset is lifted. The switch hook also switches primary power on to the transmitter.

Fixed receivers employ a circuit similar to the mobile units with the addition of a mechanical relay operated by the squelch circuit. This relay switches the audio output from the receiver and supplies the operating signal for the switchboard call lamp and the receiver switching circuit in the control terminal. It is adjusted so that in the presence of any signal less than that which will produce the minimum acceptable signal/noise ratio, there is no output from the receiver.

The circuits of the driver unit for base transmitters is in most cases identical with that of mobile transmitters. The power amplifier, employing two beam power tetrodes in a balanced circuit, is link coupled to the driver.

Control Terminal

The major units comprising the control terminal of the experimental system operating in Melbourne are shown in Fig. 7. In this drawing, testing and monitoring facilities have been omitted for the sake of simplicity. Terminals for the public services will be essentially the same in outline with some differences in the details. As an example, the mechanism of the receiver selecting circuit is likely to be different and the control circuit will differentiate between two calling systems.

The combining circuit is a simple resistive network which divides speech (speech circuits drawn in heavy line) incoming from either a fixed receiver or the switchboard equally between the two outlets with a 6 db. transfer loss. Speech from a fixed receiver entering the combining circuit is thus directed to the switchboard and also to the base transmitter where it is re-transmitted. This feature eliminates the necessity to transmit a busy signal during periods when the telephone subscriber is not talking.

Each receiver is connected to the terminal by a two wire junction which carries the audio output and of which one wire is used to control the power to the receiver and the other to transmit the signal from the receiver squelch relay to give the call indication to the switchboard and operate the receiver selecting circuit. This circuit ensures that only one receiver at a time is switched through to the combining circuit via the filter and receiving amplifier if more than one receiver squelch relay operates.

The vogad (abbreviation of "voice operated gain adjusting device") is a compression amplifier with special features. It is much quicker to reduce gain than to increase it, while in the absence of speech its gain is set at a low level so that line noise is not greatly amplified. The vogad enables a higher level of modulation to be maintained as it gives a constant output to the modulator regardless of speaking level or length of line.

The base transmitter is automatically brought into operation when a plug is inserted in the "mobile" jack at the switchboard and is ready to accept speech or dialling almost immediately. The operation of the switchboard dial key puts power on the selective calling equipment which is controlled then by the dial impulses received.

Conclusion

For the sake of brevity much technical detail has been omitted from this article. Further and more detailed information is contained in the references given.

References

1. P.M.G. Research Laboratory Report No. 3010, "Proposed Tentative Standards for V.H.F. Mobile Services."

2. P.M.G. Research Laboratory Report No. 3113, "The Service Area of Urban Mobile Radio Telephone Networks Operating at 160 Mc/s."

3. P.M.G. Research Laboratory Report No. 3310, "Urban Mobile Radio Telephone Networks."

[Ed. note: Following successful trials with the experimental system described in this article, control equipment has been developed to permit an operating procedure more closely allied to normal trunk line service. Circuit details and operating procedure will be the subject of a subsequent paper.]

JOINTING OF AERIAL LINE WIRES

C. N. Hosking, B.Sc.

Introduction. Prior to the recent war the twist sleeve method of jointing was the standard used for jointing aerial line wires in Australia. About 1939, tests were commenced on a new type of joint which had been used in U.S.A. for some years. This consisted of butting the two ends of the wire to be jointed inside a sleeve, the inside of which has been sprayed with Nichrome, Monel Metal or Silicon Bronze. The sleeve is then compressed in several places between the jaws of a crimping tool. The particles of metal on the inside of the sleeve, which are harder than the metal of the wire, key into the wire thus forming a friction joint.

Advantages of Press Type Sleeve Joints. The press type sleeve joint has the following advantages over the twist type sleeve joint.

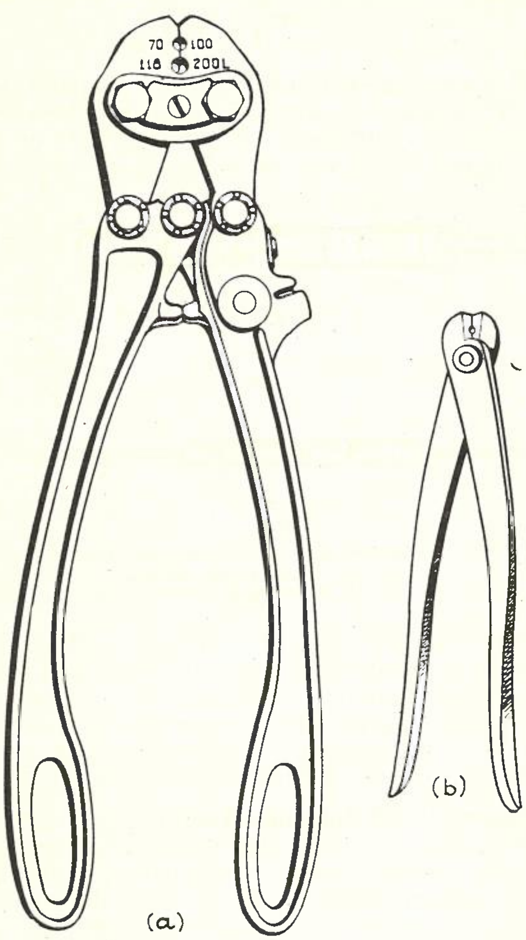


Fig. 1.—Press type jointing clamp.
(a) Bolt cutter type.
(b) Plier type.

(i) Greater strength—tests show the twist sleeve joint has an average strength of 87% of the wire strength and the press sleeve joint an average of 97%.

(ii) The mass is less, thus reducing the liability of faults due to fatigue.

(iii) The electrical resistance is more constant and closely approaches that of the wire.

(iv) There is less possibility of corrosion as the compression of the sleeve tightly around the wire prevents the ingress of moisture and air.

This type of sleeve has now been adopted in Australia as the standard for jointing wires of gauges up to 300 lb. per mile. For wires of larger size the twist type sleeve will continue to be used because the quantity of these sizes of wire in use is steadily decreasing and the production of a special jointing tool is not warranted under the circumstances.

Jointing Sleeves and Tools. Formerly obtained from U.S.A., the jointing sleeves and tools are now being manufactured in Australia. The sleeves consist of copper tubing with the bore sprayed with Monel Metal. Each sleeve is slightly indented at the centre so that the wires can be inserted only to a fixed distance.

There are two types of jointing clamps, one type being used for jointing 40 lb. C.C. wire (Fig. 1). This tool somewhat resembles a pair of pliers, and is made of chrome-zirconium steel, but is not capable of adjustment. The other tool, for jointing wires of heavier gauge, is of the "bolt cutter" type of mechanism (Fig. 1). The jaws are of high quality forged steel, each with two grooves. The compression produced by this latter tool is adjustable. A gauge for checking the compressed portion of a sleeve and a key for making the necessary adjustment to the tool is provided with each tool. The length of the handles of the Australian-made tool has been increased to improve the leverage.

There are two standard sizes of tool for jointing the larger sizes of wires, one known as "jointing clamp, 70/200L," with groove dimensions engraved 70-100 and 118-200L, and the other,

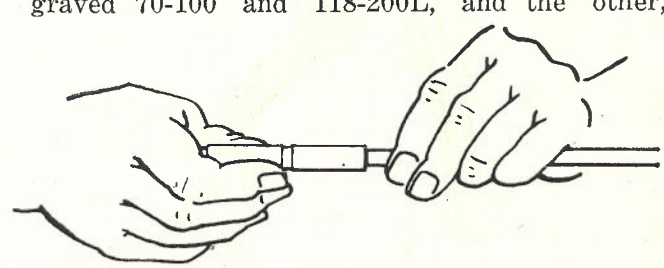


Fig. 2.—Method of inserting wire into jointing sleeve.

known as "jointing clamp, 118/300," with groove dimensions 118-200L and 237-300. Table 1 indicates the sleeve and jointing tool to be used to make a joint in each size of line wire. The size of the sleeve is identified by the colour band around the centre of the sleeve.

TABLE I

Wire	Sleeve			Jointing tool
	Description	Colour of band	External diameter	
40 lb. CC	CC.40	Nil	1/8″	Jointing clamp 40
70 lb. CC, 70 lb. HDC	CC.70	Green (light)	3/16″	Jointing clamp 70/200L
100 lb. HDC	C.100	Red	3/16″	Jointing clamp 70/200L
118 lb. CC	CC.118	Blue (dark)	7/32″	Jointing clamp 70/200L or Jointing clamp 118/300
150 lb. HDC	C.150	Orange	7/32″	Jointing clamp 70/200L or Jointing clamp 118/300
200 lb. HDC	C.200L	Black	7/32″	Jointing clamp 70/200L or Jointing clamp 118/300
200 lb. HDC	C.200H*	White	1/4″	Jointing clamp 118/300
237 lb. CC	CC.237	Grey	1/4″	Jointing clamp 118/300
262 lb. HDC	C.262	Blue (light)	1/4″	Jointing clamp 118/300
300 lb. HDC	C.300	Yellow	1/4″	Jointing clamp 118/300
200 lb. GI	GI.200†	Nil	1/4″	Jointing clamp 118/300

* Sleeves for 200 H.D.C. were originally of two types, light (200L) and heavy (200H). 200H sleeves are now obsolescent.
† Sleeves for 200 lb. GI are tinned.

Method of Making Joint. The ends of the wires to be jointed should be straight. If the joint is to be made under tension the wire is cut to the correct length so that the ends just but together. The ends of the wires are cleaned with fine emery cloth and any burrs removed. They are then inserted into the appropriate jointing sleeve from either end until they reach the centre stop. (Fig. 2).

In order to hold the wires in position while the joint is completed, the sleeve is pinched lightly with cutting pliers on each side of the centre. The sleeve is then compressed, using the appropriate groove in the appropriate jointing tool (Fig. 3). In the case of 40 lb. C.C. wire the sleeve is given three compressions on each half of the sleeve (Fig. 4b) and in all other cases two compressions on each half of the sleeve (Fig. 4a). The inner compressions are made first and alternate compressions are made with the handles of the jointing tool at 180° to the initial compressions. This is necessary to prevent the sleeve bowing as a result of the compressions.

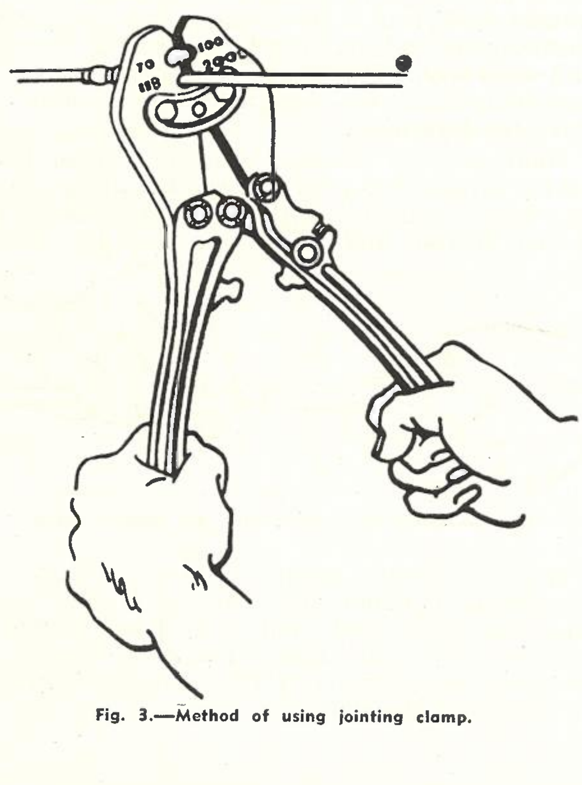


Fig. 3.—Method of using jointing clamp.

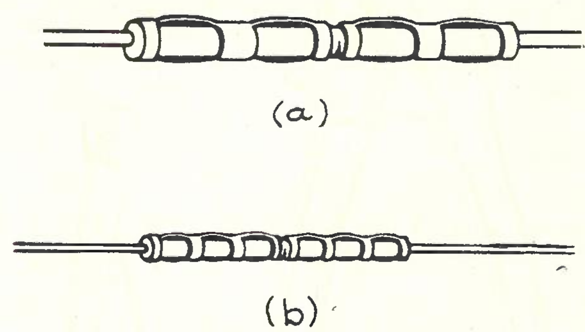


Fig. 4.—Jointing sleeves, showing compression.
(a) All sleeves except 40 C.C.
(b) 40 lb. cadmium copper sleeve.

Adjustment of Jointing Tool. Under certain circumstances, for example, when the grooves in the jaws become worn, insufficient compression may be applied to the sleeve by the jointing tool, resulting in reduced mechanical strength of the joint. The compressed sleeve can be checked with a "Go—No Go" gauge supplied with each tool. The compressed portion of the sleeve should pass the "Go" aperture of the appropriate gauge, but should not pass through the "No Go" aperture (Fig. 5). When, after continued use of the tool, the compressed sleeve will no longer pass through the "Go" aperture, the tool should be re-adjusted.

To make the necessary adjustment the handles of the tool are fully opened. Then the locking screw parallel to and nearest the handle (Fig. 6) is loosened one or two turns, using the adjusting

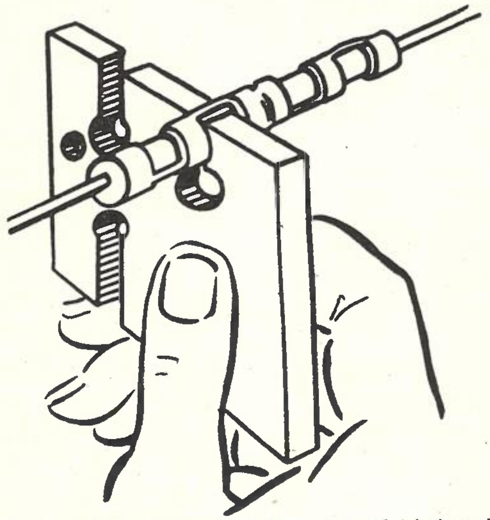


Fig. 5.—Use of gauge to check dimensions of jointing clamp.

key. The adjustment screw at right angles to the handle is then screwed in a clockwise direction a fraction of a turn at a time, until the compressed portion of the sleeve will pass through the "Go" aperture, but will still not pass through the "No Go" aperture. The locking screw is then tightened.

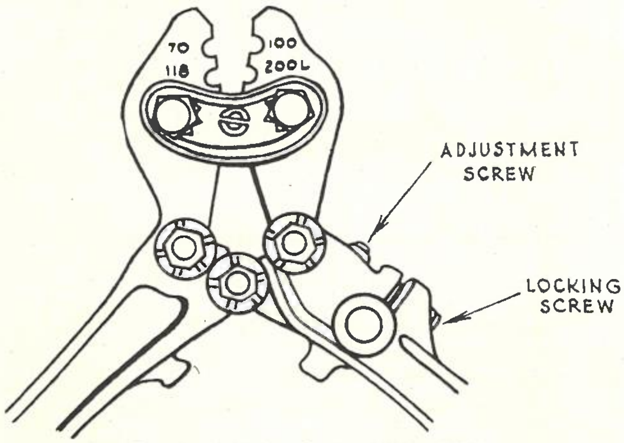


Fig. 6.—Adjustment of jointing clamp.

Future Possible Developments. It is likely that the field of use of the press-type sleeve will be widened in the future. Tests are now being conducted with press-type sleeves for making drip-point connections on line wire terminations. The use of press-type sleeves will enable the soldered drip point to be dispensed with. The sleeve used is an ordinary press-type sleeve with half of the section cut away for about a third of its length at the centre of the sleeve. The manner in which the sleeve is applied is illustrated in Fig. 7. To date trials have been conducted with 40 lb. C.C. and 70 lb. C.C. line wire.

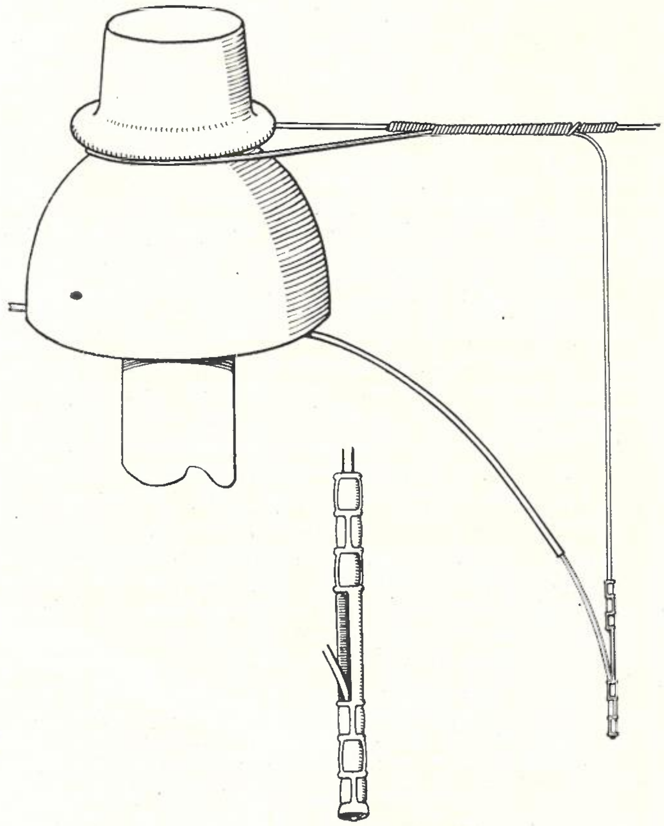


Fig. 7.—Line wire termination press type sleeve drip point connection.

In the case of 40 lb. wire, the covered wire is only a few mils smaller in diameter than the line wire, and, therefore, the CC 40 sleeve is quite satisfactory. In the case of 70 lb. wire there is a difference of .022 inches, but, since the mechanical strength of the joint is not important, the CC 70 sleeve is satisfactory. In the case of the large line wires, it is expected that a satisfactory method of terminating line wire and covered wire in the same sleeve will be developed.

LONG LINE COMMUNICATIONS IN FAR NORTHERN QUEENSLAND

W. D. McKenzie, A.M.I.E. (Aust.)

Introduction

A comprehensive re-arrangement of all long-line equipment in the Cape York Peninsula area of Queensland was carried out recently to meet changed conditions in the area following the conclusion of the war. As transport and other facilities in this little known area are limited, and in some cases even primitive, the work involved some unusual features, and complete organisation to the minutest detail was necessary before the project was undertaken. In order that the conditions may be appreciated, a description of the various towns and transport arrangements is included in this article, together with a brief description of the more interesting technical aspects of the work.

Re-arrangements Carried Out

The re-arrangement and installation of long-line equipment at centres extending from Cairns to Thursday Island included the following work:

(i) A S.T.C. type S.O.S. three-channel carrier telephone terminal was installed temporarily at Mount Surprise to provide a Townsville-Mount Surprise system. The original system operated between Townsville and Cape York, and the latter terminal had to be recovered and transferred to Mount Surprise for permanent installation at a later date.

(ii) A T.M.C. type S.K. single-channel carrier telephone system, which was modified in the Brisbane Transmission Laboratory to use S.B. frequencies so that it would work above a two-band system, was installed between Mount Surprise and Coen. This system, which is subsequently referred to as a type S.B., was extended to Townsville on a four-wire basis via one channel of the S.O.S. terminal at Mount Surprise.

(iii) A G.E.C. type F.A. single-channel carrier telephone system was installed between Coen and Thursday Island, with an intermediate carrier repeater at Cape York. Pad switching and tap facilities were provided so that Coen had access to either of the two systems, which were normally connected together to provide an overall 6 db. circuit between Thursday Island and Townsville.

(iv) The existing three-channel carrier repeaters at Mount Surprise, Fairview and Coen were disconnected and recovered.

(v) The Fairview carrier and V.F. repeater station was closed down.

(vi) A two-band carrier telephone system was installed between Cooktown and Cairns, with a repeater at Mount Surprise. 14 mH loading was added to a 3-mile section of 10 lb. conductor cable at Cooktown to improve the transmission qualities of the pairs used for the two-band carrier system and the Coen V.F. repeater.

(vii) V.F. repeaters or terminal amplifiers were installed at Thursday Island, Cape York, Coen and Cooktown.

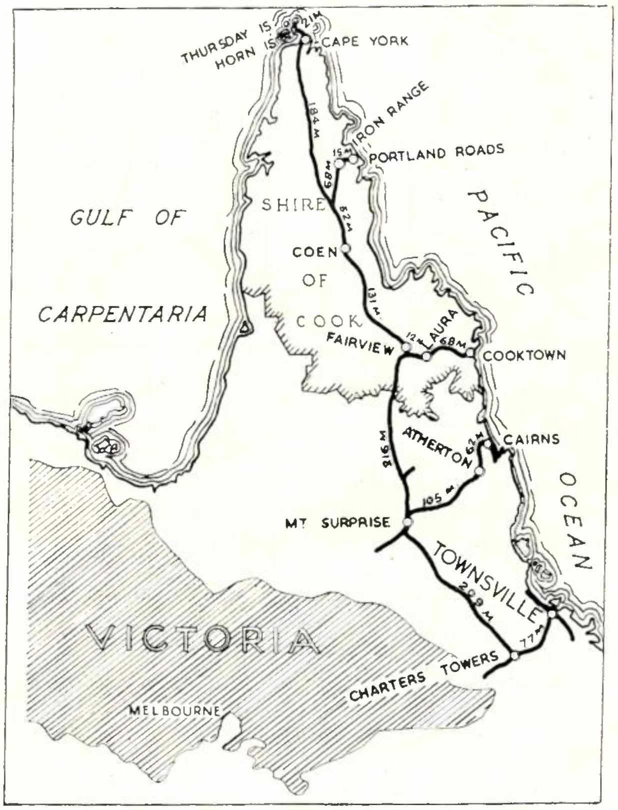


Fig. 1.—Map of North Queensland showing Trunk Routes.

Fig. 1, which includes a superimposed map of Victoria, drawn to the same scale for comparison purposes, shows the area involved. The Cook Shire, which covers 50,000 square miles and has a population of 1200, is also indicated.

Description of Localities and Plant Installed

Early in October, 1949, the installation staff of four technicians travelled by air from Brisbane to Cairns to instal the terminal of a two-band carrier telephone system and arrange the despatch of equipment to Cooktown, Mount Surprise, Coen, Cape York and Thursday Island. The writer followed three weeks later to conduct transmission tests and line up this equipment.

Cairns, 1000 miles north of Brisbane, is a well-known tourist resort, with a population of 16,000. It is also an important carrier station, but a description of this city and the long-line equipment installed there is beyond the scope of this article. After a few days in Cairns, two of the installation staff travelled to Cooktown by sea to instal the other terminal of the two-band system and a V.F. terminal amplifier.

Cooktown is named after Captain Cook, who landed there to carry out repairs to the "Endeavour" after the ship had been damaged on the Barrier Reef in 1770. A party from the ship, under the direction of Joseph Banks, explored the country in the vicinity and in a subsequent report made special reference to the giant anthills (see Fig. 2) that they had encountered. When the Palmer goldfields were in operation, 35,000 people lived in Cooktown, but with the cessation of mining activities the population gradually dwindled, and there are now only 500 inhabitants. Most of the buildings are extremely old and in a bad state of repair. The main shopping block was completely destroyed by fire in 1919 and has never been rebuilt. Further extensive damage was caused by a severe cyclone which struck the town in 1948. A panoramic view of Cooktown, taken from a hill which rises above the town, is shown in Fig. 3.

Fig. 2.—Giant Anthills, North Queensland.

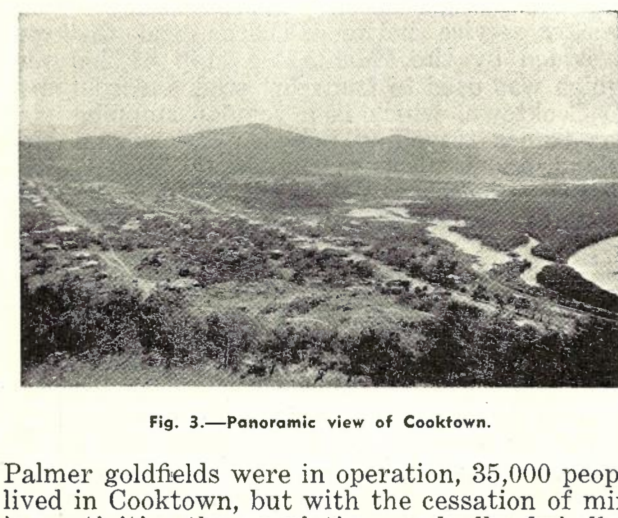


Fig. 3.—Panoramic view of Cooktown.

When the installation of long line equipment had been finalised, the technical staff returned to Cairns by sea on the "Malita," and then travelled by rail to Mount Surprise to instal the two-band system repeater and the S.B. single-channel and S.O.S. three-channel terminals.

Mount Surprise is a small town about 165 miles from Cairns, on the Cairns-Forsayth railway. It has a population of 100 and is an important carrier repeater station for systems operating between Townsville and the far north, and also for the inland route between Townsville and Cairns.

The other two members of the installation staff left Cairns by chartered plane, referred to later in this article, to instal two single-channel terminals and two V.F. terminal amplifiers at Coen, which is 280 miles north of Cairns and 240 miles south of Cape York. It is a small town with a total population, including natives, of less than 100, and is divided into two separate sections by a creek, the Post Office and repeater station being situated on one side and the rest of the town on the other.

Fig. 4.—Pedestrian Bridge, Coen.

The pedestrian who wishes to go from the town to the post office to buy stamps, collect mail, or even pass the time of day with the genial postmaster, has the choice of following the road for half a mile and wading the creek, or taking the short-cut of about 300 yards, using the so-called bridge, which consists of a fallen tree (see Fig. 4). The locals invariably use the latter if motor transport is not available.

Upon completion of their work at Coen, the installation staff travelled by the commercial plane service to Horn Island, which is $1\frac{1}{2}$ miles from Thursday Island, to instal the type F.A. carrier terminal and a V.F. terminal amplifier at Thursday Island; to recover the existing S.O.S. carrier terminal at Cape York and to instal the carrier repeater for the F.A. system as well as a V.F. repeater.

Modern Douglas airliners are used for the

Cairns-Horn Island service, but the passengers receive a shock when they alight at the Horn Island aerodrome, which is $3\frac{1}{2}$ miles from the jetty. The transport provided is an ancient bus fitted with two rows of parallel seats, but several of the intervening floor-boards are either loose or missing. After some delay to enable the luggage to be taken aboard a separate truck and loaded on to the boat, the driver of the so-called passenger vehicle sets off with apparently one ambition, namely to reach the jetty in the shortest possible time. Horn Island is flat and surrounded by mangrove swamps, and except for the small maintenance staff at the aerodrome is uninhabited.

Thursday Island is one of the smallest of the group, including Monday, Tuesday, Wednesday, Friday, Hammond, Goode, Horn and Prince of Wales Islands. Most of these are surrounded by reefs and, except for isolated mission stations, are uninhabited. The island is peanut shaped and has a total area of one and a quarter square miles, and a population of 1000, including less than 100 whites, who are either public servants or business people. The concave-shaped southern side has a good, deep sea port, which is one of the few places in these islands that is free from reefs. The residential and business area is concentrated in a comparatively narrow strip along the waterfront as the rest of the island is hilly and the soil generally poor. The economical life of its inhabitants is based on pearl and trochus shell. A large proportion of the world's shell for the manufacture of buttons, knife handles, sleeve links, etc., is obtained from the area between Thursday Island and Broome, and there is also a market for beche-de-mer or trepang, which is regarded as a food delicacy in the eastern countries. Prior to the war, the crews of the pearling luggers usually included Japanese divers, but this work is now carried out almost exclusively by natives who, in conjunction with the Department of Native Affairs, own a considerable portion of the pearling fleet.

Cape York itself, the extreme northern point of Australia, is a long, low shelf of rock tapering to the edge of the water. The carrier station, which is situated in a rocky gully a quarter of a mile from the beach, was established during the recent war, when the site was chosen to ensure concealment from enemy planes and ships. The choice was admirable because it is part surrounded by hills, and, aided by a camouflaged roof, is concealed until one approaches to within a couple of hundred yards of the site. The building is a Sydney Williams prefabricated steel and galvanised iron structure. When all factors are considered, there can be few more remote or desolate communication centres in the Commonwealth. Only a few white people live in the extreme north of the Peninsula, and the telephone provides an important link with the outside world.

When off duty the maintenance staff devote most of their time to shooting and fishing, wild pigs and turkeys being plentiful and the fishing excellent. There is an attractive beach near the carrier station, but swimming, because of sharks, is too risky.

The recovered three-channel type S.O.S. carrier telephone system between Townsville and Cape York, a distance of 883 miles, included intermediate repeaters at Charters Towers, Mount Surprise, Fairview and Coen. One channel was used as a bearer circuit for a four-channel telegraph system, but this was disconnected at the conclusion of the war, and the channel used as a speaking circuit by the maintenance staff or terminated in an amplifier and speaker so that they could listen to a broadcasting programme relayed from Townsville. The quality was nothing to enthuse over, but only those officers who are familiar with the Cape York Carrier Station can fully appreciate its entertainment value. The second channel was extended from Cape York to Thursday Island through submarine cable and open wire line, with an attenuation of 18 db. at voice frequencies. The third channel was extended back to Coen on a physical circuit equipped with terminal amplifiers.

Transport Facilities

In many instances special arrangements had to be made to transport staff and equipment to the various centres. Carrier equipment was forwarded from Charters Towers, Townsville and Brisbane by rail to Cairns, which was used as a forwarding base. Cooktown is only 100 miles north of Cairns, but the intervening country is very mountainous and, because of the complete absence of connecting roads, all supplies and personnel were carried by ship or plane.

The s.s. "Elsanna," a ship of 2500 tons, travels from Brisbane to Thursday Island, via Cairns and Cooktown, once each month. There is also a weekly service between Cairns and Cooktown provided by the "Malita," a ship of 200 tons, which was used to transport staff and equipment to Cooktown, which is a regular stopping place for planes travelling between Cairns and Horn Island, and is also used by the Qantas organisation to refuel planes flying the "Bird of Paradise" route to New Guinea.

Fairview, which was a carrier and V.F. repeater station until it was closed down during the course of these re-arrangements, is reached via a small branch railway line between Cooktown and Laura, a distance of 67 miles, and thence by road for another 15 miles. This railway was built to carry supplies and personnel to the Palmer Goldfields, but the service is now restricted to a return rail motor trip each week, thus providing a link between the coastal port of Cooktown and the inland cattle country. Due to the absence of connecting roads, the trunk route follows this railway line to Laura, and is then extended to Fairview where it joins the main North-South route.

A rail jinker, which consists of a three-wheeled tricycle fitted with a motor cycle engine, is used by the lines staff to maintain the Cooktown-Laura section of the telephone line. This method of transport was used during the recent visit by the writer, who has vivid memories of a return trip from Cooktown to Laura. The jinker carries the driver and one passenger, but no clutch or gears are provided, and the method of starting is to get behind and push for anything up to 100 yards. When sufficient momentum is attained, the motor sometimes starts, and the perspiring runners hang on grimly until they can climb on to the vehicle, which has a maximum speed of 20 m.p.h. The service is reasonably efficient, if not altogether comfortable.

The transport of equipment to Coen presents a real problem. Small boats can unload supplies at Port Stewart or Annie River, but, in each case, the service is infrequent, the connecting roads extremely rough and transport costs almost prohibitive. Packhorses are used for the regular mail service from Coen to Wenlock-Moreton-Merluna and return, a distance of 350 miles, which takes 13 days.

Under favourable conditions, motor vehicles equipped with four-wheel drive can follow the trunk route. This method was used during the war to carry heavy equipment, including diesel engines, for the Fairview and Coen carrier repeater stations together with the parts for prefabricated Sydney Williams buildings. The roads, and particularly the creek crossings, were maintained by the Army, but have since fallen into disrepair and linemen are often held up for days before they can return to their base or proceed along the line to clear a fault.

The work carried out at Coen by the transmission staff involved the transport of equipment, tools and staff weighing nearly two tons. Extensive enquiries were made and it was finally decided that the only practicable method was to charter a special plane from Australian National Airways, who operate the only commercial plane service in this area. Dummy racks of the same overall dimensions as the largest equipment, namely the two carrier terminals, were constructed, and the Company advised that they could be loaded into a plane without being dismantled. The D.C.3 airliner, "Tullana," was used for the passenger service from Cairns to Horn Island and return on Saturday, 15th October, 1949. During the week-end all but the front three rows of seats were removed and the carrier equipment, tools and staff were flown from Cairns to Coen on a chartered flight on Monday, 17th October. Fig. 5 illustrates the equipment inside the plane, and Fig 6 shows it being unloaded at the Coen aerodrome, which is 15 miles from the township. A new all-weather road is under construction, but until such time as this is available pack horses have to be used to convey passengers and luggage to and from the aerodrome during the wet season. The present road is rough but trafficable, except for this period, and the long-line equipment was carried on it without any damage.

The type F.A. single channel carrier terminal for Thursday Island, and the carrier repeater for Cape York, were carried on the "Elsana" from Cairns to Thursday Island and stored at the local Post Office until the installation staff arrived a few weeks later. There is a fortnightly barge ser-

Fig. 5.—Long-line Equipment loaded in Plane.

Fig. 6.—Long-line Equipment being unloaded at Coen Aerodrome.

vice from Thursday Island to Cape York, which unloads equipment and supplies at Red Island Point, 23 miles by road from the carrier station. During the months between December and May, this road is impassable because of the numerous creek crossings that have to be negotiated. If conditions are favourable, the barge can anchor off Cape York Post Office, and mails, light supplies, etc., are taken ashore in a dinghy.

The P.M.G.'s Department has a 25 ft. whaleboat which is used for submarine cable repairs. This boat, affectionately named "Salome," is fitted with a Simplex twin cylinder marine engine and is under the control of the Thursday Island Line Foreman. Navigation in these waters is difficult because of swift tides and hidden reefs, and is almost invariably carried out by native boys, who have an intimate knowledge of the area, even though very few of them can read a chart. The navigation of "Salome" is entrusted to "Jerry" (see Fig. 7), a very likeable Saibai islander, who

Fig. 7.—"Jerry," with Thursday Island in background.

is employed as an exempt lineman. During the writer's visit, the "Salome" carried two cwt. of equipment and five officers from Thursday Island to Cape York, a distance of twenty miles. The journey usually takes about three and a half hours but, on this particular occasion, a heavy swell was encountered between Possession Island and Peak Point, which is near the Cape York beach. The small boat was tossed about like a cork and made little headway for perhaps half an hour, with the result that the journey took over four hours. The testing instruments and other equipment were not damaged, but the passengers breathed a sigh of relief when the boat finally anchored just off the shore. The equipment was transferred to the beach with the aid of willing helpers, who waded through water to a depth of three feet. The "Salome" is shown in Fig. 8, which was taken from the Cape York beach just after it had left on the return journey to Thursday Island, at the conclusion of the transmission tests.

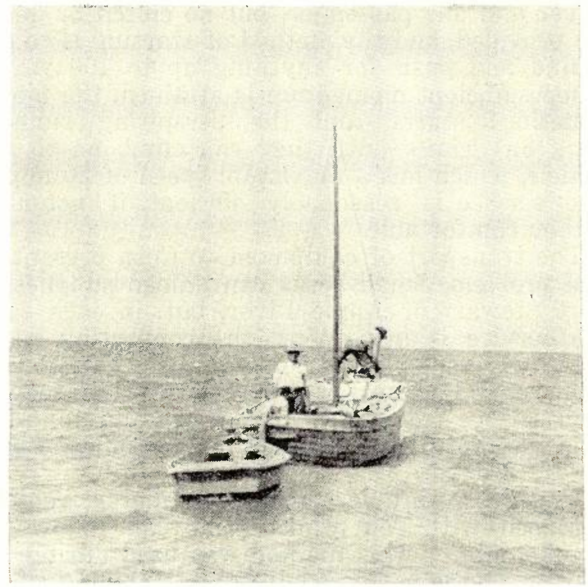


Fig. 8.—"Salome" leaving Cape York Beach.

Special Technical Features

The Cairns-Cooktown two-band carrier telephone system, which was manufactured by Standard Telephones and Cables Pty. Ltd., was the first of its type installed in Queensland. It is designed to provide a stable zero loss channel over open wire lines using 5.6 kc/s line filters, the system being connected through the normal low pass section. Only one carrier frequency of 5.6 kc/s is used, this being employed in the "B-A" direction (Cooktown-Cairns for this particular application). Crystal controlled oscillators, similar to those provided in recent deliveries of three-channel carrier telephone systems from the same company, ensure freedom from synchronisation troubles. The lower side band of 3.2 kc/s to 5.3 kc/s is transmitted to line at a maximum level of + 17 db, the carrier frequency and upper side band being suppressed.

A voice frequency range of 300 to 2400 c/s is transmitted in the "A-B" direction. The system operates from the normal 24 V. and 132 V. secondary batteries, or direct from the 50 c/s commercial supply, via suitable rectifiers. Station batteries were used at Cairns, and commercial supply units were installed at Cooktown to provide rectified 24 V. and 132 V. for relay operation and anode supply respectively, and a 24 V. step-down transformer heated the type 328A and 329A tubes used. Fig. 9 shows the essential details of the "B" terminal in block schematic form. The

"A" terminal includes a corresponding demodulator and 5.6 kc/s oscillator.

A repeater was installed at Mount Surprise, which is 297 miles from Cooktown and 167 miles

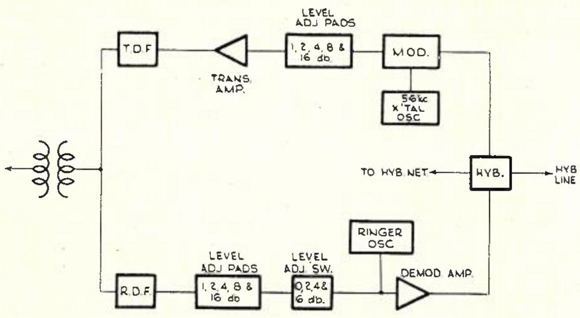


Fig. 9.—Schematic of "B" Terminal of Two Band System.

from Cairns. The repeater follows conventional design and includes level adjusting pads (1, 2, 4, 8 and 16 db.) and switches (0, 2, 4 and 6 db) of a similar type to those shown in Fig. 9 for each direction of transmission. A common bearer circuit was used between Mount Surprise and Fairview, a distance of 216 miles, for the Cairns-Cooktown two-band and the Mount Surprise-Coen single-channel systems.

The only equipment readily available for the latter application was a TMC type S.K. system, which transmits lower sideband frequencies of 4.1 to 6.5 kc/s in the "B-A" direction. The carrier range of the two-band system (3.2 to 5.3 kc/s) overlaps this range; hence it was decided to modify the S.K. system to use S.B. frequencies. Details of the respective oscillator and side-band frequencies in kc/s are:—

Type of System	A—B Direction		B—A Direction	
	Oscillator frequency	Sideband frequencies	Oscillator frequency	Sideband frequencies
S.K.	10.3	7.6 — 10.0	6.867	4.1 — 6.5
S.B.	6.6	6.8 — 9.4	10.1	10.3—12.9

It can be seen from the above table that small changes only were required in the various oscillator frequencies. The 6.867 kc/s oscillator ("B" terminal S.K.) was converted to 6.6 kc/s ("A" terminal S.B.) and, similarly, the 10.3 kc/s oscillator ("A" terminal S.K.) was converted to 10.1 kc/s ("B" terminal S.B.) by the addition of small condensers in each case.

The system had to operate over 347 miles of line and level calculations indicated that an outgoing level of + 20 db. was necessary and that the incoming level in the high frequency direction would be — 20 db. With these extreme levels auxiliary filters were necessary in the receiving section of each terminal to aid discrimination. The existing S.K. filters were removed and new filters to meet the modified side-band requirements were designed and manufactured, using magnetic dust core inductances and silvered mica condensers. Figs. 10 and 11 show the schematic circuit of typical completed band pass and high pass filters and their frequency versus attenuation characteristics respectively.

The submarine cable between Cape York and Thursday Island is divided into two sections, one of 14 miles, between Cape York and Horn Island, and the other of 1½ miles between Horn and Thursday Islands. The remainder of the circuit consists of 5 miles of 200 lb. copper open wire line on Horn Island. The cable impedance is 125 ohms and the overall attenuation of the circuit 38 db. at carrier frequencies. Matching transformers to meet these conditions were provided as indicated in Fig. 12. It will be seen that no transformers were included in the voice frequency circuit which employs 17 c/s ringing facilities.

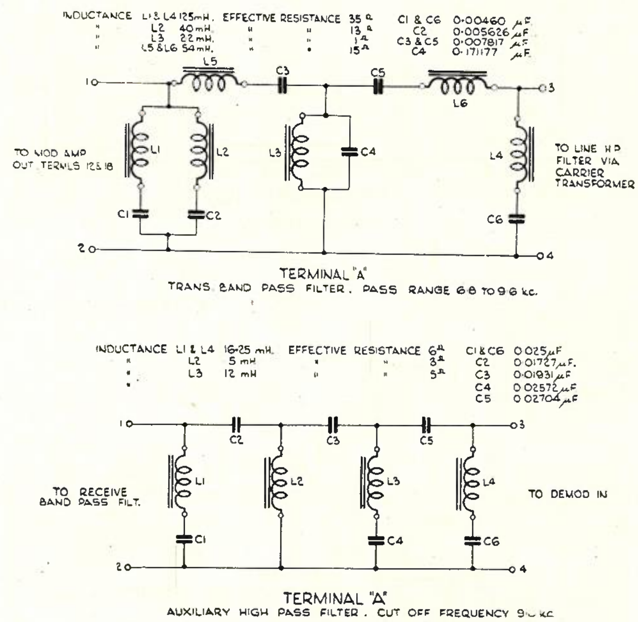


Fig. 10.—Schematic Circuits of Band Pass and High Pass Filters.

There being no commercial power supplies at Mount Surprise, Cooktown, Coen or Cape York, prime movers ranging from 4 horse power, standby petrol engine generators to 35 horse power, 4-cylinder diesel alternators with associated rectifiers, secondary batteries, etc., were installed in 1942 at all stations except Cooktown, where arrangements were made to extend the Civil Aviation power supply (230 V. A.C.) to the Post Office to operate the two-band system.

Conclusion

Due to faulty pairs in the paper insulated submarine cable, action is in hand to replace it by a new cable. When this is installed, the carrier and voice frequency repeaters at Cape York will be

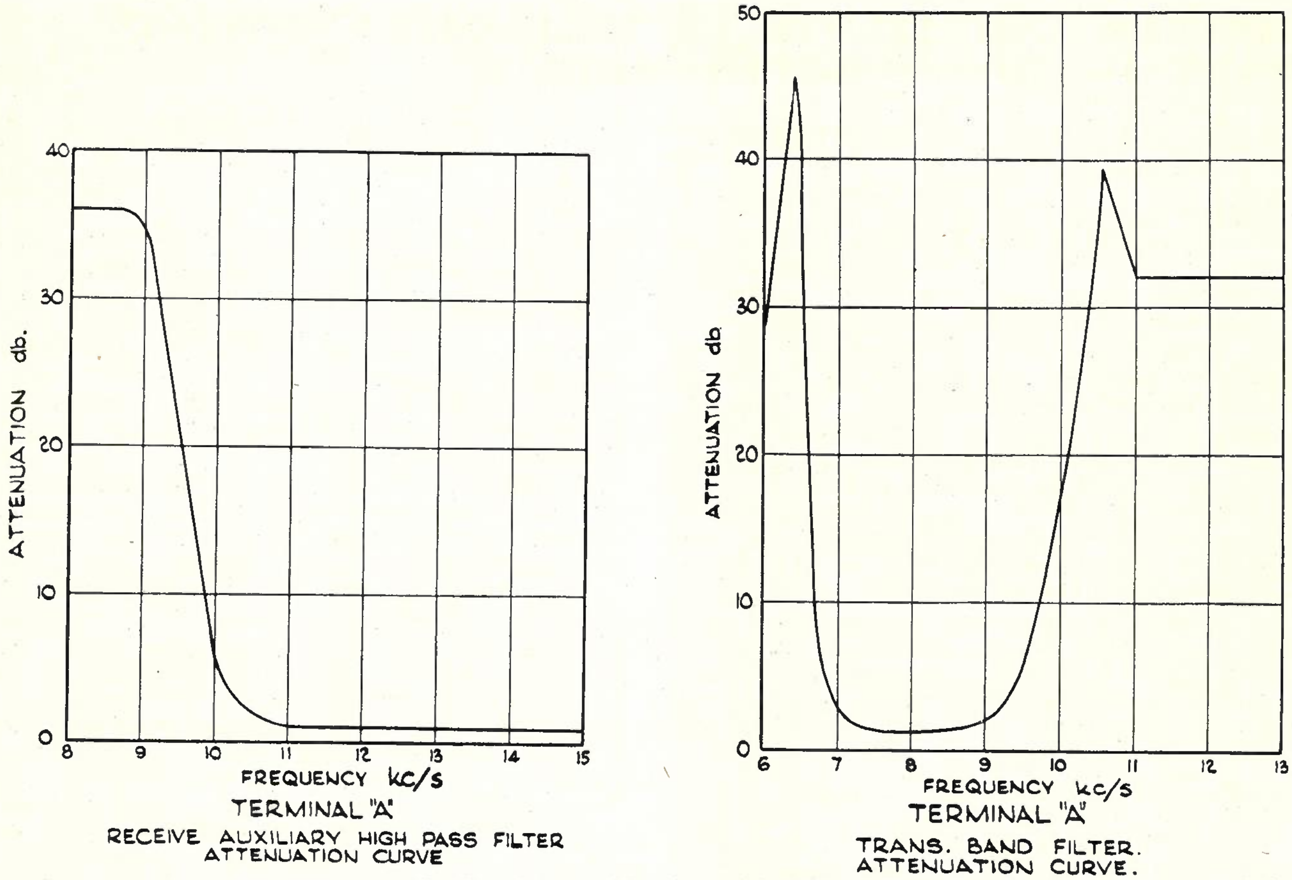


Fig. 11.—Characteristics of High Pass and Band Pass Filters.

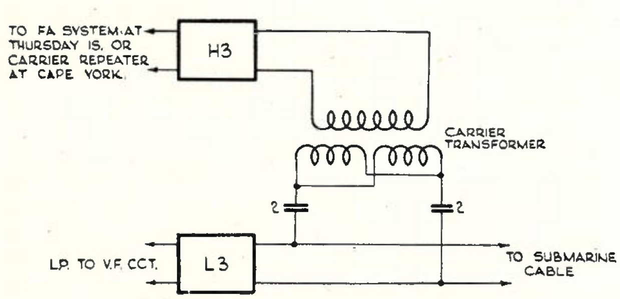


Fig. 12.—Submarine Cable Switching arrangements.

moved to more congenial surroundings and wind-driven generators with standby auxiliary power plant will replace the two existing diesel alternators at Cape York.

The whole of the field work discussed in this article was completed within a period of six weeks. A tribute is due to the technical staff whose duties were carried out under difficult conditions, and also to the officers in Brisbane, whose attention to detail and arrangement of supplies were so thorough that the relatively few field officers were relieved of any equipment worries.

METALS AND ALLOYS IN TELECOMMUNICATION PART II — NON-FERROUS METALS

H. Weir

COPPER AND ITS ALLOYS

Copper

Copper is one of the earliest metals used by man, and is said to have been in use 2,000 years before the flood. It was probably then found in its metallic state, but afterwards accidentally "smelted" by a fire built in contact with some ore containing copper. Copper is next to silver in heat and electrical conductivity, is ductile and malleable, can be joined with ease by soldering, brazing and welding, and is resistant to many forms of corrosion. These properties are also found (together with other desirable ones) in its alloys. It is therefore not surprising that copper and its alloys find wide use in general engineering practice, as well as in electrical engineering and the specialised field of communication engineering. The thermal and electrical conductivities at 20 deg. C. of other metals relative to copper are given below. The close agreement of electrical and thermal conductivities will be noted.

Table No. 6

Metal	Electrical conductivity	Thermal conducitvity
Copper	100	100
Silver	106	108
Aluminium	62	56
Magnesium	39	41
Zinc	29	29
Nickel	25	15
Cadmium	23	24
Iron	17	17
Steel	13–17	13–17
Platinum	16	18
Tin	15	17
Lead	8	9
Antimony	4.5	5
Mercury	2.0	–
Bismuth	1.7	1.7

High conductivity (H.C.) copper is usually electrolytically refined to a high degree of purity and is used mainly for electrical purposes. Best select copper (99.75% Cu) does not reach the conductivity standard of high conductivity copper, but is suitable for a wide range of uses. Arsenical copper contains up to 0.5% arsenic and is largely used for fireboxes in locomotives and similar uses.

A greater annual tonnage of copper is produced than any other non-ferrous metal. It is readily fabricated by cold rolling, drawing, pressing and spinning and by extrusion, forging and stamping at elevated temperatures. The mechanical properties of copper vary widely according to the mechanical treatment and physical condition. Representative values are as in table:

Treatment	Ultimate tensile stress tons./sq. in.	Elongation %	Brinell hardness
Cast	10-11	25-30	40-45
Hot rolled	14-16	50-60	40-45
Cold rolled	20-26	5-20	80-100
Cold drawn (wire)	25-30	1-5	

In common with other non-ferrous metals, -cop per has no well-defined elastic limit. Because the highest electrical conductivity can only be obtained with the pure metal, copper is extensively used in the pure state, about one-half the total production of copper being so used for electrical purposes. However, for overhead aerial work, the strength of hard drawn copper leaves much to be desired. Unfortunately, although the ultimate tensile stress can be much improved by alloying, this is usually accompanied by a serious loss of conductivity: for instance 10% aluminium more than doubles the ultimate tensile stress but increases the resistance about six times. However, the addition of about 0.9% cadmium increases the tensile strength about 50% (i.e., 45 tons/sq. in.) and reduces the conductivity only about 15% (these figures are for hard-drawn wire 0.064 in. diameter in each case). For larger sections such as trolley wires an ultimate tensile stress of 28 tons/sq. in. with 89% electrical conductivity can be obtained.

Brasses

Strictly speaking, brass is an alloy consisting principally of copper and zinc, and bronze one of copper and tin. Unfortunately some loose terminology has come into use, and some alloys, e.g., manganese bronze and tobin bronze, are not bronze but brass, and another, aluminium bronze, contains no tin.

Brasses are alloys of copper and zinc, the useful range containing from 10% to 50% zinc. Those containing below 36% zinc are known as Alpha brasses and are suitable for cold working. Those from 36% to 42% zinc are known as Alpha-Beta brasses, and whilst harder and stronger than the Alpha group are better adapted to hot-working or casting.

90% Cu, 10% Zn; 85% Cu, 15% Zn. Sometimes known as gilding metal. Used for imitation of gold, and architectural and other decorative metal work, flexible metal for pipe line inserts and bellows, parts required to be joined by brazing. Ultimate tensile stress 26/33 tons/sq. in., elongation 50%.

70% Cu, 30% Zn. Termed cartridge brass from one of its uses. Used where strength combined with ductility are required and for deep-drawing and pressing. This is the most important Alpha brass and has the greatest elongation values (70% in the annealed state). Typical physical properties are:

Treatment	0.1 per cent. proof stress tons/sq. in.	Ultimate tensile stress tons/sq. in.	Elongation %	Brinell hardness
Chill cast	6	16	65	60
Hard rolled sheet	25	30-40	10-15	150-200
Annealed sheet	6	20-23	65-75	60

When 1%-Sn is added, the resistance to salt water corrosion is improved, and the alloy is known as Admiralty or Naval Brass, and was formerly used for condenser tubes, but has been superseded for this purpose by 80/20 copper-nickel alloy.

65% Cu, 35% Zn; 63% Cu, 37% Zn. Alloys for cold press work which are cheaper than the 70/30. The 63/37 is sometimes known as "Basis" brass. In the annealed state the ultimate tensile stress is 23 tons/sq. in. and elongation 60%, and when hard rolled the ultimate tensile stress is 38 tons/sq. in.

60% Cu, 40% Zn is the best of the Alpha-Beta group and is also known as Muntz metal. Typical properties as cast are: ultimate tensile stress 22/25 tons/sq. in., elongation 40/45% and Brinell 90/100. It is much used in the form of rolled sheet, and for articles which do not have to be cold-worked in manufacture. It can also be readily hot-stamped or extruded. For the latter purpose about 1% to 3% lead is often added to improve the machining qualities of the extruded rod. However, this reduces the impact strength and makes welding or brazing difficult.

The electrical conductivity of the 70/30, 65/35, and 60/40 brasses is about 27%, and thermal conductivity about 30% of hard drawn copper.

"Temper" of Brasses: The effect of cold working is usually referred to in the following terms:—

Soft temper—annealed—Brinell hardness below 80.

Quarter hard—80-100.
Half hard—100-120.
Hard—120-150.
Spring hard—over 150.

Manganese Bronze, as previously noted, is really a brass, and is made from 60/40 brass by adding small amounts of manganese, iron, tin and aluminium and reducing the amount of copper. The total amount of such additions rarely exceeds 4%. A typical casting alloy for automobile or marine purposes is 56/58% Cu, 41.5/39.5% Zn, 0.25% Mn, 0.25% Al, 1.0% Fe, 1.0% Sn.

Properties as cast are ultimate tensile stress 34 tons/sq. in., limit of proportionality 11 tons/sq. in., yield point 17 tons/sq. in., Brinell 140, elongation 28%. Extruded and hot rolled types have improved properties up to 35 tons/sq. in. ultimate tensile stress with 22% elongation. Manganese bronze is also a useful welding alloy and will weld satisfactorily most metals and alloys in common use except those containing aluminium.

Tobin Bronze is also a 60/40 brass with the addition of 0.5% to 1% of tin. The ultimate tensile stress of the annealed rod is about 24 tons/sq. in., which can be increased by hard drawing to about 30 tons/sq. in. It is used as a welding rod for similar purposes to manganese bronze, and also for marine propeller shafts and general shipboard use. The electrical conductivity is 25% of hard drawn copper.

Aluminium Brass, 76% Cu, 22% Zn, 2% Al, is a sea-water corrosion resisting alloy sometimes used for condenser tubes. Physical properties extruded are ultimate tensile stress 22 tons/sq. in., elongation 70%, 0.1% proof stress, 6 tons/sq. in., and hard drawn, ultimate tensile stress 40 tons/sq. in., elongation 10%, 0.1% proof stress, 28 tons/sq. in.

55% Cu, 45% Zn; 50% Cu, 50% Zn. Are used for brazing where low-melting point and free running (for close joints) properties are required. Sometimes a small amount of tin is added to further reduce the melting point and increase the tensile strength.

Alloys of less than 50% copper and over 50% zinc become increasingly brittle as the Zn increases and have no commercial use at present.

Nickel Silver.—This alloy, formerly known as German Silver, does not contain any silver, but is really a nickel brass, as it usually comprises 70/30 brass with the addition of 7-30% nickel. A typical alloy is, 55% Cu, 27% Zn, 18% Ni. This is known as 18% Nickel Silver and the physical properties (annealed) are, 0.1% proof stress, 15 tons/sq. in. ultimate tensile stress, 26 tons/sq. in. elongation 40%, reduction in area 60%, Brinell 82. Cold rolling increases the ultimate tensile stress to 40/60 tons/sq. in. Nickel silver is used for some automobile parts such as radiator shells, fittings for shops, lavatories and ships, as a base metal for spoons and forks to be electroplated (E.P.N.S.), for resistance wire in electrical work, and for relay and key springs in communication engineering. The nickel has a remarkable decolourising effect on the brass, amounts of the order of 20% Ni. giving the alloy a silvery white appearance. Such alloys take a high polish and have a good corrosion resistance.

Bronzes

True bronzes are alloys of copper and tin, the tin content varying from 4 to 20%. Small amounts of phosphorus or zinc are often added as deoxidisers.

Gunmetal.—This is perhaps the best known and most widely used of the bronzes, and is essentially a 10% tin bronze, 2% zinc being added sometimes, when the alloy is known as "Admiralty Gunmetal." An 88/10/2 alloy sand-cast has an ultimate tensile stress of 17 tons/sq. in. with elongation 15% and Brinell 60-80. This alloy is used for castings where strength and resistance to salt water corrosion are required, also for gear-wheels. The necessity for, and action of, a deoxidiser in copper alloys may be explained as follows. In melting copper, some copper oxide is formed, and does not float on the surface, but dissolves in the molten copper, thereby making it porous and weak. In brass the addition of zinc reduces the copper oxide to copper and the resultant zinc oxide floats on the surface as dross and may be removed. In the case of bronze, the tin also reduces the copper oxide to copper, but the tin oxide, although insoluble, is heavy and does not float, but remains in the melt, with resultant weakness and porosity. The addition of 2% zinc in the 88/10/2 mixture reduces the tin oxide to tin, and the zinc oxide can be readily removed as in the case of brass. Phosphorus is also employed as an addition to bronze, usually as phosphor-copper (18% phosphorus) and may function in two ways. When used solely as a deoxidiser, only traces of phosphorus remain. However, when over 0.1% remains, the phosphorus becomes a definite alloying agent.

Wrought Phosphor Bronze.—Contains 2.5% to 8.5% tin and 0.1 to 0.35% phosphorus, is resistant to sea water corrosion and has a high elastic limit. It is used in rod, sheet and wire form for springs. Typical properties of a 93.7% Cu, 6% Sn and 0.3% P. bronze are:—

Treatment	Ultimate tensile stress tons/sq. in.	Elongation %
Cast	15	18
Annealed	20	30
Hard drawn	33	14

Cast Phosphor Bronze.—Contains 9% to 13% tin and 0.3% to 1% phosphorus. It is used mainly for machine parts needing a bearing surface capable of heavy loading with low friction. Typical properties of a 88.7% Cu, 11% Sn, 0.3% P. bronze are:—

Ultimate tensile stress tons/sq. in.	Yield point tons/sq. in.	Elongation %	Brinell hardness
17	10	10	85

Nickel Bronze.—If 5% nickel replaces half the tin in the 88/10/2 gunmetal, an alloy results which can be heat-treated to give an ultimate tensile stress of 37 tons/sq. in. with elongation 10% and a Brinell of 170. Other nickel bronzes containing up to 10% nickel as well as tin and zinc and at least 80% copper are in use for bearings and steam fittings. The 10% nickel alloy is white in colour.

Bell Metal is a true bronze containing 12%-25% tin.

Other Bronzes (so called)

Aluminium Bronze is an alloy of copper and aluminium containing 5% to 11% aluminium. These alloys possess high strength and resistance to corrosion and fatigue, and good working properties. Special casting technique is necessary to prevent the formation of aluminium oxide and resulting poor casting strength, and welding is difficult, alloys of over 10% aluminium being unweldable. A 7% alloy may be hot- or cold-worked. As cast an ultimate tensile stress of 21 tons/sq. in. is obtained, which may be increased bp rolling to 40 tons/sq. in. with elongation 18%, and Brinell of 195. The 10% alloy is mostly used for casting and as cast may have an ultimate tensile stress of 31 tons/sq. in. with elongation 20%. This alloy (10%) may be heat-treated by quenching from 900 degs. C. to give over 50 tons/sq. in. ultimate tensile stress with an elongation of 2%. These properties may be modified by tempering (as in the case of carbon steel).

Beryllium Bronze or Beryllium Copper.—This bronze contains 2%-3% Beryllium, 98-97% copper and may also be temper hardened. These alloys have good elastic properties and a high endurance limit. They are therefore employed for springs of various kinds and for tools which must not cause sparks as may those of steel, or which must be non-magnetic. For a typical alloy (2% Be) the ultimate tensile stress is 31 tons/sq. in. in the annealed state and this can be increased to over 80 tons/sq. in. by cold rolling and tempering at 275 degs. C. for one hour.

Silicon Bronze contains up to 5% silicon, and sometimes small amounts of manganese, zinc or iron. One such is 95% Cu, 4% Si, 1% Mn, and is known under the trade name of "Everdur." Another is 88% Cu, 5% Si, 5% Fe, 2% Zn. Such alloys have very good corrosion resistance, can be readily soldered, brazed or welded, and have reasonable strength and toughness. As cast the ultimate tensile stress is from 16 to 22 tons/sq. in., with elongation 25% to 10%, and a Brinell hardness of 100 to 120. These figures can, of course, be improved by cold working and it then provides a corrosion resisting alloy with the strength of medium carbon steel.

COMPLEX ALLOYS

Aluminium, iron, manganese, tin, nickel and silicon are added in various combinations to 60/40 brass and sold under various trade names, the object being to improve the tensile strength and hardness without seriously reducing the ductility. These are sometimes known as "High Tensile" or "Complex" Brass.

Cupro-Nickels

Copper and nickel form alloys in all proportions. The most important are:—

98% Cu, 2% Ni—Used for locomotive fire box stays.

80% Cu, 20% Ni—Used for condenser tubes and bullet envelopes.

60% Cu, 40% Ni—Electrical resistance wires and thermocouples (Eureka, Constantan).

30% Cu, 68% Ni, 2% Fe, is the alloy known as Monel Metal, and was originally made direct from an ore containing nickel and copper. This alloy has a strength superior to mild steel and has good corrosion resistance to brine, all alkalis, sulphuric acid and superheated steam, and deserves to be much more widely known and used than it is. Ordinary Monel castings have an ultimate tensile stress of about 20 tons/sq. in. with elongation 12% and Brinell hardness 120. Cold drawing increases the ultimate tensile stress to 40-45 tons/sq. in., with a yield point of 35-40 tons-sq. in., elongation 18%-20% and Brinell hardness 110-120. Improved varieties, known as "K," "R" and "S" Monel, can be temper-hardened to an ultimate tensile stress of 78 tons/sq. in. with elongation 15% and Brinell hardness 320. These alloys are generally preferred to stainless steel as they are readily machined, soldered, brazed or welded, have equivalent strength and superior corrosion resistance. They are used extensively for high-pressure superheated steam fittings, turbine blades, valve stems and seats, joint rings, and in the aircraft industry for valve seats in aluminium cylinder heads, petrol pipes and structural parts of seaplanes and flying boats.

Chromium-Copper

Chromium-Copper alloy, containing 0.5% chromium, is said to have 85% of the thermal conductivity of hard-drawn copper, which is about twice that of aluminium. It is used for cylinder head castings.

NICKEL, ALUMINIUM, MAGNESIUM

Nickel is one of the most important metals used in engineering, as it is an essential component of a wide range of alloys and has a markedly beneficial effect on their physical and mechanical properties. It is an essential component of the high tensile steels, and its lack was a serious blow to the German war machine, the main sources being in Canada and New Caledonia. Its uses for alloying with steel have been dealt with at some length in Part I, and its addition to brass and bronze in the section dealing with copper alloys, wherein the important alloy Monel metal is also treated. Nickel itself is used for electroplating, and for containers in industrial processes wherein resistance to alkalis and organic acids is necessary. It also resists the action of hydrochloric and hydrofluoric acids. The metal is ductile, malleable, machineable and magnetic, although to a lesser degree than iron. It can be readily soldered, brazed and welded. Nickel can also be rolled on to steel to form nickel-clad plate. Alloys not already dealt with earlier are a group of nickel-chromium alloys of approximately 80% Ni, 20% Cr, sometimes with modifications. This group is characterised by high strength, which is maintained at high temperatures, and resistance to oxidation at elevated temperatures. They are, of course, expensive. Some of these will be described briefly.

80% Ni, 20% Cr. This is a well known resistance alloy (Nichrome 1) having a resistance over 60 times that of hard-drawn copper, and resists oxidation and scaling up to 1000°C. Its use for heating and cooking appliances is well known. The melting point is 1375°C., and the ultimate tensile stress 60 tons/sq. in.

65% Ni, 15% Cr, 20% Fe, is a cheaper alloy, where iron replaces some of the nickel and chromium. It is known as Nichrome II. It is not suitable for working at over 850°C. Its electrical resistance is almost the same as Nichrome I, but the ultimate tensile stress is lower (47 tons/sq. in.).

"Bright-Ray" alloys are practically identical with "Nichrome" I and II, and used for the same purposes. They are also deposited on the faces of internal combustion engine valves by the oxy-acetylene process for long life under severe conditions.

"Inconel" contains 86% Ni, 12%-14% Cr, and the remainder Fe. It is used for aero-engine exhaust manifolds. It can be soldered, brazed and welded. It is ductile and can be wrapped round its own diameter without fracture.

The "Nimonic" series of alloys are essentially 80% Ni, 20% Cr, which have been modified by various additions so as to be amenable to heat-treatment. The modifications have not been released by the makers. "Nimonic 80" is extensively used for turbine blades and other parts in gas turbines and jet engines because of its resistance to oxidation and scaling. Its tensile strength is comparatively well maintained at elevated temperatures. It has very good "creep" characteristics at high temperatures, the load for 0.2% strain in 1000 hours being:—

Temperature °C.	Tons/sq. in.
600	25
650	19.5
700	13.5
750	7

Hence its use and importance in jet engine construction.

Nickel-Chromium-Iron (37/18). This is composed of 37% Ni, 18% Cr, 2% Si, 43% Fe. The physical properties are, 0.1% proof stress, 24 tons/sq. in., ultimate tensile stress 47 tons/sq. in., elongation 39%, reduction in area 50%, Brinell hardness 183.

The high-nickel magnetic alloys have been described in Part 1, under "Special Steels for Electrical Purposes."

The Light Alloys

These comprise the alloys based on aluminium or magnesium, whose outstanding characteristic is their light weight. Aluminium (specific gravity 2.68) is only one-third the weight of steel, and magnesium (specific gravity 1.75) only two-thirds that of aluminium. These two metals form the basis of the light-strong alloys which have such a wide use in the automobile and aircraft industries.

Aluminium is also characterised by its high conductivity of heat and electricity (approx. 60% that of copper), resistance to corrosion and affinity for oxygen. The latter causes the surface to be covered with a natural film of oxide, which makes the metal difficult to solder and requires the use of very active fluxes when welding. The unalloyed metal is used for cooking utensils, for surfacing telescope mirrors (for which purpose it is superior to other metals) and for overhead electrical conductors. For this latter purpose it is necessary to reinforce the wire with a central core of galvanised steel wire, owing to the low strength of the metal. It can, however, form the base of a number of alloys with strengths equal to mild steel.

A very large number of such alloys for casting and fabricating are sold under trade names, and it is impossible to deal with all of them in the space available. Some typical alloys will therefore be described. Such alloys seldom contain less than 85% aluminium, and have specific gravities less than 3.

Aluminium-Copper Alloys. These are casting alloys and were amongst the earliest used. Two alloys—BSS 4L11 and 3L8 are in common use. The first contains 6%-8% copper and the latter 12% copper. Mechanical properties are:—

Alloy	Copper %	0.1% Proof stress tons/sq. in.	Ultimate tensile stress tons/sq. in.	Elongation %
BSS-4L11	7	4	12	9
BSS-3L8	12	5	13	2

and they are used for automobile parts, such as crankcases and gearboxes, which are not highly stressed. They are severely corroded by salt water.

Aluminium-zinc alloys are cheap, but are hot-short, and are not generally used except with the addition of other metals.

Aluminium-copper-zinc alloys. A typical alloy, BSS.2L5, contains 3% Cu and 13% Zn. It has an ultimate tensile stress of 14 tons/sq. in., with 6% elongation. Strength at elevated temperatures and corrosion resistance are poor.

Aluminium-silicon alloys have from 11% to to 13% silicon, and are widely used for engineering purposes when modified by the addition of a small amount (about 0.01%) of sodium. The effect is not fully explained, but seems to be in the nature of refinement of structure. They possess good casting qualities (fluidity, low shrinkage) and good resistance to marine corrosion with reasonable strength (14 tons/sq. in.). "Alpax," "Silumin" and "Wilmil" are of this type.

Complex alloys which can be heat-treated have been developed, and these include "Y" alloy, developed in the National Physical Laboratory during the First World War, and the famous "R.R." series developed by Messrs. Rolls-Royce, and since marketed by High Duty Alloys Ltd., under the name of "Hiduminium."

"Y" Alloy. 4% Cu, 2% Ni, 1.5% Mg, 92.5% Al, is used as a piston alloy for internal combustion engines, and retains its strength at moderate temperatures. Its physical properties are:—

Treatment	Ultimate tensile stress tons/sq.in.	Elongation %	Brinell hardness
Chill cast	13	1	80
Heat-treated	19	4	105

The heat-treatment consists of heating at 500°-520°C. for six hours, followed by ageing at room temperature for at least seven days or boiling in water for two hours.

"RR" Casting Alloys are those known as RR.50 and 53. Their percentage composition and ultimate tensile stress are:—

	Cu	Ni	Mg	Fe	Ti	Si	Al	Ultimate tensile stress tons/sq.in.
RR. 50	1.3	1.3	0.1	1.0	0.18	2.2	93.92	16
RR. 53	2.23	1.3	1.6	1.4	0.1	2.25	91.12	22

Wrought Alloys are of two general types, those which may be work-hardened and those which need heat-treatment to develop their maximum strength. The work-hardened group include:—

The ageing period is four to five days. A modified alloy for electric overhead conductors contains 1.2% of magnesium and silicon, and has a conductivity only 10% less than pure aluminium.

Type	Composition %	Temper	Ultimate tensile stress tons/sq. in.	0.1% proof stress tons/sq. in.	Elongation %
Al-Mn	1.5 Mn	Soft Hard	6.5 15	— 11	33 3
Al-Si	11 Si	Soft Hard	9 13	— 10	25 6
Al-Mg-Mn	7 Mg/0.5 Mn	Soft	23	11	23
M.G. 7		Hard	25	18	15
Birmabright	1 Mg. 2 Mg. 3 Mg. 5 Mg. 7 Mg.	Extruded Extruded Extruded Extruded Extruded	10 11 15 17 20	7 6 7½ 9 9	18 20 22 17 17

The Birmabright series has good corrosion resistance and is used for lifeboat hulls. The heat-treated group of wrought alloys include Duralumin and the RR forging alloys.

Duralumin. 4% Cu, 0.5% Mn, 0.5% Mg, 0.5% Fe, 0.5% Si, was discovered accidentally by a German, Dr. Wilm, early in the century. He made tensile and hardness tests after quenching on a 3.5% Cu, 0.5% Mg alloy, and was disappointed with the results, which were not impressive. Some doubt was expressed regarding the accuracy of the tests and they were repeated on the same specimens a few days later. It was found that the hardness and tensile strength were much higher. It was found that the alloy could be markedly improved by cold working, quenching and ageing. Typical properties are:—

Condition	0.1% proof stress tons/sq. in.	Ultimate tensile stress tons/sq. in.	Elongation %	Reduction in area %	Brinell hardness
Cast	—	11	10	—	63
Worked and air-cooled 500°C.	7	18	21	44	65
Worked and quenched 500°C.	7	17	20	20	63
Worked, quenched and aged	15	26	20	35	98

Duralumin sheets can be obtained with a coating of pure aluminium on either side (Alclad, Aldural) when extra corrosion resistance is required. Duralumin loses its strength above 150°C.

RR.56 and RR.77. Used for forgings, etc., including connecting rods for internal combustion engines. The soft condition after quenching is stable, and machining and straightening can be done at leisure before tempering at 170°C. for 15-20 hours.

Type	Composition %	0.1% proof stress tons/sq. in.	Ultimate tensile stress tons/sq. in.	Elongation %	Brinell hardness
RR. 56	2 Cu, 1.3 Ni, 0.8 Mg, 1.4 Fe, 0.7 Si, 0.1 Ti.	24	29	15	140
RR. 77	2 Cu, up to 1 Ni, 5 Zn, 3 Mg.	27	33	8	—

There are many other such alloys, but space does not permit individual description. Additional information may be found in the references at the end of Part 1.

Magnesium. Magnesium is seldom used in the pure state, except for aircraft flares and photographic flash light purposes. The metal burns readily and special care has to be taken in welding, casting and machining, particularly as molten or burning magnesium reacts violently with water. It is cast in sand mixed with 5% sulphur or in steel dies. The usual alloying metals are aluminium, zinc and manganese. One group is known as "Elektron" and covers a wide range of sand and die casting and wrought alloys. These are the lightest commercial alloys available, being two-thirds the weight of duralumin and one-quarter the weight of steel. The mechanical properties are about equal to those of the normal aluminium alloys, but their weight is 40% less. Examples are given in the following table:—

Composition %	Use	Ultimate tensile stress tons/sq. in.	0.1% proof stress tons/sq. in.	Elongation %
2 Mn	Castings	6-7	1-5	3-5
8.5 Al, 3.5 Zn, 0.25 Mn (Elektron AZG)	Castings heat-treated	15	5	9-14
11 Al, 1.5 Zn, 1 Mn (Elektron AZM)	Extruded or Forged	18-20	10	12-16
8.5 Al, 0.5 Zn, .25 Mn (Elektron AZ885)	Forged	18-22	11-14	8-15
10 Al, 1 Zn, 0.5 Mn	Castings	15-17	7-9	1-3
8 Al, 8 Cd, 2 Ag	Forged and heat-treated (1" bars)	27	27	4

The last-mentioned is a recently developed high tensile alloy for airscrews. In general, the magnesium alloys compare unfavourably with the best aluminium alloys in strength at elevated temperatures and corrosion resistance, and their chief application is where saving in weight is essential. For instance, a landing wheel for a heavy bomber, which weighs 150 lbs. in magnesium alloy, would weigh 220 lb. in alloy steel.

SOLDERS AND LOW MELTING POINT ALLOYS

Solders may be divided into two groups—soft and hard. The soft solders melt below 300°C. and the hard solders above 600°C. There is an unfortunate lack of solders with melting points in between. The soft solders are familiar to all, and consist mainly of alloys of lead and tin in varying proportions. A study of the melting points of various lead-tin alloys reveals some interesting features. Fig. 7 shows the melting points of various alloys plotted against lead and tin content. It will be seen that an alloy of 63% tin and 37% lead has the lowest melting point of the range, viz., 183°C. The line CBE is drawn through this point. Below this line, alloys containing between 15% and 100% tin are completely solid. Between the lines CB and AB, BE and BD the solders are a mixture of liquid and solid particles, i.e., in a pasty condition. Above the lines AB and BD the alloys are completely liquid. Consider a common wiping solder containing 33% tin and 67% lead. The solder will be completely liquid above 250°C., pasty between 250°C. and 183°C., but not solid until below 183°C. It is this "pasty" range which allows "wiping" technique to be employed. A solder containing only 25% tin would be even more suitable,

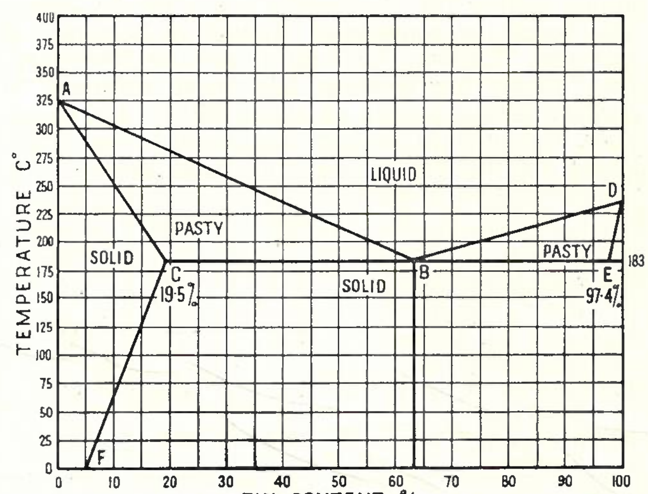


Fig. 7.—Equilibrium Diagram Tin-Lead.

and would be cheaper on account of the lower tin content. The slightly higher melting point of

270°C. should not be serious. The 63% tin solder has no pasty range but changes immediately from liquid to solid. It is, therefore, well suited for soldering wiring to tags, and requires less heat to melt; the tensile strength is also higher than any other in the range. Obviously the temperature of 183°C. and the 63/37 tin-lead alloy are important in the tin-lead series. Similar effects occur in many (but not all) alloy systems, and the special composition which has the lowest melting point, and also entirely solidifies at the same temperature, is known as the eutectic alloy. By careful choice of constituents it is possible to make alloys of unusually low melting points, some below the boiling point of water. These will be referred to later. Other soft solders besides the lead-tin alloys are known but not used to any great extent. Some of these are tabulated below:—

Designation or use	Composition %	Solid °C.	Liquid °C.
For lead coating copper	95 Pb, 5 Sn	290	313
Joints in copper tube	95 Sn, 5 Sb	232	241
Wiped joints lead pipe	68 Pb, 23 Sn, 9 Cd	145	235
For high temperatures	94.5 Pb, 5.5 Ag	304	368
For high temperatures	95 Cd, 5 Ag	338	393
For high temperatures	92.5 Cd, 7.5 Zn (Eutectic)	264	264
For high temperatures	50 Cd, 50 Zn	264	326

Hard solders are alloys of copper and zinc, sometimes with additions of silver and/or cadmium. The joints are very much stronger than those made with soft solder, but much higher temperatures are involved, and a different technique, calling for the use of a gas or oxy-acetylene torch, or sometimes "induction heating" is required. The use of the 60/40 and 50/50 copper-zinc alloys for brazing has been referred to earlier. Temperatures of about 850°C. are necessary. Other hard solders containing silver have lower melting points. Four of these are:—

Composition %	Solid °C.	Liquid °C.	Strength as cast tons/sq. in.
28.5 Cu, 10 Zn, 61.5 Ag (B.S. "A" grade)	690	735	25
37 Cu, 19 Zn, 44 Ag (B.S. "B" grade)	700	775	25
15 Cu, 16 Zn, 50 Ag, 19 Cd (Easy-Flo)	595	630	30
80 Cu, 15 Ag, 5 P (Sil-fos)	705	705	46

Low melting Point Alloys

These mostly contain lead, tin, bismuth and cadmium, and are of approximately eutectic composition. Compositions and melting points are tabulated in the following table:—

Composition %	Melting Point °C.	Melting Point °F.
41 Bi, 22 Pb, 10.7 Sn, 8.2 Cd, 18.1 In	47	117
49 Bi, 28 Pb, 13 Sn, 10 Cd (Wood's Metal) (Cerro bend)	70	158
50 Bi, 25 Pb, 25 Sn, (Rose's Metal)	94	203
55Bi, 45 Pb (Cerro base) (does not expand or contract on freezing)	125	256
60 Bi, 40 Cd	144	291
48 Bi, 28.5 Pb, 14.5 Sn, 9 Sb (Cerro matrix) (expands on cooling)	110	217

The last-named is used for mounting punches and dies on base plates and saves time and cost in building up dies and punches, and also affords accurate location of punches in relation to dies. "Cerro bend" is used as a filler for tubes during bending operations. It can be removed by heating the tube in boiling water.

Type metals are alloys of lead, tin and antimony. The antimony gives sufficient hardness to withstand wear of long periods of printing use. The usual range is 5-10% Sn, 15-20% Sb, and 60-80% Pb. They melt about 250°C. and are usually cast at about 265°C.

"Britannia Metal" and "Pewter" are practically identical and consist of 94-95% Sn, 4-5% Sb, with 1% Cu being sometimes added. The melting point is about 250°C., and they are used as a base for articles to be silver-plated, such as teapots, beer mugs, salt cellars, etc.

Bearing Alloys

The "white metal" alloys have either a tin or lead base, antimony and/or copper being added as hardeners. The tin base alloys are usually regarded as superior. The original "Babbit" metal (due to Sir Isaac Babbit) was 89% Sn, 7.4% Sb, 3.6% Cu. Another typical alloy is 93% Sn, 3.5% Sb, 3.5% Cu. The latter alloy has a yield point (in compression) of 3.6 tons/sq. in. and a Brinell hardness of 25. Another, of 86% Sn, 10.5% Sb, 3.5% Cu, has a yield point in compression of 4.3 tons/sq. in. and a Brinell hardness of 33. An alloy of 78% Sn, 11% Sb, 11% Cu, has a wide plastic range and can be readily moulded for repair work. Lead is often added to cheapen the metal. The lead base white-metals usually contain 10-15% Sb, about 1% Cu and 2-10% Sn. They are cheaper than the tin-base alloys, but have not the same load capacity. Moreover, the load capacity falls more rapidly with temperature rise. Originally it was common practice to cast the white-metal direct to the big-end eye of automobile connecting rods, the bearing then being bored to size. However, the need for replaceable bearings led to the use of steel shells having about 0.030" to 0.040" of white metal lining. Latest practice is to reduce this to 0.002" to 0.004" and this prevents "hammering," facilitates heat-flow, and, should the bearing melt, continued operation for a short emergency period at reduced load is usually possible.

Copper-base bearing metals are usually of gunmetal, phosphor-bronze, manganese bronze or other high tensile brass, silicon bronze, or aluminium bronze. These have been already described.

Lead-bronze is a recent development for high-duty bearings in automobile, tractor, diesel and aircraft engines. Such alloys usually contain 70-75% copper and 30-25% lead, with tin up to 1½% max. They are harder at all working temperatures than the white metals, and have superior wear resistance and much higher thermal conductivity, so that heat may be conducted away faster. The load capacity is said to be 20-25% higher than for the best white metals. They are, however, not so plastic and cannot adjust themselves to slight dimensional differences, so that greater clearance is usually allowed. Casting temperatures are also much higher, being about 1100°C. as against about 400°C. for white metal. It is also necessary to use a brazing flux (borax) instead of a soldering flux (zinc chloride).

Aluminium Alloy Bearings. It might also be mentioned that the R.R. 56 aluminium alloy previously mentioned is also a satisfactory bearing alloy, and it is customary for automobile and motor cycle engine connecting rods made of this alloy to run directly on the crankshaft (hardened) without any bearing insert.

Cadmium copper (3%Cu) and cadmium-copper-silver (2% Cu, 0.5% Ag) have also been used for bearing metals and are stated to be superior to white-metal. However, accurately fitted shells and hardened shafts are necessary. They are cheaper than the lead-bronzes.

Moulded Metallic Powder Bearings are a recent development in powder metallurgy. 90% powdered copper and 10% powdered tin are moulded in presses at about 20 tons/sq. in. The moulded product is sintered at about 700°C. and quenched in lubricating oil. The structure is porous and readily absorbs oil. Up to 1½% powdered graphite can also be added to the mixture. Typical applications are small motors in domestic appliances, phonograph motors, clocks, etc.

DIE-CASTING ALLOYS

The term "Die-casting" is applied to a process of casting metals, either under pressure or by gravity in metal (usually steel) moulds. The process has the following advantages:—

(1) The castings are very accurate, and in the case of pressure die-casting are sufficiently accurate for most purposes not to need subsequent machining.
(2) They can be produced rapidly, thus facilitating mass production.
(3) Inserts, studs, bushes and similar objects of other metal can be cast in position.
(4) Holes can be provided to a high degree of precision and external threads can be cast with reasonable accuracy. Spur, worm, or bevel gearing can also be satisfactorily die-cast in small sizes.
(5) The general finish is such that further work is not required.
(6) Thin sections (down to 1/16" or less) can be cast.

The drawbacks are:—

(1) The process is economical only for large numbers, as the cost of the dies has to be included.
(2) It is limited to a few groups of metals of relatively low strength.

Alloys mostly used for die-casting have aluminium, tin, lead or zinc as a base.

The Aluminium base alloys are by far the strongest of the group, but suffer from the disadvantages of high casting temperatures (700°C. and upwards) and lack of sharpness and accuracy compared with the others. Any of the casting alloys previously described may be used.

Lead Base alloys contain about 80% lead together with 10-15% each antimony and tin. The strength is low and melting point about 340°C. They are mostly used for toys, type metal and bearings.

Tin-base alloys usually contain some copper, lead and antimony. The strength is also low, and melting point about 350°C. The shrinkage is low and they are used for number wheels, speedometer parts and bearings. Most of the "white-metals" previously described under "Bearing metals" may be die-cast.

Zinc base alloys. These are the most widely used die-casting alloys. Most of them contain up to 4% aluminium and 1% copper. Considerable trouble was experienced initially with these alloys due to inter-granular corrosion which developed with age and finally led to failure. This is stated to be due to impurities in the zinc, mainly lead, cadmium and tin. Zinc of 99.99%+ is now used for these alloys, and there has been some improvement and failures are not nearly as common. It is not considered, however, that they are yet entirely free from this defect. Typical alloys, sold under the trade names of Mazak, Zamak and Durak, are as follow:—

Alloy	Composition %				Melting point °C.	Ultimate tensile stress tons/sq. in.	Brinell hardness
	Al	Cu	Mg	Zn			
Mazak	4	—	.04	95.96	381	18-20	74-83
Zamak	4	2.5	.03	93.47	394	21	83
Durak	4	1	.03	94.97	380	23	100

These alloys are relatively cheap, have good die-casting qualities at relatively low temperatures (which allows cheaper die steels to be used) and can be cast in very thin sections under pressure. They can readily be plated. They cannot be soldered, and welding is difficult, on account of the oxides formed on the molten metal, and for which no satisfactory flux is available. Welds are only possible by a "puddling" process, when the oxides are removed with a steel rod or spatula. Applications of zinc-base die castings include automobile radiator grilles, window frames, speedometers, carburettor and petrol pump bodies, door fittings and handles, tail and side lamps, various instrument parts, vacuum cleaner and other domestic machine parts, typewriter frames, calculating machine parts, etc.

SUPER-HARD CUTTING AND SPECIAL ALLOYS

The high-speed steels have already been described in Part 1. The series of alloys known as "Stellite" are much harder, and hardest of all are the various preparations of tungsten carbide, which are produced by sintering. The latter are not alloys in the true sense of the word, but consist of tungsten carbide powder cemented together by another metal, usually cobalt.

"Stellite" is made in various grades of hardness and impact resistance, according to composition, which is 5-10% Wo, 25-30% Cr, 45-65% Co, with some carbon. The Brinell hardness varies from 400 to 600, and is maintained even at red heat. The alloys are used for the usual hard-surfacing purposes, including tipped cutting tools for lathes, planers, etc., surfacing valve seats for internal combustion engines, and hard-surfacing plough-shares, dredge buckets, mechanical shovels and similar uses. The alloys are very resistant to abrasion and corrosion at high temperatures. They can be applied by the usual welding techniques, the melting point being below that of mild steel. Some care is needed with cast iron, as the melting point of this is not much above that of "Stellite."

Tungsten Carbide. This material is prepared from metallic tungsten powder and carbon by sintering in an electric furnace at 1500°C. in an atmosphere of hydrogen. The resulting compound (still in powder form) is mixed with 5-20% of powdered cobalt and pressed into blanks. This is pre-sintered for about half an hour at 700°-900°C. and the blocks are finally cut and ground to shape, followed by a final sintering at 1400°C-1500°C. The finished blanks are brazed to steel shanks by the oxy-acetylene, furnace or induction heating processes.

A very good article on the whole process is "Tungsten Carbide Tipped Tools," by F. S. Lewis, Post Office Electrical Engineers' Journal, January, 1949, page 213. Tungsten carbide, sometimes with the addition of small amounts of titanium or tantalum carbide, is processed as described above and sold under several trade names, such as "Widia," "Wimet," "Mitia," "Cutanit," "Ardoloy," "Firthite," Tungstalloy," "Kennametal," etc. They are amongst the hardest cutting materials known and require special diamond grinding wheels. Drills tipped with tungsten carbide can drill holes in glass, tile, pottery, concrete and masonry without difficulty.

Heusler's Alloy. This is a magnetic alloy which does not contain either iron or nickel. It comprises 55% Cu, 30% Mn and 15% Al.

G.E.C. Heavy Alloy is made by a sintering process from 90% Wo, 6% Ni and 4% Cu. The specific gravity is approximately 17, which is twice as heavy as steel, and 50% heavier than lead. It was developed for use in aircraft for balance weights where minimum space was required. Tensile strength is over 40 tons/sq. in., and the Brinell hardness 250-290. It can be machined, and resists atmospheric and salt water corrosion. It is also used for screens in X-ray units and circuit-breaker contacts, the latter because it resists arcing remarkably well.

CONCLUSION

In the review in this article and in Part 1 in the previous issue, obviously it has not been practicable to deal with all aspects of ferrous and non-ferrous metals. It is hoped, however, that sufficient of the fundamentals have been covered to be of general interest and value to the reader.

ORGANISATION OF ENGINEERING FUNCTIONS IN A BRITISH POST OFFICE TELEPHONE MANAGER'S AREA

C. E. C. Skuse

Introduction

Generally the overall organisation of the British Post Office does not differ greatly from that in the Australian Post Office, but administrative management of all branches in the Telephone Service under one executive is arranged in smaller units. Whereas in the Australian Post Office the State Deputy-Director is the first overall executive officer controlling all functions within the telephone service, in the British Post Office such overall administrative control is arranged in smaller units called Telephone Manager's areas.

So far as the Post Office services are concerned, the United Kingdom is divided into nine regions. Each of these regions has a Regional Director as the executive controller of all matters relating to mail, telegraph and telephone services within the region. The London Region, on account of the complexity of the services within it, has separate Regional Directors for mail and telephone services. The nine regions are again divided territorially into administrative units, referred to previously as Telephone Manager's areas. Within these areas a Telephone Manager is in executive control within defined devolved authority limits and responsible to the Regional Director. As an example, London has nine Telephone Managers' areas as follow:—City, Centre, Long Distance, North-West, West, South-West, South-East, East and North.

It is the purpose of this article to give a brief description of the Engineering organisation within one of the London Telephone Manager's areas. Staff complements are quoted, but it should be realised that the territories will vary, and the numbers of Engineers, Assistant Engineers and Inspectors will also vary.

In order to give an idea of the general Telephone Manager's area organisation, Fig. 1 includes in tree form the divisions under the control of the Telephone Manager.

It will be seen by reference to Fig. 1 that the Engineering Administration is divided on a functional basis, and the organisation within each division will be outlined separately.

The area which is the subject of this description is one of the outer London territories, of approximately 300 square miles, and is served by 55 exchange areas, 24 being automatic. Within this area are 166,000 exchange lines, including 12,000 on a two-party shared basis, and a total of 223,000 stations. The installed wire mileage approximates 1,088,000 underground, and 16,000 overhead miles. Total staff within the area is approximately 4700. This figure includes all engineering, traffic, clerical and sales personnel.

Engineering Planning Division

While overall planning principles and policy are directed by the Engineer-in-Chief through the Chief Regional Engineer, detailed planning and estimating of line works within a Telephone Manager's area are carried out by the area staff. Exchange planning is directed by staff of the Chief Regional Engineer, who is engineering adviser to the Regional Director, but detailed estimating of these works is under the control of the Executive Engineer Construction.

Generally, it can be said that the Executive Engineer Planning controls local line planning and estimating, and junction and trunk estimating, planning of the latter works being carried out by Chief Regional Engineer's and Engineer-in-Chief's staffs, respectively. Organisation within the Planning division is given in Fig 2.

Each of the 13 Assistant Engineers shown in Fig. 2 would cover works within approximately four exchange areas, and would have the assistance of from four to six Technical Officers for surveys and compilation of estimate data, schedules, etc. Of these technical assistants two would be graded Technician, and the others Technical

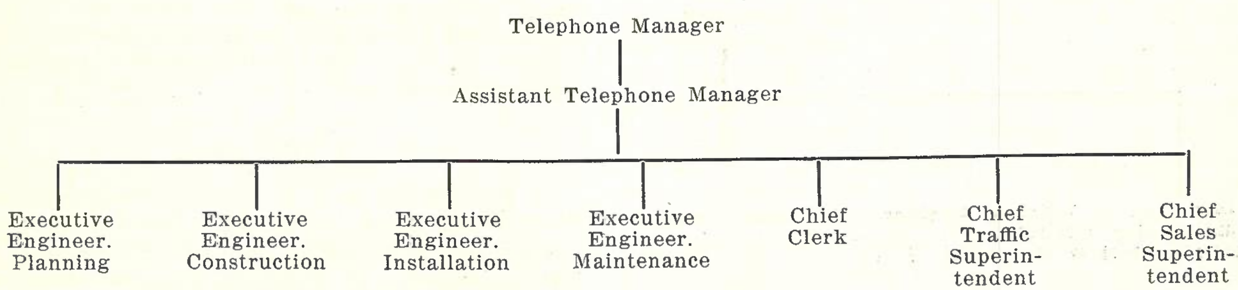


Fig. 1.

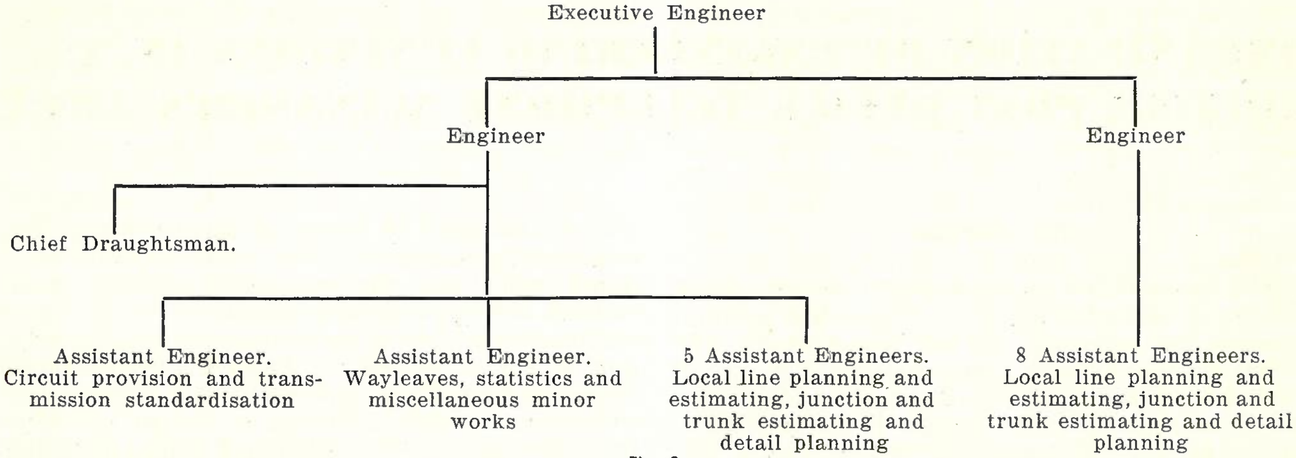


Fig. 2.

Officer. The equivalent grades in the Australian Post Office would be Line Foreman Grade 2 and Lineman Grade 2, respectively.

The Assistant Engineer with his assistants prepares detailed plans, estimates, jointing schedules, wayleave applications, etc., for all works in the areas covered, except certain minor works prepared and authorised by the Assistant Engineer on miscellaneous duties. These latter, however, are subject to oversight and concurrence by the Assistant Engineer Planning, in order that all such works are in accord with the planning scheme for the exchange area.

The estimates and schedules prepared cover works operations down to as small as four-pair cables, and indicate exact pole sites agreed to by Local Authorities and other wayleave grantors. Cabinet and pillar sites are also clearly defined by the Assistant Engineer Planning, as agreed to by wayleave grantors, and detailed site plans prepared.

Construction Division

The Executive Engineer Construction has control of the execution of all major works, which for this purpose may be classified as all works involving over 100 manhours. The works under 100 manhours are normally carried out by installation staff, and in exceptional circumstances by maintenance units, on a loan basis. The organisation within the Construction division is shown in tree form in Fig. 3.

Conduit Construction Works are largely carried out by contractors from estimates prepared by the Planning division, and it is necessary to set up an organisation to supervise these works. This is done by a staff of trained Technicians qualified as Works Supervisors, under the control of the Assistant Engineer, Conduit Works. The Technicians oversee all contract work, ensure that standard construction methods are used, and generally guard the Department's interests.

Contract diaries, giving details of actual work performed, are prepared and these are checked by the Works Supervisor to ensure accuracy of costing data. Approximately nine Works Supervising Technicians would be engaged on this work, in such an area. Clerical check of diaries, schedules, contracts, orders, reinstatement vouchers, etc., are dealt with in the major works control office.

Cabling Works estimates prepared in Planning division pass to the major works control office for execution of the necessary work. The Works Con-

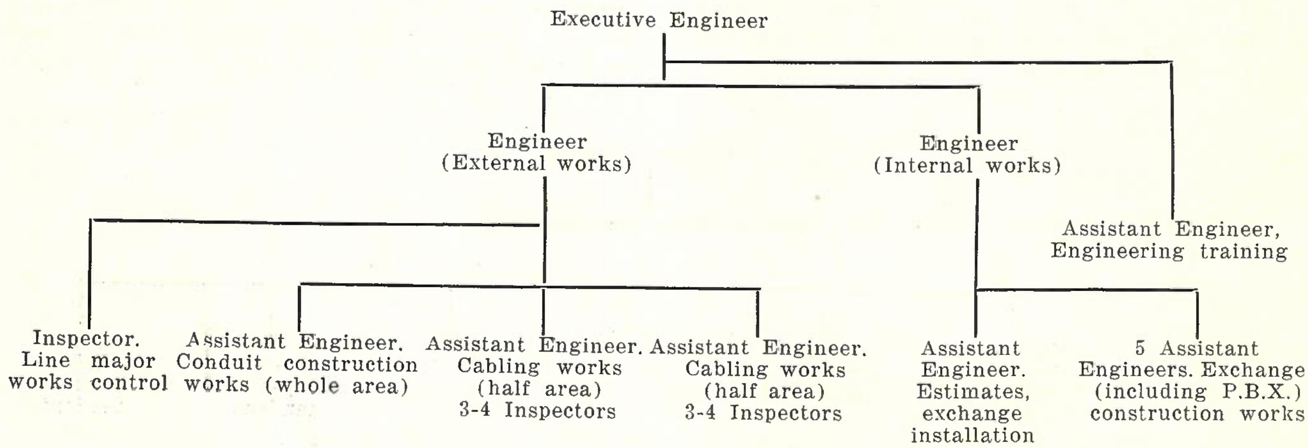


Fig. 3.

trol is staffed by an Inspector, assisted by three Technical Officers and approximately six clerical assistants. The Works Control organisation was set up to reduce the volume of clerical work of Assistant Engineers and Inspectors engaged on line works, and leave them more time to devote to field supervision of works in progress. The arrangements are of an experimental nature, and as set up at present are subject to some modification.

The Control Inspector, under guidance of the Engineer, allocates staff to the various works, co-ordinates usage of mechanical aids, requisitions stores. Records are maintained of works progress from workmen's diaries and daily progress reports. Priority of execution is arranged by consultation between planning and construction engineers.

Stores requisitioned for major works are consigned to depots known as Works Order Stores in the vicinity of the actual work. These stores are usually lock-up rooms in exchange buildings, and are arranged so that entry may be obtained direct from the exchange yard, to facilitate loading and unloading. The two Assistant Engineers on cabling works generally co-ordinate works execution, and supervise works in progress through the medium of Field Inspectors. No Works Control exists to co-ordinate exchange construction works, and the Assistant Engineers supervise these jobs largely on a territorial basis. Technicians carry out direct supervision on the site and control staff employed on the individual works.

The training officer is an Assistant Engineer who maintains training programmes for youths in training, generally supervising the actual training of these recruits. He also maintains liaison with the Regional Training Schools, and arranges refresher courses for all engineering personnel. Reports are made on the progress of youths, and guidance is given to them on their future careers.

Installation Division

For control of subscribers' installation and minor works jobs, the Telephone Manager's area is divided into a number of installation areas. An Installation Office, complete with Section Stock Stores and Cable Recording staff, is situated within each such installation area. The Executive Engineer is in administrative control of installation functions for the whole area, and in the area described is assisted by an Engineer, three Assistant Engineers and twenty-one Inspectors. The general organisation is shown in Fig. 4.

Within each installation area the Assistant Engineer is assisted by two or three Inspectors. The arrangements are that the office constitutes a minor works and advice note (Telephone order) control, and to maintain regular contact one of the Inspectors is designated Control Inspector and remains full time in the office organising works programmes, checking daily diaries and workmen's progress reports. A clerical assistant is stationed at each Installation Office to assist the Control Inspector with routine clerical duties.

As previously mentioned, a Section Stock Stores and a Cable Recording Office is associated with each Installation Office. The former is a complete stores depot and holds a comprehensive stock of Line and Equipment Stores, including small switchboards, kiosks, ducts and cable. The latter is staffed by cable recorders of the Lineman Grade 2 category, supervised by a Line Foreman.

Actual day-to-day control of staff and issue of Advice Notes and minor works is vested in a skilled workman Class I or Distributor Officer, who is advised by the Control Inspector of works priorities. Foremen supervise works in the field, but the Distributor Officer issues work to line staff and maintains "staff whereabouts" schedules, for supervision purposes. For efficient handling of such Advice Notes or minor works authorities, the Distributor Officer is provided with a specially designed Distributor Cabinet, in which are filed in priority and exchange area order the various works authority papers.

Staff units controlled would include Telephone Fitters, Fitter Jointer pairs (i.e., a Fitter and a Jointer working together), utility gangs and jointers. The utility gangs are equipped with specially designed 30 cwt. utility vehicles, which include a tool kit and a van stock of general line stores items, and the gang would normally be composed of a Foreman, O/H Wireman, Jointer, and Fitter. Thus a utility gang can proceed with

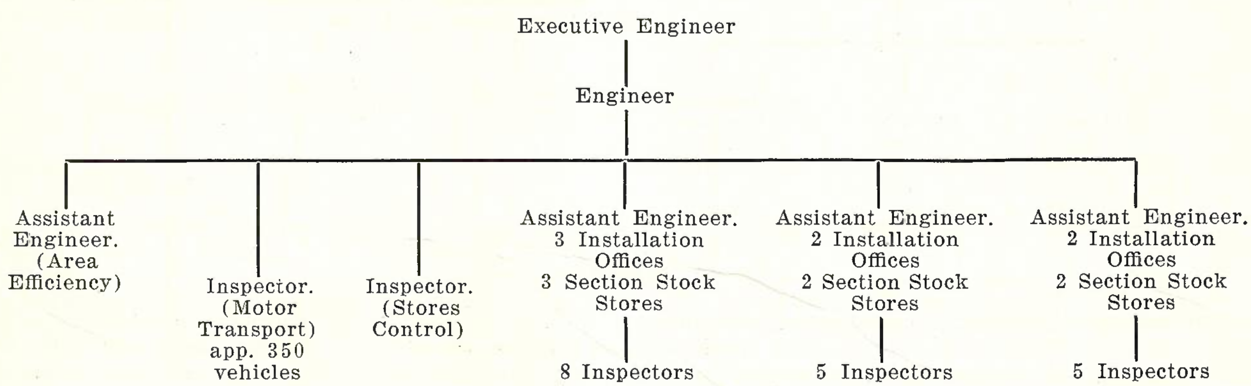


Fig. 4.

advice note works to completion in one visit, and are not hampered with daily calls at stores for normal work requirements. The Stores Control Inspector acts as liaison officer between the various Section Stock Stores, and co-ordinates the supply of items urgently required from Stores Department sources and not available within the area.

Co-ordination of usage and maintenance of the area motor transport fleet is arranged by the Motor Transport Inspector. Actual maintenance of the vehicles is carried out by the Motor Transport Branch, at various garages in the area—these garages are not under the control of the Telephone Manager, and vehicle provision or maintenance is arranged on a user-supplier basis.

Also under administrative control of the Executive Engineer Installation is the Area Efficiency Assistant Engineer. This officer investigates for the Telephone Manager, or any Executive Engineer, any problems not able to be answered by the normal supervising staff. These problems would include costing trends, engineering methods and organisation, usage of mechanical aids and equipment, and the Efficiency Officer would investigate personally and submit a report with any recommendations direct to the Telephone Manager or Executive Engineer. The author, prior to taking up appointment with the Australian Post Office, was engaged on Area Efficiency duties in the London Region.

Maintenance Division

Engineering maintenance in a Telephone Manager's area is divided into two main functional groups—

(a) Exchange equipment maintenance.
(b) External plant maintenance, including subscribers' apparatus.

A staff tree for maintenance division organisation is given in Fig. 5.

Exchange Equipment Maintenance Engineers are assisted by three or four Assistant Engineers, who each control one or more exchanges, dependent upon the size and complexity of the equipment to be maintained. Only apparatus within the exchanges and repeater stations is maintained by these Engineers and their staffs. External plant maintenance is controlled by an Engineer assisted by three Assistant Engineers, two being responsible for overhead, underground and subscribers' apparatus maintenance, the third for heavy cable and aerial maintenance and renewals for the whole area. Heavy maintenance includes all cables above 100 pairs, and also the heavier loaded aerial routes. Each of the Assistant Engineers has three or four inspectors controlling staff within his part of the area.

The control of faults and maintenance work is arranged by the establishment of maintenance control centres staffed by a Technician. These control centres are set up at certain exchanges on a separate Test Desk position with, in certain cases, test lines to the exchanges controlled. The control officer records faults, prepares fault statistics, and issues to maintenance staff faults for clearance, maintaining at the same time a diary sheet of the maintenance staff visits, job by job. Faults are normally reported to traffic staff, and Registered Dockets are used to advise the maintenance control officer of each fault.

An additional area co-ordinating fault control exists, staffed on a twenty-four hour basis, to deal with inter-area queries and provide maintenance control facilities during off normal hours. Certain maintenance staffs are scheduled for emergency attendances, and are on call at all times.

Chief Clerk's Division

Clerical organisation within a Telephone Manager's office may be broadly divided into two parts, one providing clerical personnel for engineering matters, the other for the commercial aspects of the telephone service. Engineering clerical staffs include assistants to Engineers in works controls, etc. The provision of wages sheets prepared from workmen's diaries is a clerical function, as are the following:—

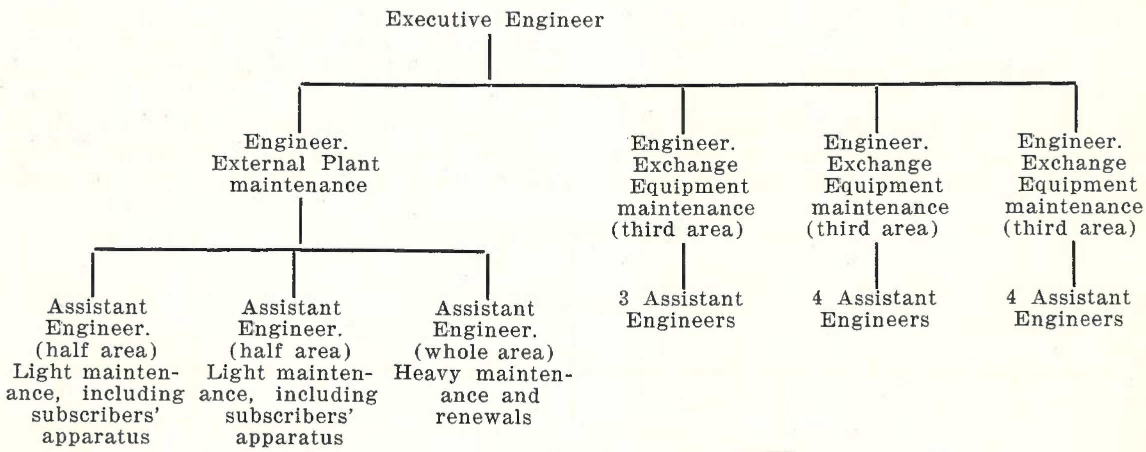


Fig. 5.

Care of Stores Dockets in the form of requisition and delivery note duplicates.

Costing of estimates and compilation of Works Order statistics and general cost statistics.

General correspondence and maintenance of records for transport, wayleave and advice notes.

Building accommodation, including office equipment provision, is also a function of the clerical division. Commercial clerical staffs prepare subscribers' accounts from call tickets, rental data, etc., provide a typing pool, and generally carry out clerical work on the commercial side of the service.

Chief Traffic Superintendent

The Chief Traffic Superintendent is responsible to the Telephone Manager for all matters relating to service to existing subscribers; also supervises the operating staffs and arranges training where necessary. Equipment data in the form of traffic statistics are prepared by traffic officers prior to passing to the Engineering Trunk and Junction Planning staffs in the form of Trunk and Junction circuit requirement forecasts.

Chief Sales Superintendent

The Chief Sales Superintendent is responsible for dealings with the public on telephone service matters, and his staff includes sales officers who handle subscribers' agreements and supply information to potential subscribers on the various facilities available.

On the sales staff, also, are the Telephone Development Survey Officers, who provide the fundamental survey data used by the Local Line Planning Engineers. Areas are systematically surveyed, and forecasts of telephone development in the next twenty years given in five-year periods. Trends in wartime and post-war conditions have made it necessary to maintain lists of potential subscribers to whom service cannot be given. Clerical staff attached to the sales division maintain these records and close liaison with cable recording staffs in the various Installation Offices, in order that service may be given as soon as plant becomes available.

Conclusion

An attempt has been made to describe briefly the essential features and the organisation of Telephone Managers' areas in the British Post Office. Many items could be treated at greater length and in greater detail, but that is not the purpose of this article, which is intended only as a brief summary of how the organisation of telephone affairs is carried out in the United Kingdom.

THE B.P.O. TYPE 2,000 GROUP SELECTOR RACK EQUIPPED WITH GRADING FACILITIES

By T. E. Dalston, Equipment Engineering Division, Automatic Telephone & Electric Company Limited, Liverpool

SYNOPSIS

The article first outlines the investigations which precede the development and standardisation of the new rack, the basic design principles of which are similar to those of the Company's earlier designs for overseas administrations. A general description is given of the rack design and the method of providing the grading facilities. Details are then given of the connection strip mounting arrangements and jumpering facilities, terminations of bank multiples and on the I.D.F., grading, jumpering and exchange trunking, and finally the I.D.F. arrangements. The standard basis of providing the rack equipment and cabling is then described and the article concludes with descriptions of several special features, illustrations being included.

INVESTIGATION PRIOR TO DEVELOPMENT AND STANDARDISATION

Prior to authorising the development of the Type 2000 group selector rack with grading facilities, the B.P.O. fully investigated the question of providing greater flexibility in exchange cabling schemes, in the interests of interchangeability and subsequent rearrangement of equipment. A number of schemes were examined, and consideration was given to various methods of cabling between ranks of selectors. These included the centralised T.D.F. scheme, which had been the standard method for a number of years. Even in this scheme, however, experience has proved that modifications to gradings often mean interference with permanent cabling.

It was considered that the main problem of arranging for greater flexibility in exchange cabling could be solved by producing a scheme in which alterations, in the use and grouping of racks of selectors to meet traffic variations, could be carried out merely by jumpering changes.

Agreement was reached that a satisfactory solution could be obtained by a system of specially wired and cabled unit racks, equipped with grading facilities at the rear of the shelves. This system would be applicable to group, 1st code and "A" digit selectors, and also uniselectors. In view, however, of the urgency of arranging for the development of this type of rack to meet post-war requirements, it was considered that the group selector rack, 200 outlets only, should be the first to be developed.

It was known that the basic principles of the new design had already been embodied in a group selector rack, developed and manufactured by A. T. & E. Co. Ltd., for overseas administrations as described in the "Strowger Journal," Vol. IV, No. 4, December, 1938. It was considered that the development of the new unit rack would not give rise to any manufacturing difficulties. Development of the group selector rack with grading facilities was allocated to the Company, and liaison with the Engineer-in-Chief's representatives was established and maintained during the full period of the development.

All facilities, design features, and basis of provision of equipment and rack cabling, details of which are given in this article, were investigated and agreed, and before final manufacturing drawings were prepared a sample rack was built in the Company's factory, in order to demonstrate that all requirements could be met. The sample rack was examined by representatives of the British contractors, and by officials of the Telephone, Maintenance and Equipment Branches of the Engineer-in-Chief's office. It was agreed that the rack fulfilled all the requirements and that the design was satisfactory from a manufacturing point of view.

RACK DESIGN AND PROVISION OF GRADING FACILITIES

(a) General

The new standard rack meets all conditions and requirements for 200 outlet group selector, and 2nd and subsequent code selector racks.

Manufacturing drawings to cover two heights of racks, 8 ft. 6½ in. and 10 ft. 6½ in., have been completed, the equipment being arranged as shown in Figs. 1 and 3.

From the point of view of rack capacity and the arrangement of shelves and banks, as viewed from the front of the rack, the design follows the standard 200 outlet group selector rack without grading facilities. There are, however, differences as regards fusing and rack common equipment, which are outlined in another section of this article.

The grading facilities are provided on connection strips fitted at the rear of shelves B to F on both the 8 ft. 6½ in. and 10 ft. 6½ in. racks, as shown in Figs. 2 and 4 respectively.

[We acknowledge with thanks permission by the Automatic Telephone & Electric Company Limited, Liverpool, and the Engineer-in-Chief of the British Post Office to print this article, which appeared in the Strowger Journal, Volume 7, No. 1, of November, 1949. Racks of the type described are being purchased for extensive use in Australia.]

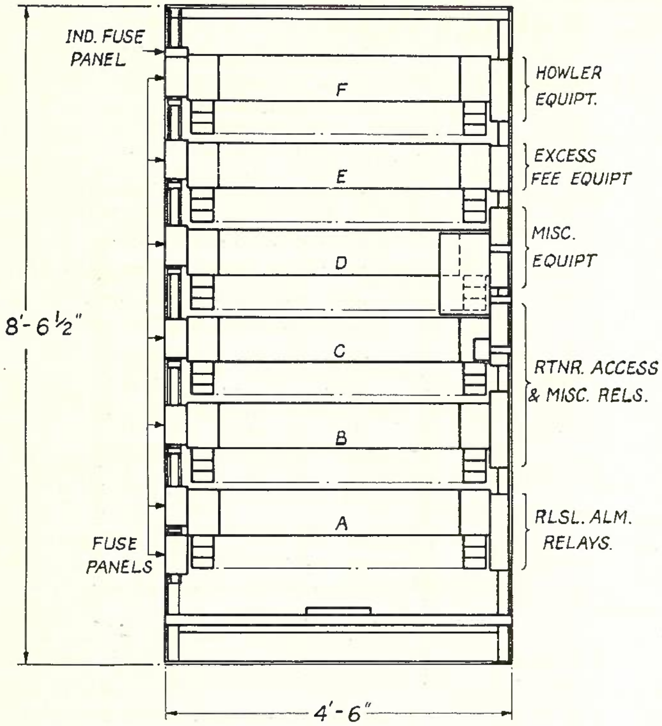


Fig. 1.—8' 6½" Rack, Front View.

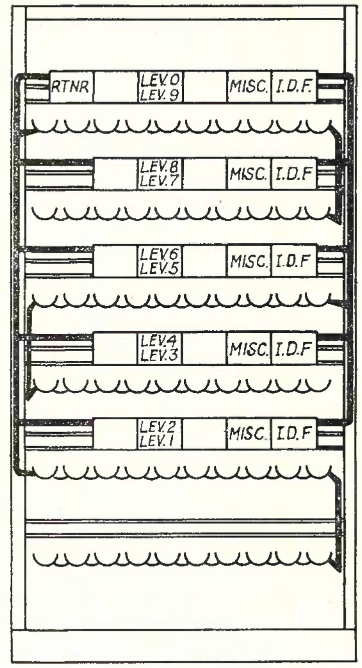


Fig. 2.—8' 6½" Rack, Rear View.

As the 10 ft. 6½ in. rack has the larger capacity, i.e., eight shelves of selectors, and is the height of rack most generally used, the following details and illustrations refer to the 10 ft. 6½ in. rack.

On the 8 ft. 6½ in. rack, the mounting and arrangement of connection strips and the grading and jumpering facilities are identical with the 10 ft. 6½ in. rack, but the former only caters for three multiples of twenty banks on six shelves, while the latter is equipped with four multiples of twenty banks on eight shelves.

(b) Connection strip mounting arrangements and jumpering facilities

Figs. 2 and 4 illustrate the complete arrangement of connection strips required for the termination of the bank multiples, I.D.F. circuits, and certain rack services such as spare level circuits, multi-metering pulses, and the routiner test line interception relays.

The connection strips are mounted at the rear of shelves B to F, on mounting brackets of the design shown in Fig. 5, seven of these brackets being required on each shelf as shown in Fig. 6.

The mounting bracket was specially designed for the new standard rack, and in addition to providing for the fixing of the connection strips it incorporates the following special features:—

(i) The jumper ring is formed in the lower half of the bracket, thus providing a jumper field behind the lower half of the connection strips, on each shelf, and permitting the feeding of jumper wires through the lower fanning holes of the connection strips.

(ii) The top horizontal member of the jumper ring provides a very satisfactory support for the various cables which have to be fed along the shelves and wired to the connection strips and shelf jacks as illustrated in Figs. 6 and 7.

(iii) Provision is made for the fixing of metal designation labels across the top and bottom of all connection strips mounted at the rear of the shelves. In addition and in order to facilitate the marking of all connection strips fitted at the rear of the rack, a fibre label has been designed and can be fixed at one or each end of the connection strips. Tapped inserts are fitted in the connection strip base for the fixing of these fibre labels. Figs. 5 and 8 show the metal and fibre labels.

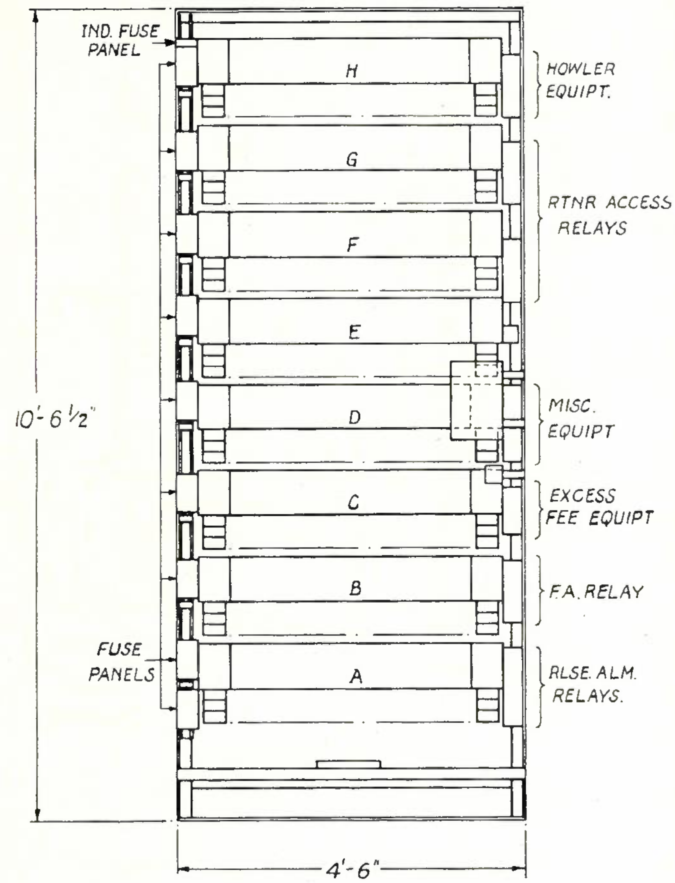


Fig. 3.—10' 6½" Rack, Front View.

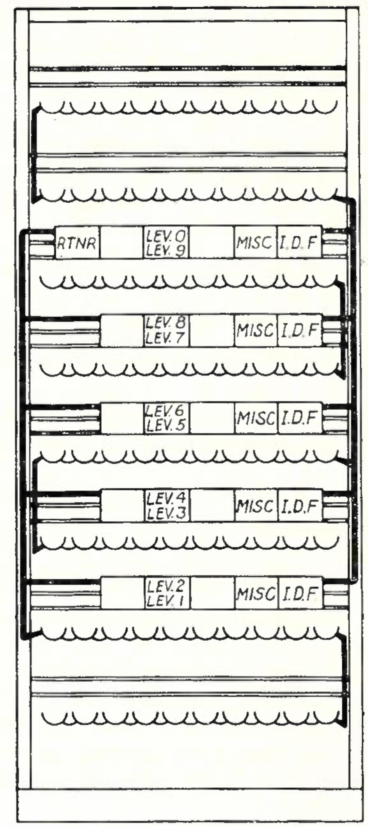


Fig. 4.—10' 6½" Rack, Rear View.

Apart from the necessity for incorporating the above features in the new mounting bracket, the fact had to be kept in mind that the overall dimensions must not exceed those of the standard mounting brackets in use on other types of standard selector racks. This was essential in order to use existing standard rack guard rails and shelf covers and to maintain B.P.O. standard rack aisle dimensions. Experiments were carried out on the sample rack during the development stages to determine the best position for the jumper field along each shelf.

In addition to the type of bracket shown in Fig. 5, a further set of brackets was designed and experimented with. In this case the jumper ring was formed by extending the top of the bracket so that the jumper wires would run along the shelf, together with the incoming shelf jack cables, at the rear of the shelf jacks, and feed through the top fanning holes of the connection strips.

Practical tests in the running of jumper wires were carried out on two shelves, one fitted with the latter type of bracket, and the other fitted with the type illustrated in Fig. 5. It was found that with the type shown in Fig. 5 there is no difficulty in the running of the jumper wires, which are practically obscured and not subject to being disturbed once they have been run in and terminated.

With the alternative type of bracket it was seen that the jumper field would cause congestion behind the shelf jacks, and reduce accessibility from the point of view of wiring and maintenance.

The type of bracket shown in Fig. 5 was therefore approved and has been standardised for use on the new standard group selector rack. With seven of these brackets fitted on each of shelves B to F, and with all connection strips in position, jumper wires can readily be run between any connection strips on the same shelf.

In order to complete the jumpering facilities on a rack basis, it was necessary to provide inter-shelf jumpering arrangements, so that jumper wires can be run from the connection strips on any one shelf to the connection strips on each or any other shelf, and without fouling the rack cabling. This is achieved by the fitting of special jumper rings, one for each shelf on which connection strips are fitted. These jumper rings are clamped to the rack brackets fixed on the right-hand upright of the rack (rear view of rack), see Figs. 6 and 9.

Inter-rack jumpering facilities are not provided, and all rack-to-rack ties are carried out in switchboard cable and/or switchboard wire, details of which are given later in this article.

(c) Arrangement of bank multiples and terminations on bank multiple connection strips

From Figs. 2 and 4 it will be seen that the 8 ft. 6½ in. rack is equipped with three sets of twenty banks in multiple, and the 10 ft. 6½ in. rack with four sets of twenty banks in multiple.

Outlets 1 to 20 for levels 1 to 0 of each set of twenty banks are wired to the bank multiple connection strips on shelves B to F in accordance with Figs. 2 and 4, and are terminated on the 10 ft. 6½ in. racks as indicated in Fig. 10. The terminations on the 8 ft. 6½ in. racks are completed in the same order, but for multiples AB, CD and EF only.

On both the 8 ft. 6½ in. and 10 ft. 6½ in. racks two main cable forms, one on each upright, are required to complete the wiring of all levels for all shelves to the bank multiple connection strips, and these cable forms complete the bank cabling as follows:—

(i) 8 **ft. 6½ in. Racks** (Fig. 2).

Cable form on left-hand upright serves multiples AB and EF.

Cable form on right-hand upright serves multiple CD.

(ii) **10 ft 6½ in. Racks** (Fig. 4).

Cable form on left-hand upright serves multiples AB and EF.

Cable form on right-hand upright serves multiples CD and GH.

Owing to variations in factory wiring practices, certain British manufacturers prefer to make three cable forms on the 8 ft. 6½ in. rack, and four cable forms on the 10 ft. 6½ in. rack, that is, one cable form per set of twenty banks in multiple. The B.P.O. has agreed to this arrangement as an alternative, and the standard drawings have been arranged accordingly. A. T. & E. Co. Ltd. prefer to make only the two

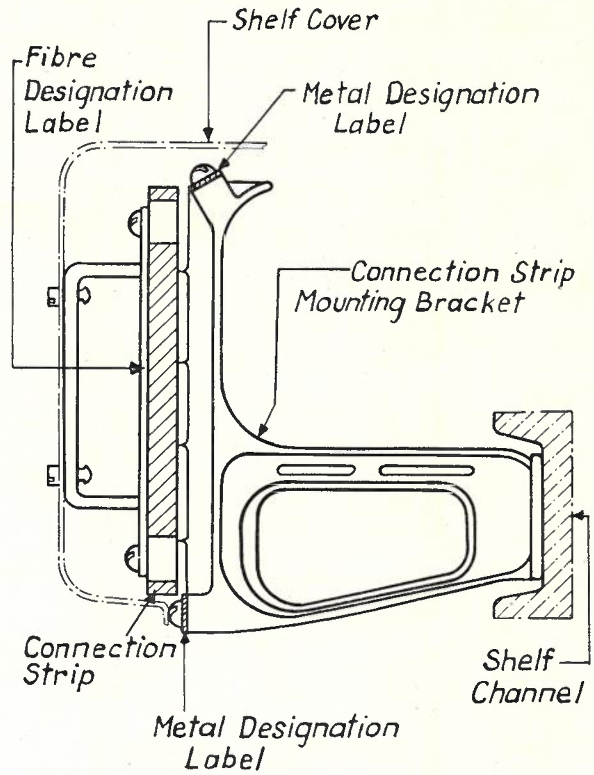


Fig. 5.—Connection Strip Mounting Bracket.

cable forms per rack, on the basis of experience gained on the rack of this type manufactured for Overseas administrations prior to standardisation by the B.P.O.

(d) **Terminations on I.D.F. and miscellaneous, etc. Connection strips.**

In addition to the connection strips required for the termination of the bank multiples, others are fitted on shelves B to F, as shown in Figs. 2 and 4, for the termination of I.D.F. circuits and rack services, as illustrated in Figs. 11 to 15.

The connection strips for the I.D.F. circuits are 9 by 20 and are fitted in the end position on each of shelves B to F. These connection strips cater for the termination of 100, 200 or 300 circuits in accordance with the details given with Fig. 11, and to meet the following standard cabling provision in exchanges equipped with the new standard group selector rack:—

(i) 100 circuits for 1st selector and 1st numerical selector racks.

(ii) 200 circuits for all other ranks of selectors.

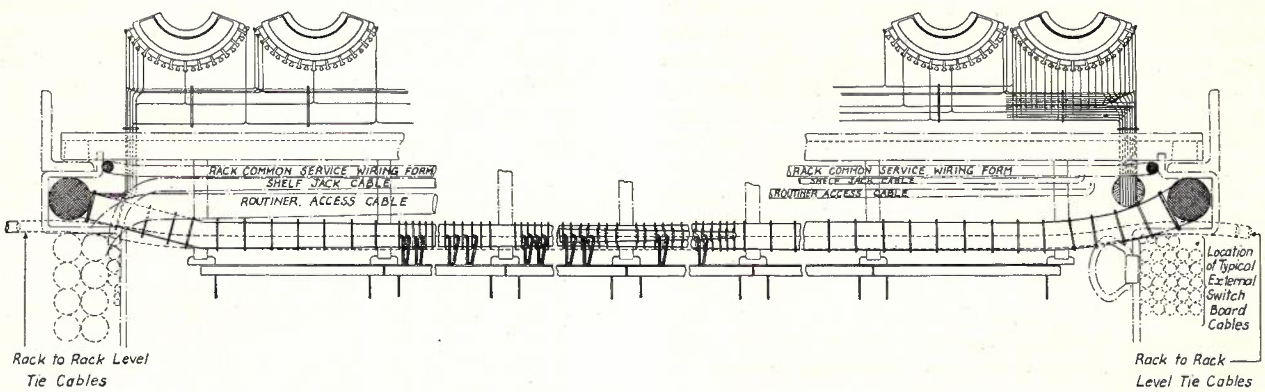


Fig. 6.—Plan View of Shelves B-F.

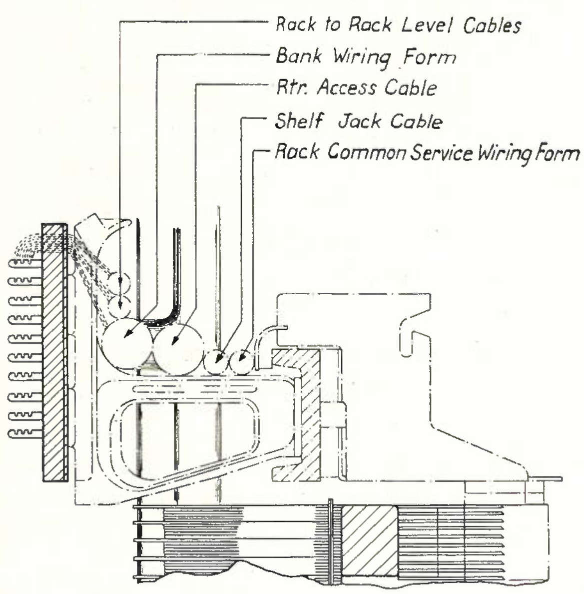


Fig. 7.—Cabling along Shelves.

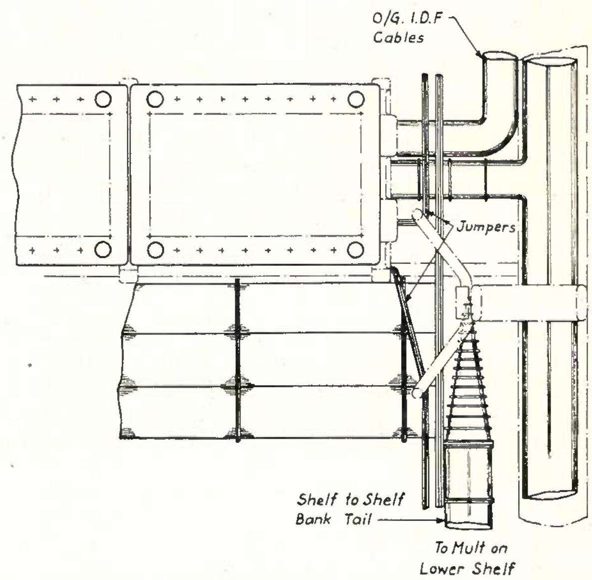


Fig. 9.—Jumper Rings for Inter-shelf Jumpering.

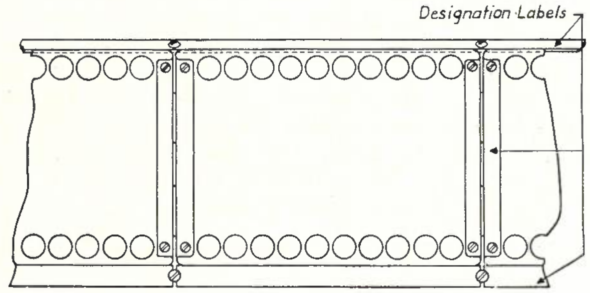


Fig. 8.—Correction Strips and Designation Labels.

In special cases where the standard provision of I.D.F. circuits will not suffice, additional circuits, to make a total of 300 per rack, can be specified.

The P1 and P2 banks, 11th step contacts, for levels 1 to 0 of each multiple of twenty banks, AB, CD, etc., are wired to the connection strip in the fifth position on shelf F, designated MISC, in Figs. 2 and 4, and are terminated in accordance with Fig. 12.

The P1-11th step contacts are used for connections to the overflow meters on working and spare levels, and the P2-11th step contacts are wired out in order to provide easy access to these contacts in the event of them being required for automatic routining purposes in the future.

From Fig. 12 it will be seen that on this same connection strip tags are allocated for the spare level N.U. tone circuits, on the following basis: —one set of tags for the rack local wiring, which are wired to one side of the break jacks fitted on the right-hand upright, as shown in Fig. 17; one set of tags designated I/C and wired to the other side of the break jacks, and a further set of tags designated O/G. From the tags designated "Local," the three spare level circuits are wired to connection strips designated MISC on shelves E, D, C and B, and are terminated in accordance with Figs. 13 and 14.

The spare level N.U. tone circuits are thus available on each of the shelves on which the bank multiples are terminated, and the spare level circuits, from the I.D.F., or from a previous rack associated with the same spare level equipment, are terminated on the connection strip on shelf F, on the I/C tags. The latter tags are strapped to the O/G tags, from which are cabled the circuits to the next rack in the same group.

On the connection strip fitted in the fifth position on shelf D and designated MISC, as per Figs. 2 and 4, provision is made for the termination of the pulses and vertical marking bank wiring for levels 1 to 0 of multiples AB, CD, EF and GH, on multi-metering 2nd code selector racks. The allocation of the tags is shown in Fig. 14, and the associated localising jacks, fitted in a miscellaneous mounting, on the right-hand upright as per Figs. 1 and 3, are arranged in accordance with Fig. 16.

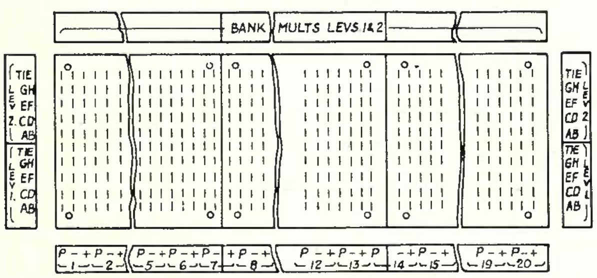


FIG. 10. BANK MULT. CONNECTION STRIPS ON SHELF "B"

SHELF "C" AS FIG. 10. BUT LEVELS 1 & 2 TO BE 3 & 4
" "D" " " 10 " " 1& 2 " " 5& 6
" "E" " " 10 " " 1& 2 " " 7& 8
" "F" " " 10 " " 1& 2 " " 9& 10

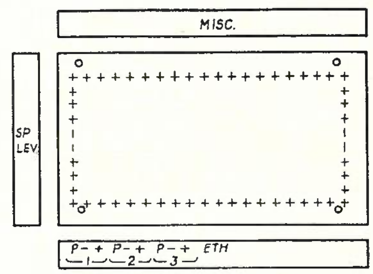


FIG. 13

SPARE LEVEL CONNECTION STRIP ON SHELVES B. C & E

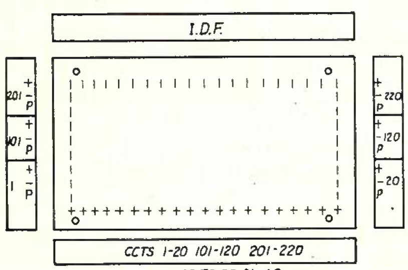


FIG. 11

I.D.F. CCT. CONN. STRIP ON SHELF "B"

SHELF "C" AS FIG. 11. BUT 1-20 TO BE 21-40, 101-120 TO BE 121-140, 201-220 TO BE 221-240

SHELF "D" AS FIG. 11. BUT 1-20 TO BE 41-60, 101-120 TO BE 141-160, 201-220 TO BE 241-260

SHELF "E" AS FIG. 11. BUT 1-20 TO BE 61-80, 101-120 TO BE 161-180, 201-120 TO BE 261-280

SHELF "F" AS FIG. 11 BUT 1-20 TO BE 81-100, 101-120 TO BE 181-200, 201-220 TO BE 281-300

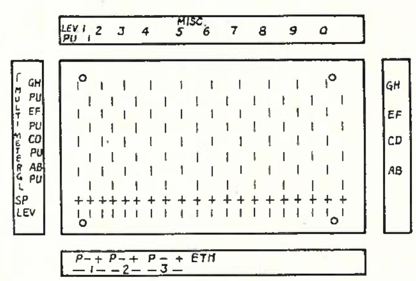


FIG. 14

MULTI-METERING & SPARE LEVEL CONN. STRIP ON SHELF "D"

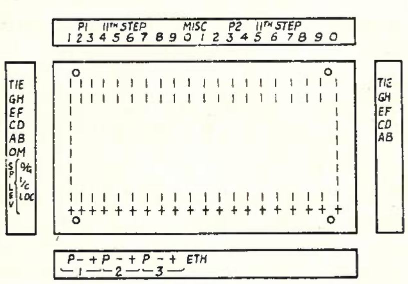


FIG. 12

P1 & P2- 11TH STEP & SPARE LEVEL CONN. STRIP ON SHELF "F"

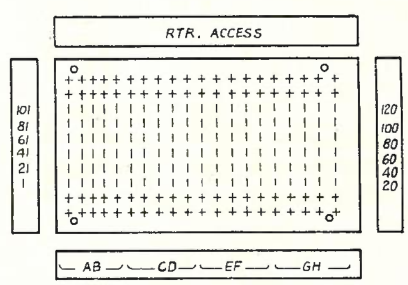


FIG. 15

CONN. STRIP FOR TEST LINE INTERCEPTION RELAYS ON SHELF "F"

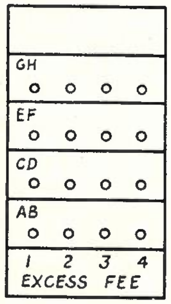


Fig. 16.—Excess Fee Localising Jacks on R.H. Uprights.

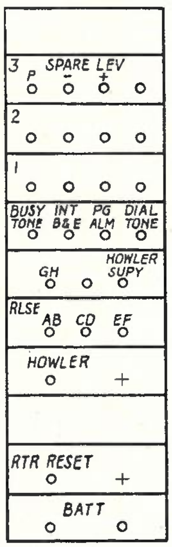


Fig. 17.—Miscellaneous Mounting on R.H. Upright.

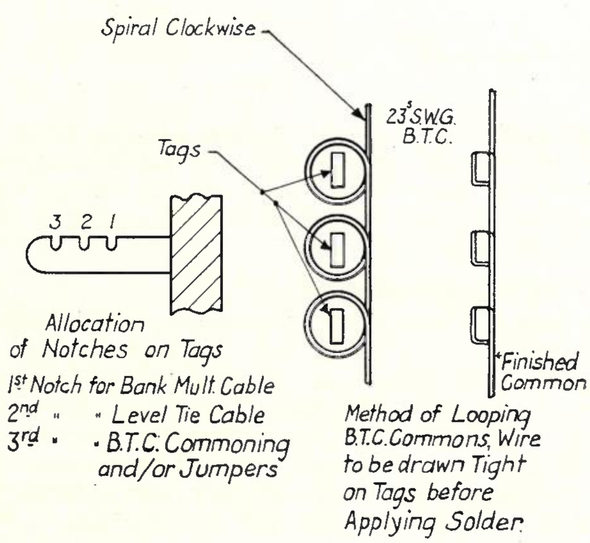


Fig. 18.

The connection strip fitted in position 1 on shelf F and designated "RTNR" in Figs. 2 and 4 is provided for the termination of the automatic routiner test line interception relays, fitted on every rack, on the right-hand upright as indicated in Figs. 1 and 3. These relays are equipped and wired on the basis of one set of relays per multiple, i.e., AB, CD, EF and GH, as per Fig. 15.

(e) **Grading and jumpering and exchange trunking.**

On all working levels on the racks in each rank of selectors, gradings are completed on the bank multiple connection strips, and the graded outlets are jumpered to the appropriate I.D.F. circuits, see Fig. 19.

By referring to Fig. 10 it will be seen that provision is made for the termination of tie cables, from adjacent racks, to a row of tags for each level.

Commoning of the outlets from the different shelves, and the commoning to the rack-to-rack tie circuits, is done by bare wire connections. The tie cables between racks enable gradings to be completed over the racks forming a grading group (see Figs. 19 and 20).

All commoning on the bank multiple connection strips is carried out with 9¼ lb. B.T.C. wire, and the wire has to be wrapped completely round each tag of the common. The method is illustrated in Fig. 18, which also shows the allocation of the notches on the tags of the connection strips.

Jumpering between the bank multiple connection strips and the I.D.F. circuits and spare level N.U. tone circuits connection strips, is carried out in 9¼ lb. switchplate wire (B.P.O. Spec. C.W.45), using colours, red (negative), white (positive), and green (private).

As mentioned previously, the jumper field on each shelf is formed behind the lower half of the connection strips, and all jumper wires feed through the lower fanning holes.

Rack-to-rack tie cables are made up of switchboard cable and/or switchboard wire as follows—

(i) When racks are adjacent, 9¼ lb. core switchboard cable, beeswaxed, or a wiring form of 9¼ lb. switchboard wire, is used. The tie cables are taken directly across the racks, as shown in Fig. 6, and are not fed via the rack uprights and rack cable runways.

(ii) When racks are not adjacent, 9¼ lb. switchboard cable is used and the tie cables are taken via the rack uprights and cable runways.

The I.D.F. circuits from each rack are cabled to the local side of I.D.F. verticals, which are part of the centralised line I.D.F., or, in the case of large exchanges, form a separate I.D.F.

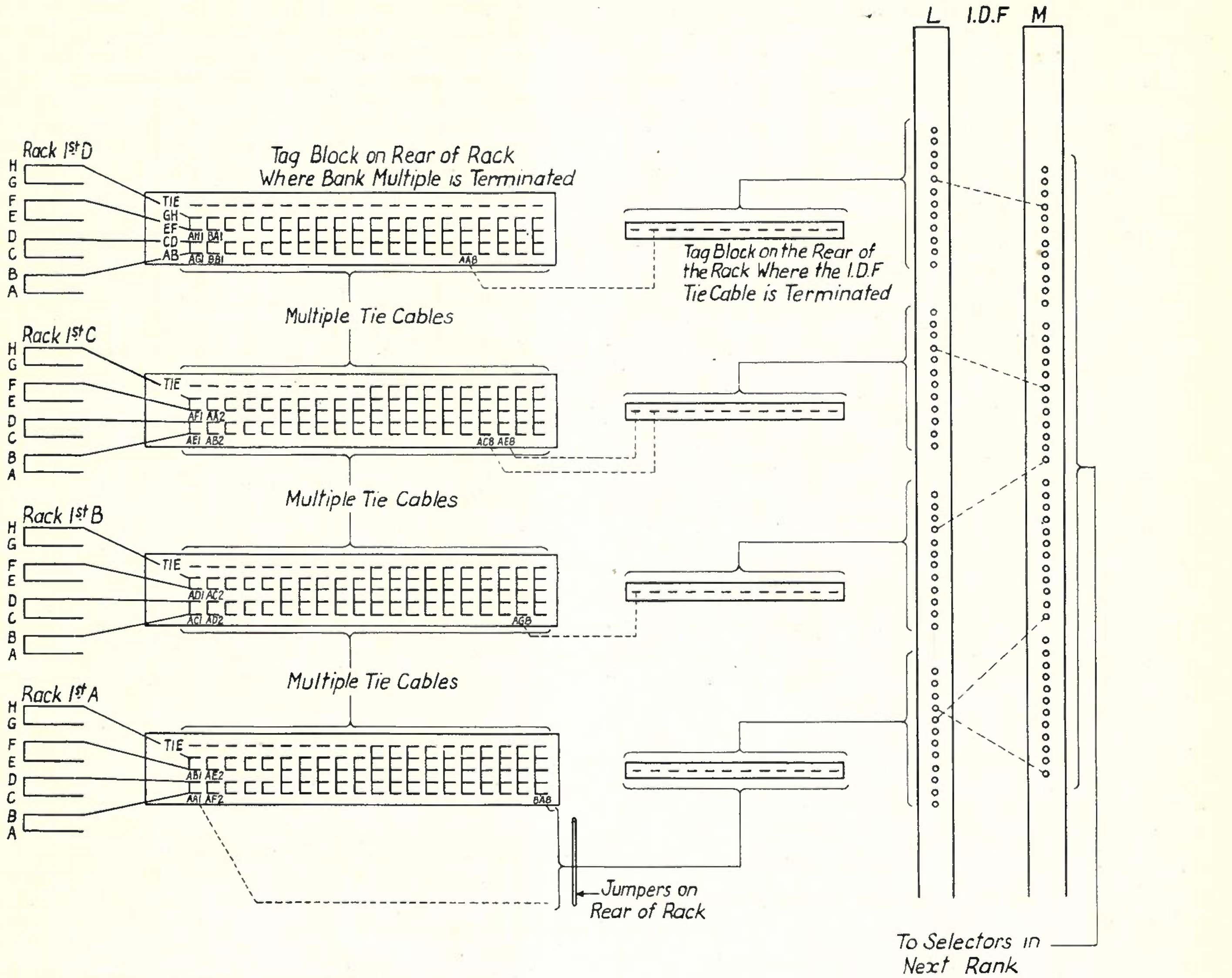


Fig. 19.—Cabling and Jumpering Scheme.

From the multiple side of these I.D.F. verticals the necessary circuits are cabled to the shelf jacks of all group and final selectors, relay sets, and to all miscellaneous and outgoing circuits, to which selector levels have to be connected.

The gradings are thus completed on the bank multiple connection strips, and the outlets are jumpered to the I.D.F. circuits terminated on each rack. At the I.D.F., the final connections to the selectors in the next rank, or to relay sets and outgoing circuits, are completed by jumpering (see Fig. 19).

Figs 21 and 22 show the arrangements for director and non-director exchange trunking, when the group selector rack with grading facilities is used. The main advantages of these schemes are that the groups of a grading can readily be re-arranged to meet traffic variations, and that the routing of the circuits via the I.D.F. ensure complete flexibility in the allocation of the outlets.

(f) **I.D.F. arrangements.**

In large exchanges, the provision of additional I.D.F. verticals, to cater for the circuits from the group and final selector racks, relay sets, etc., might result in the frame being too cumbersome in size, and with the attendant layout and cabling disadvantages. An examination into this aspect suggested a division into separate line and equipment distribution frames. With this alternative arrangement, the line I.D.F. caters for the termination of subscribers'

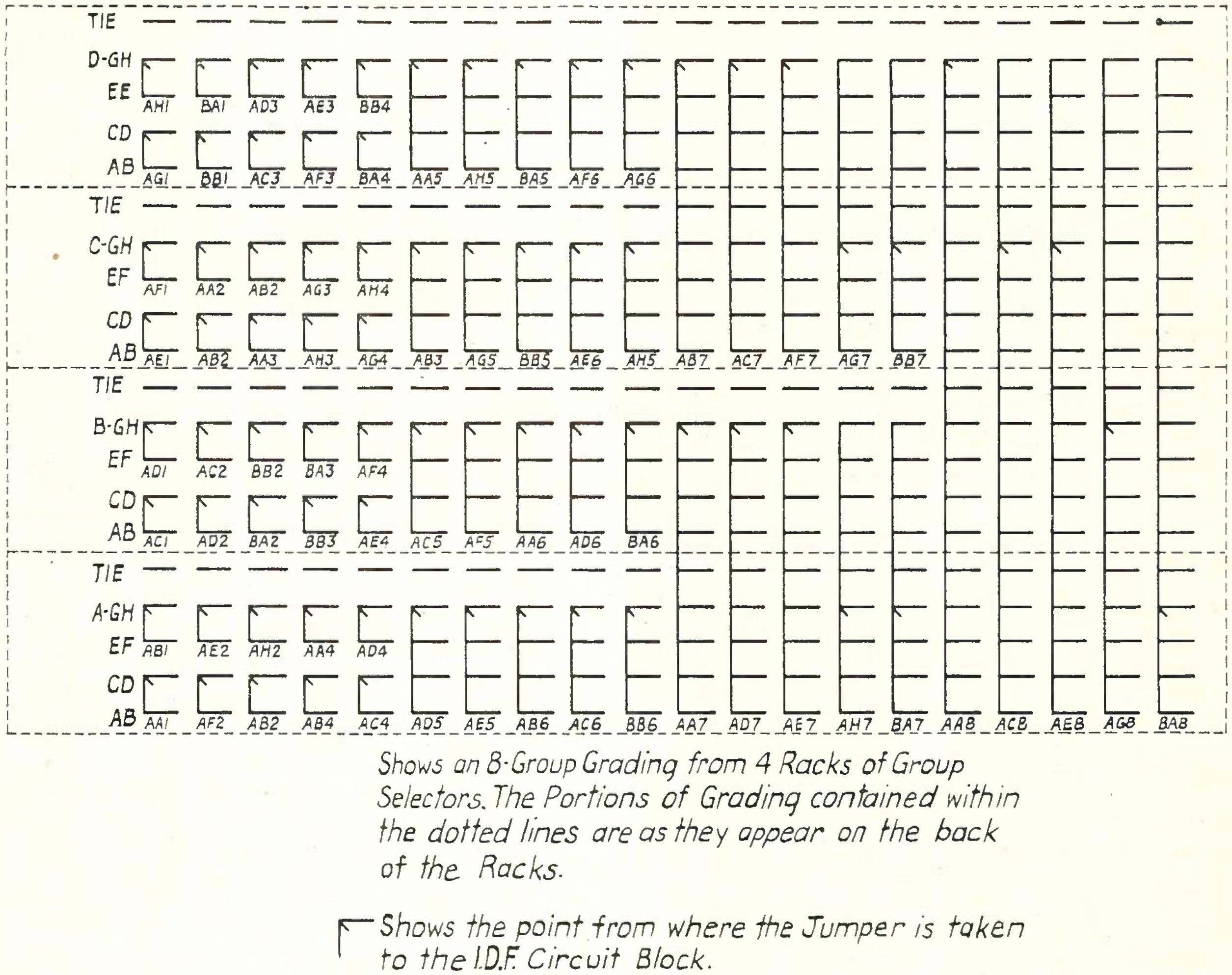


Fig. 20.—Typical Grading.

circuits from the M.D.F. and for the circuits to subscribers' uniselectors, the final selector multiples, subscribers' meters and the associated miscellaneous circuits; the equipment I.D.F. serves the group and final selector racks, relay sets, junctions, manual boards and desks, and associated services. The two I.D.F.'s would be located to meet all the requirements as regards maintenance, conservation of floor space and economy of cabling.

The B.P.O. has standardised the above arrangement, and a standard drawing, EXCH.SK.5793, has been issued by the Engineer-in-Chief's office to cover the terminations for miscellaneous circuits such as service interception, changed number, centralised service observation, meter reading, and meter observation, etc., which have to be connected to both the line and equipment I.D.F.'s. Fig. 23 shows a part of EXCH.SK.5793; the circuit diagram numbers quoted are typical only.

STANDARD BASIS OF PROVISION OF RACK EQUIPMENT AND CABLING

(a) Rack Equipment.

In order to meet all the conditions for group selector and 2nd and subsequent code selector racks, the standard rack with grading facilities is always supplied fully equipped with shelves, banks, bank multiple cables and associated connection strips, all miscellaneous and I.D.F. circuit connection strips, and all wiring and equipment for the rack common services, with the exception of the following items:—

(a) Howler circuit relays and mounting. These have only to be fitted on racks requiring this service, i.e., local 1st selectors in non-director areas. The wiring, jack and lamp (6 volt) for the howler circuit is always included with the standard rack wiring and equipment. Fig. 17 shows the mounting position for the jack and lamp.

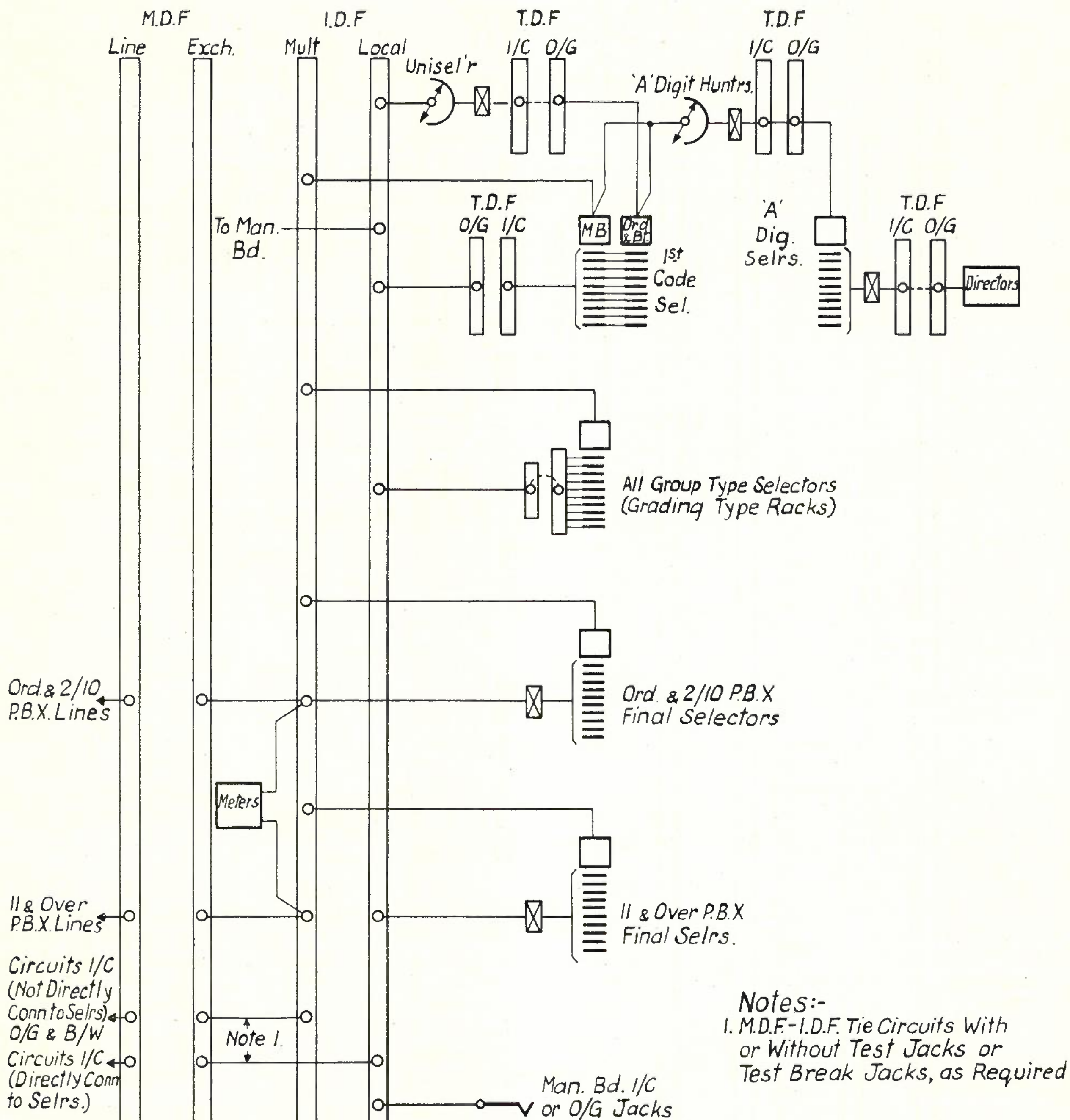


Fig. 21.—Trunking Diagram. Director Exchange.

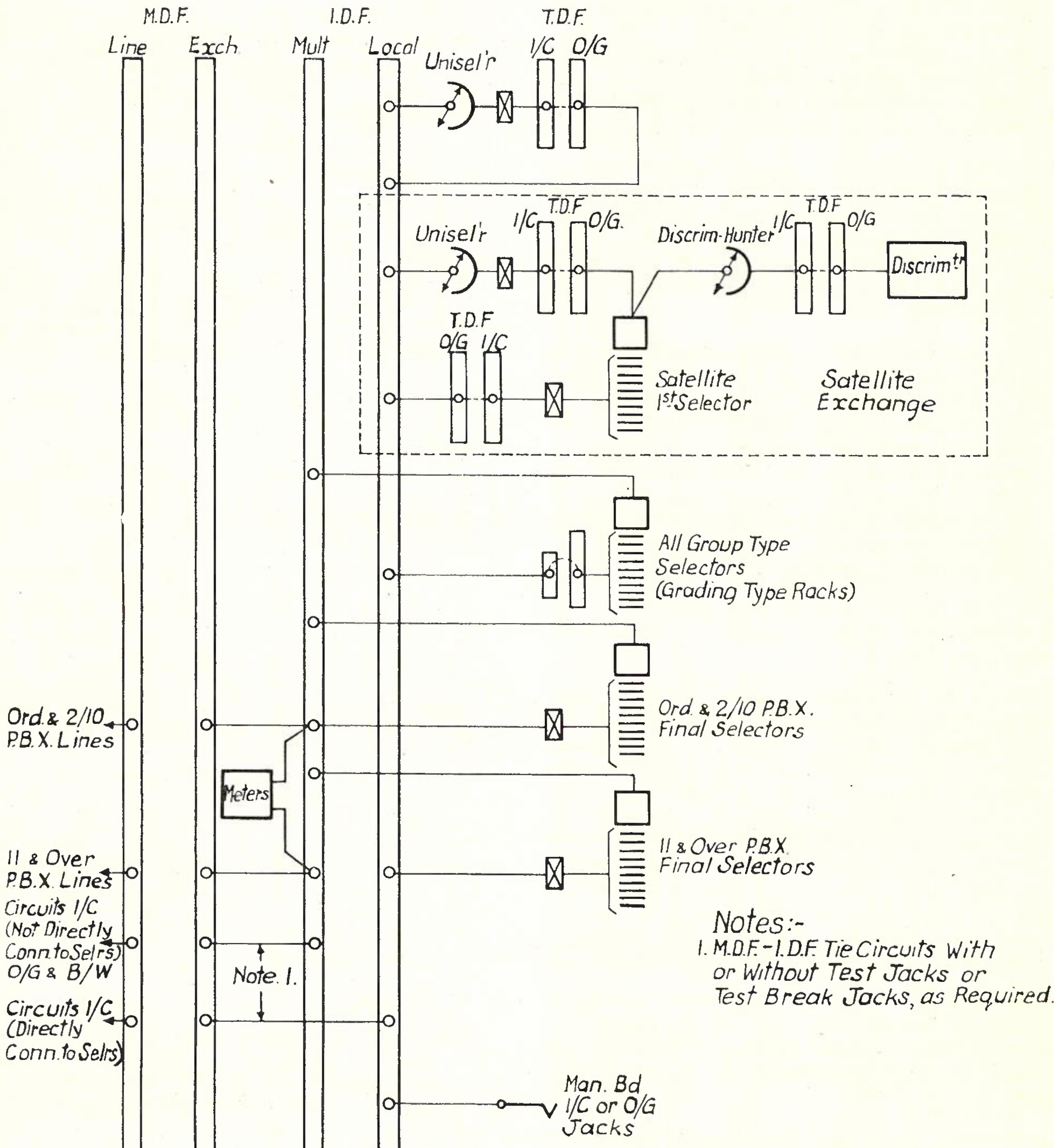


Fig. 22.—Trunking Diagram, Non-Director Exchange.

(b) All equipment and wiring required for multi-metering 2nd code selectors, viz., vertical marking banks with associated mounting brackets, multiple cables, wiring and rack isolation jacks and mounting. These items have only to be fitted on racks equipped with selectors requiring this facility. The connection strip, Fig. 14, to which each multiple of vertical marking banks, and the pulse leads are wired, is always supplied with the standard rack equipment.

In order to facilitate the fitting of vertical marking banks on any rack, and at any time, all bank assemblies on every rack are provided with the vertical marking bank mounting plate, i.e., the top bank plate in all bank positions has the extending lug required for the fitting of the vertical marking bank assembly.

(c) Routiner reset jacks on multi-metering 2nd code selector racks, or 2nd and 3rd code selector racks, through which the 1st code selector routiner test number is routed. On the standard rack a miscellaneous mounting assembly fitted on the right-hand upright, Figs. 1, 3 and 17, has a spare position in which the reset jack panel can be fitted, when required, to cater for either one or two 1st code selector routiners.

The rack is not supplied with selectors, these are ordered and shipped separately, and fitted on the racks on site.

During the development of the rack a new selector circuit to diagram AT.4727 (ATW.47270) was introduced, and selectors to this new circuit will always be specified by the B.P.O. for use with the standard rack with grading facilities. This new circuit embodies certain changes to the previous standard 2000 Type 200 outlet group selector, namely, the use of 6 volt supervisory lamp and a new P.G. alarm feature, and it caters for numerical and code selectors, with or without multi-metering, on the one diagram, whereas two diagrams were required previously.

When used as a 2nd code selector with multi-metering, a vertical wiper has to be fitted; the associated "YA" resistor is always fitted on the standard selector and wired to specified "U" points.

As the new circuit also specifies a 1.5 amp. fuse per selector, a 10-position fuse panel is required per shelf of selectors (see Figs. 1, 3 and 24). Previously, selectors were fused on the basis of one fuse per shelf of selectors.

Equipment and wiring for the following rack common services are always supplied. Certain services, such as dial tone, can be omitted from racks not requiring it, by the strapping of tags on the rack miscellaneous connection strip.

The mounting positions for the rack common equipment, on the right-hand upright, are indicated in Figs. 1 and 3.

(a) Fuse alarm relay.
(b) Release alarm (with 6-volt lamps).
(c) P.G. alarm resistors and break jacks.
(d) Interrupted battery and earth.
(e) Busy tone.
(f) Dial tone.
(g) Spare level N.U. tone.
(h) Routiner test line interception relays and routiner reset jack.
(j) Front and rear battery jacks.
(k) Traffic recorder wiring from shelf jacks to traffic recorder connection strip.
(l) Test trunk bell wiring (common round all shelf jacks to rack miscellaneous connection strip).

Fig. 26 shows the rack fuse panel, fitted on shelf A as per Figs. 1 and 3, from which the above sources are fused.

Mounting brackets for the chart holders are not supplied as part of the standard rack; these are supplied as separate items, for fitment on site.

A new P.G. alarm feature has been developed for use with the new standard rack, and the circuit for this has been designed to give an alarm should a pre-determined number of selectors be held under fault condition. It has been arranged that an alarm is not given until the condition has persisted for a period of 3 to 3½ minutes. This circuit is equipped and wired on a jacked-in relay set base, and two relay sets will be supplied per exchange, one to serve racks of incoming selectors, the other to serve racks of subscribers' selectors, and racks with mixed incoming and subscribers' selectors. The relay sets will be mounted on the alarm equipment rack, and as a number of selector racks are common to the alarm relay sets jack localisation is provided to determine which rack or racks has operated the alarm.

(b) **Rack cabling.**

(i) **Incoming to selector shelf jacks.**
The circuits incoming to the selector shelf jacks are cabled from the I.D.F. multiple side, with the full number of circuits always cabled to each rack on the following basis:—

60 circuits for 8 ft. 6½ in. racks.
80 circuits for 10 ft. 6½ in. racks.

On the I.D.F. multiple side, 6 × 20 connection strips are supplied for the termination of group or code selectors, each connection strip catering for the P, + ve and — ve of forty selectors (four shelves). For the termination of multi-metering

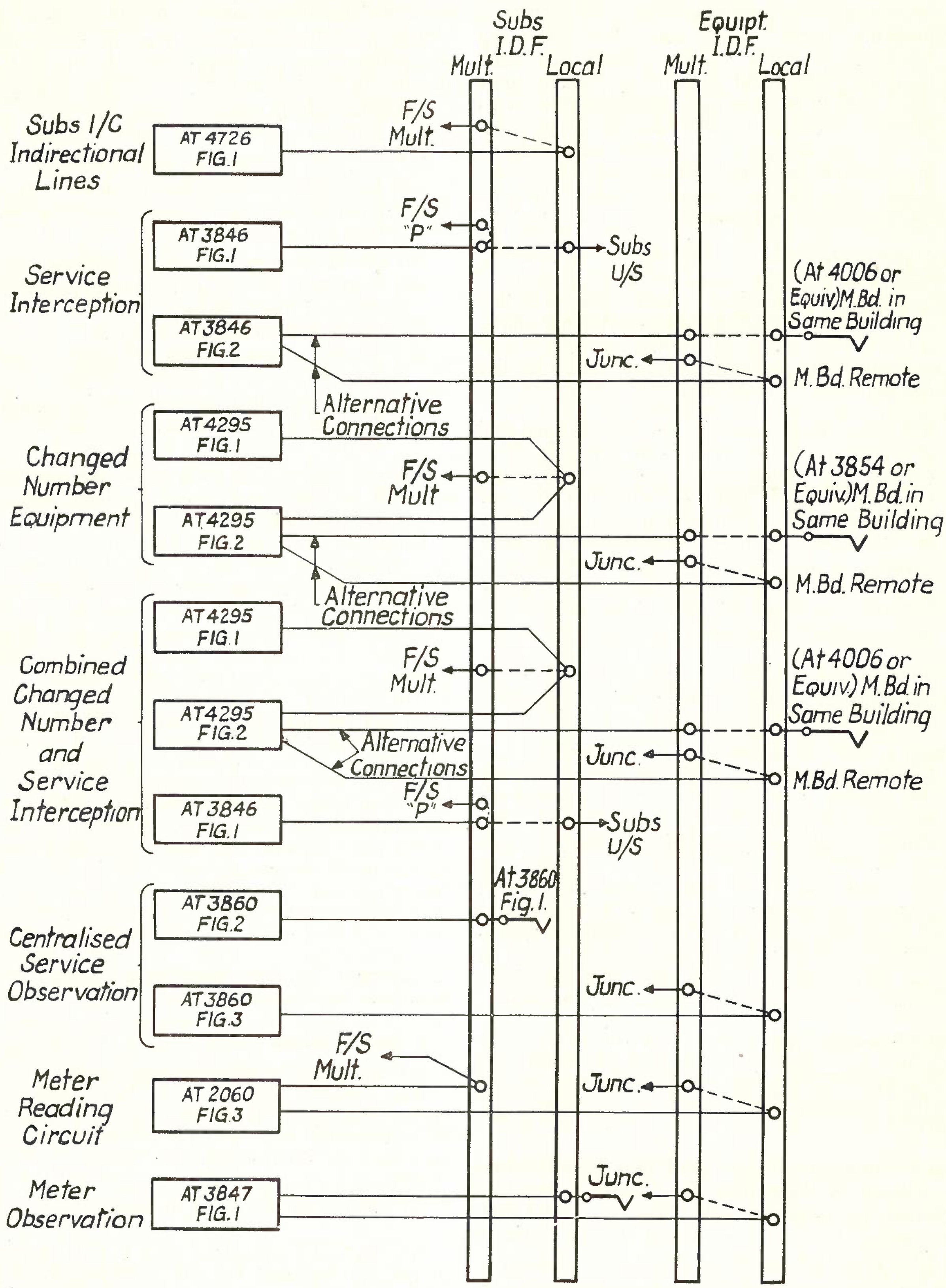


Fig. 23.—Typical Cabling Arrangements for Miscellaneous Circuits which have to be connected to both line and equipment I.D.F.s.

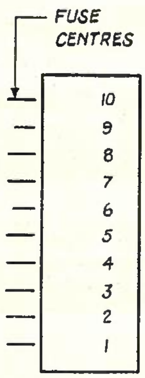


Fig. 24.—Shelf Fuse Panels fitted on all shelves.

Fig. 25.—Ind. F.A. Fuse Panel fitted on Shelf "F."

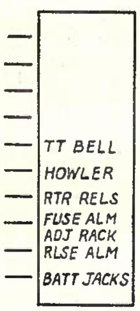


Fig. 26.—Rack Fuse Panel fitted on Shelf "A."

2nd code selectors, 8 × 20 connection strips are supplied, each connection strip catering for the P, + ve, — ve, and M of forty selectors (four shelves) of this type.

(ii) **Outgoing from rack.**

The circuits outgoing from each rack to the local side of the I.D.F. are supplied on the following basis, from both 8 ft. 6½ in. and 10 ft. 6½ in. racks:—

100 circuits for 1st selector and 1st numerical selector racks.

200 circuits for selector racks of all other ranks.

The number of outgoing circuits to the I.D.F. from the rack in a rank of selectors need only be sufficient to cover the total number of working outlets to the next rank of selectors.

During development of the new standard rack, investigations were made into a number of cases and finally it was agreed to standardise on the foregoing basis. This agreement will meet the requirements of all exchanges, and save the work of preparation and provision of detailed cabling information for each exchange, at the design stage.

At the rack end, the circuits have to be terminated on the connection strips designated "I.D.F." in Figs. 2 and 4, and in accordance with the details given under Fig. 11.

On the I.D.F. local side the circuits are terminated on 6 × 20 connection strips, i.e., forty circuits (P, + ve and — ve) per strip.

From the details given in Fig. 11 it will be seen that the I.D.F. connection strips fitted on the rack are 9 by 20, and will cater for 300 circuits, these being cabled to the I.D.F. local side from each rack. This caters for the special conditions when the standard cabling arrangements will not suffice, and in all such cases the details are supplied by the B.P.O. in the form of cabling information and issued with the associated contract specification.

(iii) **Rack tie cables.**

Rack-to-rack tie cables for all levels (on a rank basis) have always to be provided.

Rack-to-rack tie cables (on a rank basis) will always be provided for P1-11th step and P2-11th step, for all levels.

(c) **Rack photographs.**

Figs. 27 to 31 are actual photographs of a 10 ft. 6½ in. rack, and were taken in the Company's factory especially to illustrate the following points:—

Fig. 27. This is a front view of the rack and shows all shelves equipped with banks, but less the selectors. The fuse panels on left-hand upright, and the rack common services equipment mounted on the right-hand upright, are clearly shown.

Fig. 28. This is a rear view which serves to illustrate the clear lines of a fully cabled rack, from the point of view of bank multiples, and the main bank cable forms connecting the mulitples to the connection strips. One set of rack-to-rack tie cables is also shown, together with the inter-shelf jumpering arrangements, on the right-hand side of the connection strips.

It will be appreciated that, when the shelf rear covers are in position, the connection strips on shelves B to F are completely obscured, all risk of damage or interference is eliminated, and the final appearance is one of compactness.

Fig. 29. This again is taken at the rear of the rack, at a point between shelves C and D, and at the left-hand upright. The main bank cable form feeding the connection strips, and the

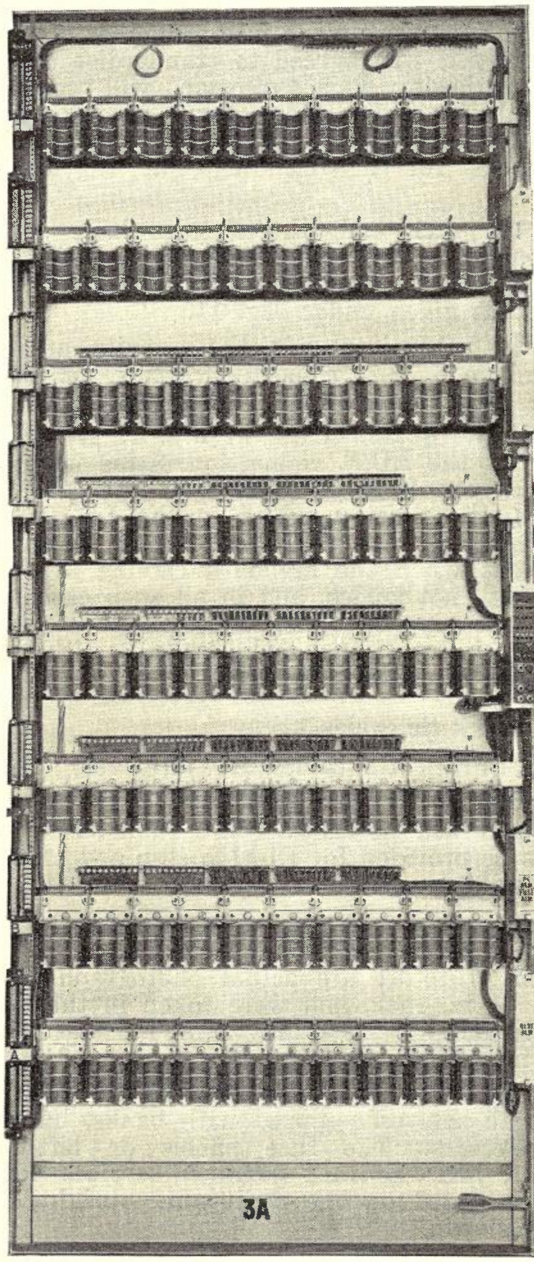


Fig. 27.

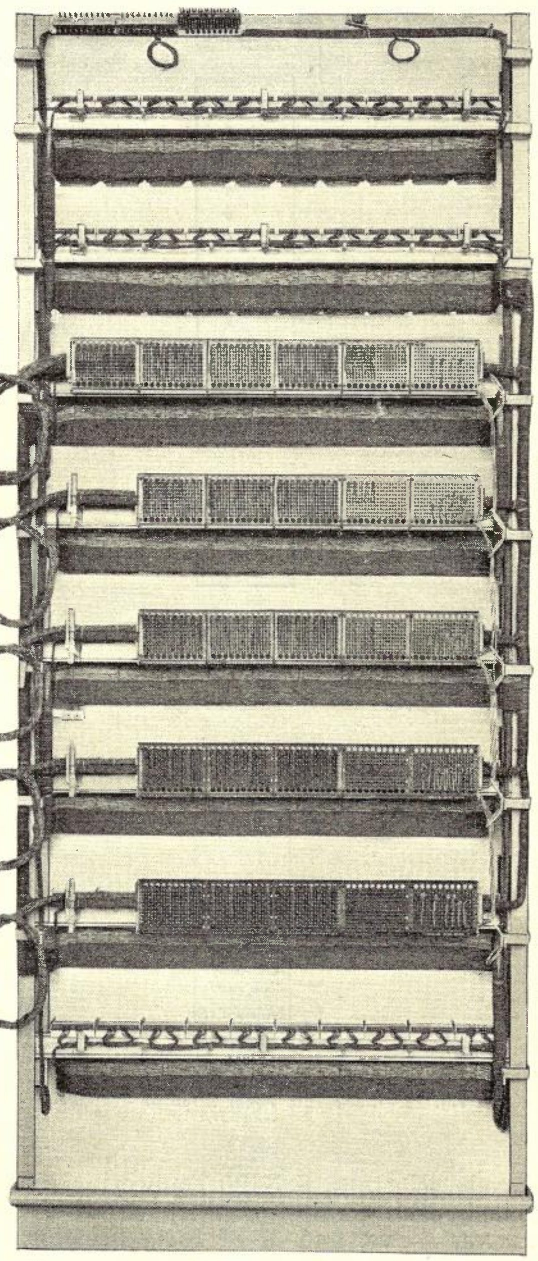


Fig. 28.

multiple form (cigar shaped) multipling the banks on shelf C to the banks on shelf D, are featured. The rack-to-rack ties are shown and it should be noted that at no point, on either the left- or right-hand uprights, is this amount of cabling exceeded on the rack side of the cable brackets.

The new type of connection strip mounting bracket is clearly shown in this photograph, and also the designation label fitted at the end of, and part of that fitted below, the connection strips.

Figs. 30 and 31. These also illustrate the arrangements at the rear of the rack, and in particular the following features:—

(i) The special jumper rings fixed to the cable brackets on the right-hand upright, to provide the inter-shelf jumpering facilities. A few jumper wires are shown.

(ii) The main bank cable forms on the left- and right-hand uprights, and shelf-to-shelf bank multiple cable forms.

(iii) Complete sets of the designation labels fitted to the end, and along the top and bottom of the connection strips.

(iv) The special design of rack cable brackets fixed to the left-and right-hand uprights.

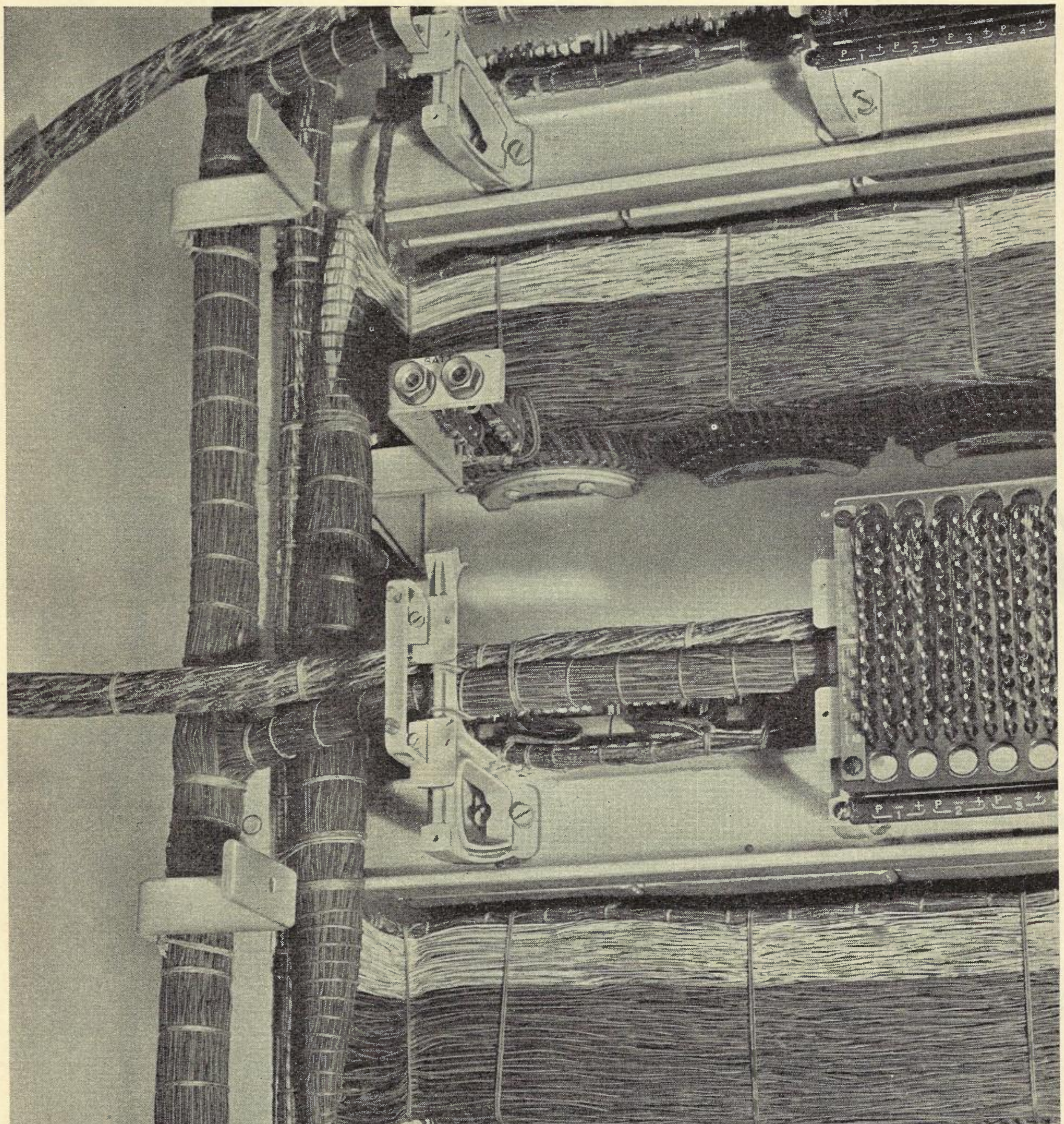


Fig. 29.

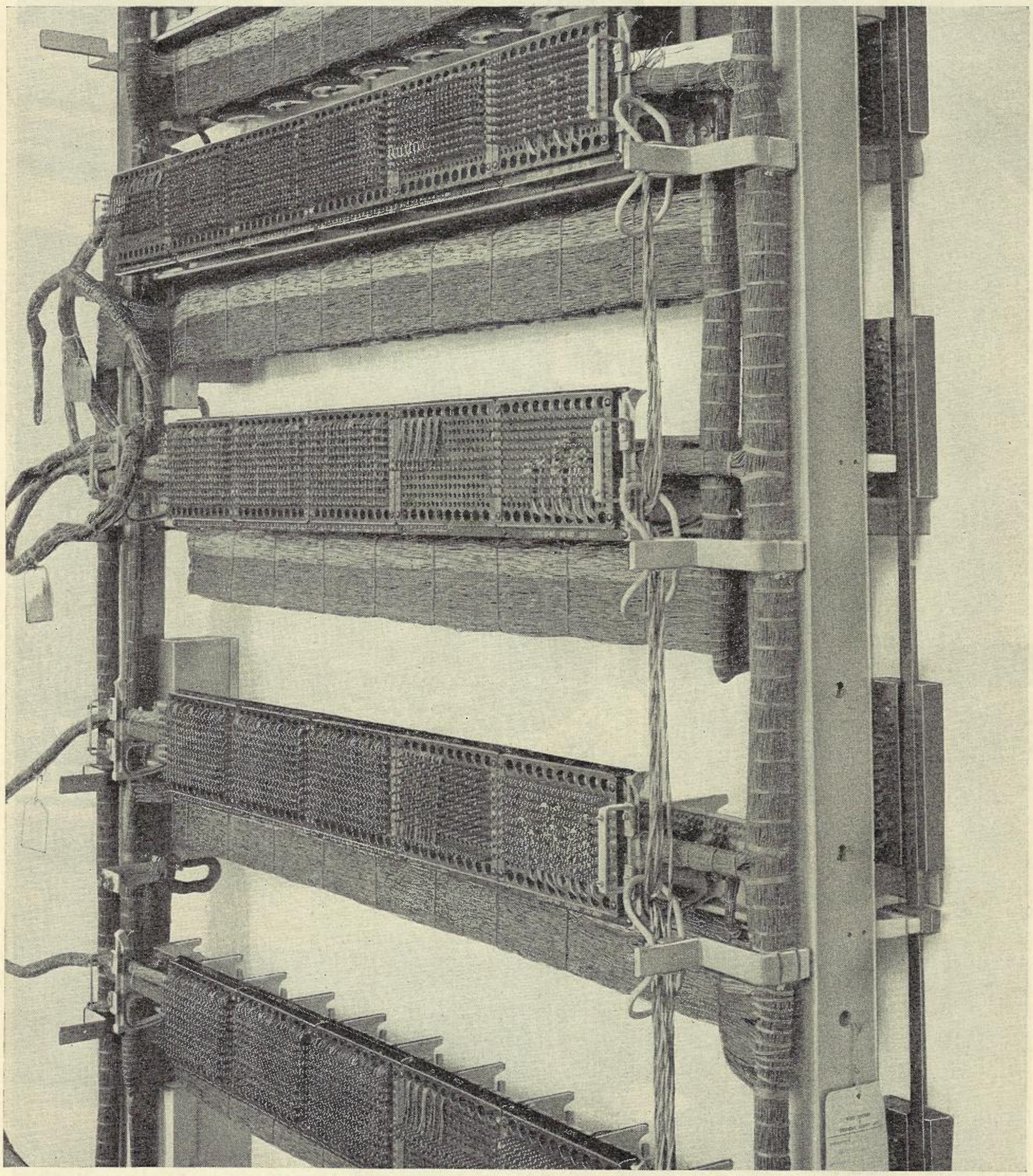


Fig. 30.

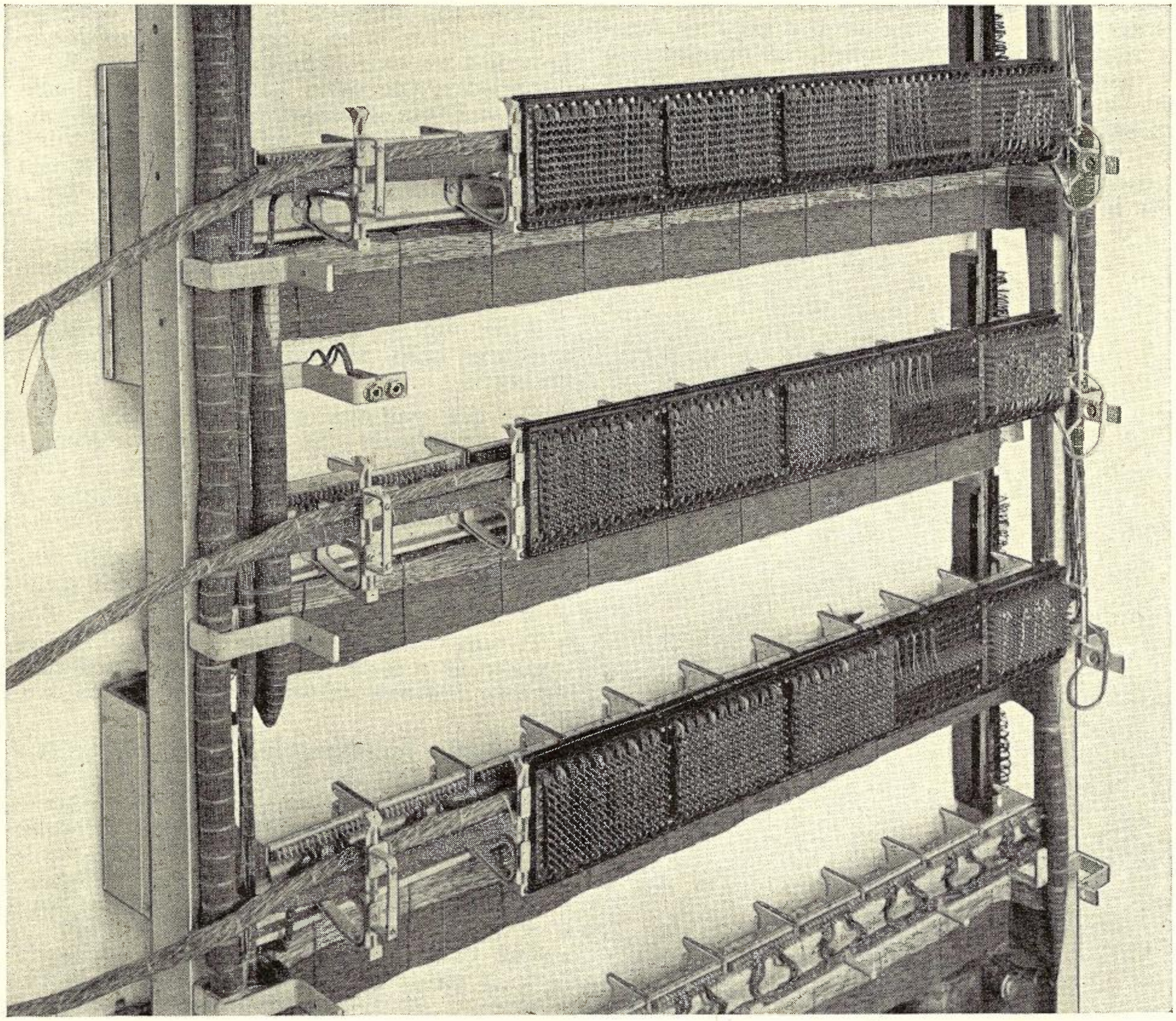


Fig. 31.

LAYING OF SUBMARINE CABLES ACROSS THE BRISBANE RIVER

N. W. J. Gibbins

Introduction.—In order to meet junction development between the "U" main exchange at Toowong, Brisbane, and its branch at Sherwood, the provision of a second junction cable was necessary. As all ducts over the existing junction route were fully occupied, an examination was made of possible alternative routes which could be developed for junction and subscribers' purposes and which would give a measure of security of service for junctions between the two exchanges. The existing and new routes are shown in Fig. 1.

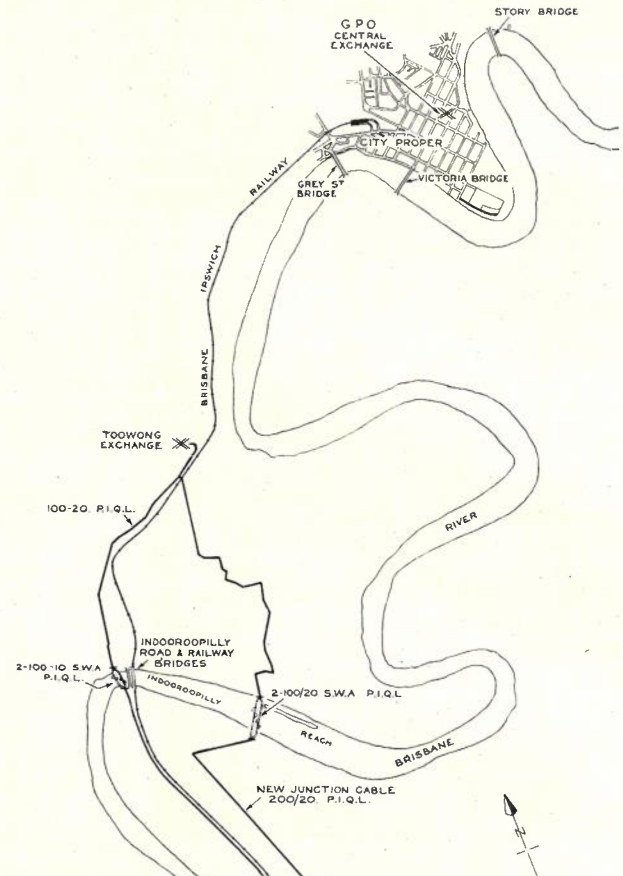


Fig. 1.—Site plan, Bamboo Crossing, Indooroopilly Reach, Brisbane River.

The shortest practicable route involved a submarine crossing of the Brisbane River which is approximately 400 yards wide at the selected point. Close examination of the approaches to the river was made to determine the most suitable position in which to place the cable. On the northern side of the river, an embankment and a stretch of 30 yards of dense mangroves had to be negotiated. The southern side was more suitable and consisted of a steep 12 ft. high bank following which the ground rose gradually to a street 70 yards away.

After consideration of predicted development and transmission requirements, it was decided to provide a 200 pair 20 lb. conductor paper insulated quad local type cable. Provision was made for the reduction of capacity unbalance of pairs in the cable using the "controlled method" described in Volume 6, No. 4, page 205, of this journal. To meet transmission requirements junction pairs were to be loaded with 88 MH coils spaced at 6,000 ft. Six pairs, which were to be reserved for V.F. programme transmission, were not to be loaded.

When determining the length of single wire armoured cable, allowance was made for the following:—

(a) the contours of the river bed, obtained from a Harbours and Marine Department plan, and

(b) possible deviation of the cable laying barge from the straight line course.

A total length of 550 yards of cable was required to be laid between the approach manholes on each side of the river.

To simplify the handling of cable at the crossing and as a security measure, it was decided to lay two 100 pair cables in preference to one 200 pair.

Necessity for Trenching River for Cable.—As this section of the Brisbane River is dredged continually by sand and gravel contractors, the Harbours and Marine Department was requested to cancel all dredging rights for 300 yards on either side of the proposed cable crossing. This request was granted but the department required a shipping channel of 21 feet at "low water spring tide" to be maintained for at least 100 feet on either side of a line of leads along the channel. At the desired cable crossing this shipping channel was close to the southern bank.

As the channel is liable to siltation following heavy flooding of the river, to allow dredging operations to be carried out at a future date, it was necessary to lay the cable at a level below 21 feet LWST. This resulted in the decision to lay the cable in a trench excavated in the river bed. The estimate for cutting 200 ft. of trench with sloping sides, 10 feet wide at the bottom and an average depth of 7 feet was £495. When actual dredging operations were commenced, it was found that the cross section was greatly different from the one supplied, due to the operations of sand and gravel contractors. The contour of the river bed at the point of crossing is shown in Fig. 2.

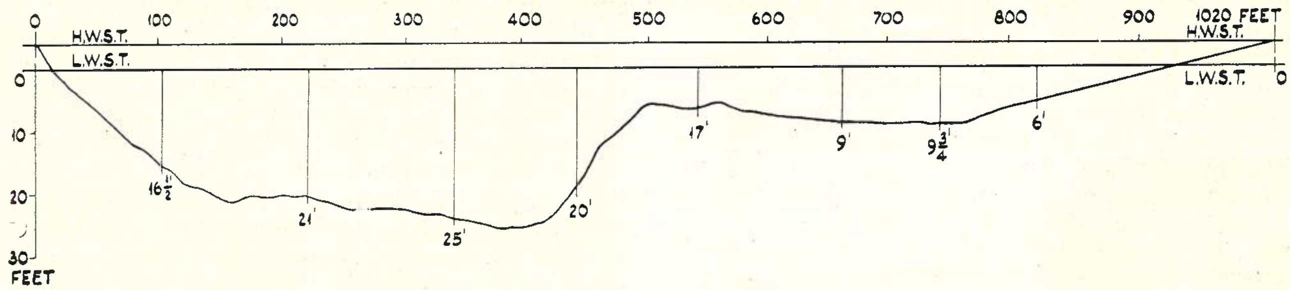


Fig. 2.—Cross-section of river at submarine cable crossing.

Preparing the Approaches.—The heavy mud amongst the mangroves on the northern side of the river made the preparatory clearing operations very difficult, and to clear the last few feet it was necessary to work off planking. It was evident that cable could not be handled under these conditions, and approximately 40 feet of temporary staging was constructed. See Fig. 3. The supports for the staging were worked approximately 5 feet into the mud and wired together. On the southern approach, clearing was limited to a small number of lantana bushes.

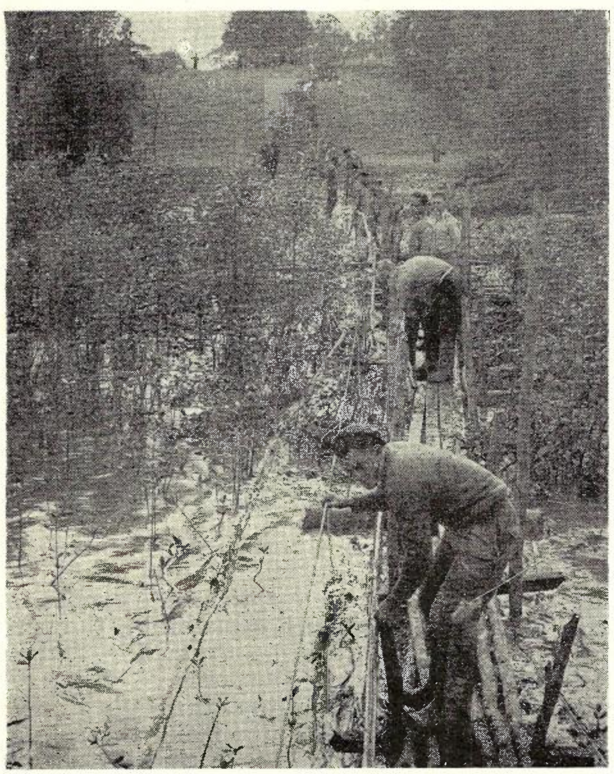


Fig. 3.—The northern bank, showing working conditions and staging.

To facilitate cable handling, the trenching on either bank was not done until after the cable had been laid across the river. Three white stakes were erected on each bank in the direct line of the cable crossing to assist the dredging and laying operations.

Preparation of Cable Barge.—The drums of cable were six feet in diameter and weighed approximately 5 tons. Drum cradles constructed from 2½ in. G.I. pipe were located towards the front of the barge and inclined at an angle so that the cables would feed off the barge 18 inches apart. It was arranged for each cable to feed through a manually operated cable brake and over cable rollers between the cradle and the brake. A guide post was erected midway between the two cable brakes to assist the control of the barge during laying operations. Three manually operated winches were securely bolted to the barge. One at the front was to provide the tractive power by drawing the barge across the river, while the two at the rear on each side were to control any lateral movement of the barge. Two old telephone poles were set on the northern bank six feet into the ground and suitably logged, to serve as an anchor for the barge traction winch rope.

Testing of Cable.—Before allowing dredging operations to proceed, it was essential that the cables be tested thoroughly. Each end was opened and the insulation resistance measurements made. The pairs were then tested for continuity and contacts. A few pairs were selected and side to side capacity unbalance and mutual capacity readings recorded for comparison purposes in the event of undue strain being applied to the cable during laying operations. Each cable length was then fitted with a schrader valve at the inner end, sealed and charged with dry air to a pressure of approximately 20 lb. per square inch. These precautions were justified as a cable sheath defect was located on one drum length at the inner end of the wire armouring. After this fault was rectified, both drum lengths maintained a constant pressure for a period of one week. It was then considered safe to allow dredging operations to proceed.

Dredging Operations.—It was anticipated that dredging operations would take approximately one week, and after examination of tides a suitable period for laying the cable was decided upon and dredging commenced.

The dredge (see Fig. 4) used was the "Mourilyan" with a bucket capacity of 1 cubic yard. On the day prior to laying, soundings were taken and one decided bump in the river was located. This bump had to be removed and further soundings taken. Dredging operations lasted 38¼ hours and 540 cubic yards were removed.

Cable Laying Operations.—On the afternoon prior to laying, the cable was loaded on to the barge and towed up the river. The Harbours

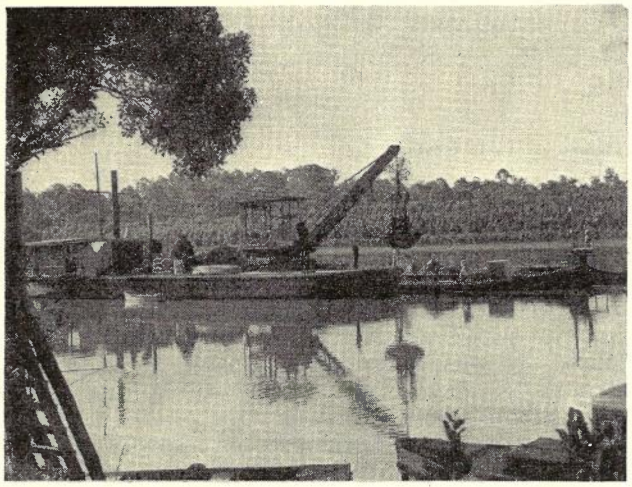


Fig. 4.—The Bucket Dredge "Mourilyan."

and Marine Department arranged for the closing of the river, but it was requested that the coral barge "Cementco" be allowed to pass shortly after noon, as it is essential that the best use be made of the tide in the higher reaches of the river. This barge carries some 2000 tons of coral daily to the Darra Lime and Cement Works, and has a draught of 15 ft. 6 ins. when loaded and 8 ft. when empty.

Fig. 5.—Barge at southern bank while cable being drawn ashore.

Two anchors were buoyed on either side of the proposed cable line in readiness for the cable laying early on the following morning. The personnel from two cable hauling parties were combined to form the nucleus of the labour required, and additional assistance was obtained from a conduit party.

On the morning of the laying, lines were attached to the buoyed anchors, dredge and a convenient tree, and the barge moved into position at the southern bank by 7.00 a.m. The cable ends were drawn ashore over cable rollers, by means of winch trucks, and left attached to the winches through a mechanical fuse of G.I. wire. The barge was ready to depart by about 7.20 a.m., some ten minutes before low water, and by this time a slight mist over the river had lifted, leaving the marking stakes on the opposite bank clearly visible. With two men on each of the port and starboard winches and four on the trac-

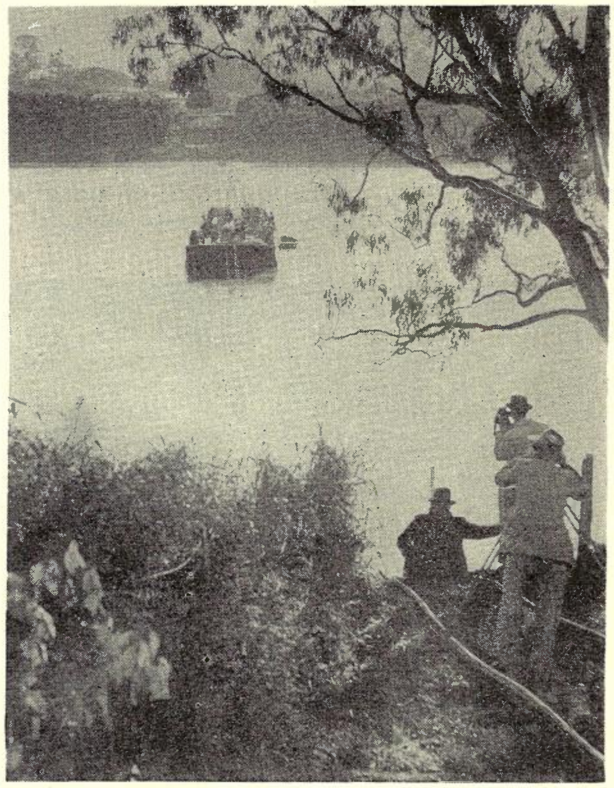


Fig. 6.—Barge in mid-stream.

tion winch, three on each of the cable drums, and one standing ready at each cable brake, the barge was slowly drawn across the river. Fig. 5 shows a close-up of the barge, and Fig. 6 shows the barge in mid-stream during the laying. The cable brakes were not required and the side anchors were changed when the angle subtended by the winch line became too small. In this manner, the position of the barge could be controlled against the effect of the tide and breeze.

Movement of the barge was controlled by a foreman of the Harbours and Marine Department who was equipped with binoculars, and communications between the barge and the shore parties were provided by portable radio equipment. When the barge grounded at the northern staging, the remaining cable on the drums was manhandled on a large bite for a few yards until a winch rope could be attached. The cable on the drum end of the bite had to be held out of the mud as the cable otherwise would quickly have sunk out of sight.

After the first cable had been landed on the northern bank, a diver supplied by the Harbours and Marine Department made his first descent to check that the cable was lying in the trench. He made four descents and each time overlapped on ground covered in the previous descent. He reported that both cables were in the trench and both lying on the bottom at all places. In some places the cables were already burying in the sand, and the trench was generally 4 to 5 feet deep. The incoming tide by this time was running strongly, and the diver could only make his way across the channel with difficulty, but he could not make any progress downstream. All cable laying operations were completed by midday.

Conclusion.—The gas pressure in the cables was tested immediately after laying and at daily intervals for several days. The cable was allowed to settle for several days before being covered in the trench, however, no movement of the cable due to tidal flow was detected. The installation of a gas pressure alarm system on this cable is now in progress.

ANSWERS TO EXAMINATION PAPERS

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

EXAMINATION No. 2817—ENGINEER, TELEPHONE EQUIPMENT

GROUP 2

Q. 6.—An automatic exchange of the pre-2000 type serves a self-contained area. A four digit numbering scheme is employed and the exchange has a capacity for 1200 lines. Traffic measurements show that on the average each subscriber to the exchange originates 0.025 traffic units in the busy hour and 80 per cent. of the traffic passes to the second selectors. The numbering scheme adopted is 2000-2999 and 3100-3299. Subscribers connected to the exchange total 1100, the spare capacity being evenly distributed over the equipment.

Give diagrams of the gradings which might be provided between first and second group selectors, the availability being 10.

The number of second selectors required for each grading may be calculated from the formula—

$$A = 0.446N - 1.03.$$

Where A is the traffic offered in traffic units and N is the number of selectors.

A.—The subscribers' lines will be arranged in two groups, one of 1000 lines numbered 2000 to 2999 and one of 200 lines numbered 3100 to 3299. The subscribers' lines, traffic and number of switches for each of the groups are—

Group	No. of Subs.	Traffic in T.U.
2000 } 2999	1000 x 11/12 = 917	917 x 0.025 x 0.8 = 18.34
3100 } 3299	200 x 11/12 = 183	183 x 0.025 x 0.8 = 3.66

Switches Required

$$(18.34 + 1.03)/0.446 = 43$$
$$(3.66 + 1.03)/0.446 = 11$$

The number of sub. groups in the grading is given by $g = 2n/a$ where (g) = number of groups, (n) = number of outlets and (a) = the availability. In this case, therefore—

$$g = (2 \times 43)/10 = 8.6$$

and taking the next even number to give a symmetrical grading g = 10. First selectors would, therefore, be spread evenly over 10 panels of 10 switch positions.

To obtain best grading (10 having 4 factors 1, 2, 5 and 10):

Let a = no. of singles b = no. of pairs
c = no. of fives d = no. of commons

therefore $a + b + c + d = 10$ .... (1)
and $10a + 5b + 2c + d = 43$ .... (2)
Subtracting, $9a + 4b + c + o = 33$ .... (3)

If a = 3 then 4b + c = 6 (from (3)).
If b = 2 c = − 2 not admissible.
If b = 1 c = 2
Substituting in (1) 3 + 1 + 2 + d = 10, d = 4
If a = 2 then 4b + c = 15 (from (3)).
If b = 3, c = 3
If b = 2, c = 7
If b = 1, c = 11
Substituting in (1)
2 + 3 + 3 + d = 10, d = 2
2 + 2 + 7 + d = 10, d = − 1 } not
2 + 1 + 11 + d = 10, d = − 3 } admissible
If a = 1 then 4b + c = 24 (from (3)).
If b = 6, c = 0
b = 5, c = 4
b = 4, c = 8
b = 3, c = 12
b = 2, c = 16
b = 1, c = 20
Substituting in (1) 1 + 6 + 0 + d = 10, d = 3
1 + 5 + 4 + d = 10, d = 0
1 + 4 + 8 + d = 10, d = − 2

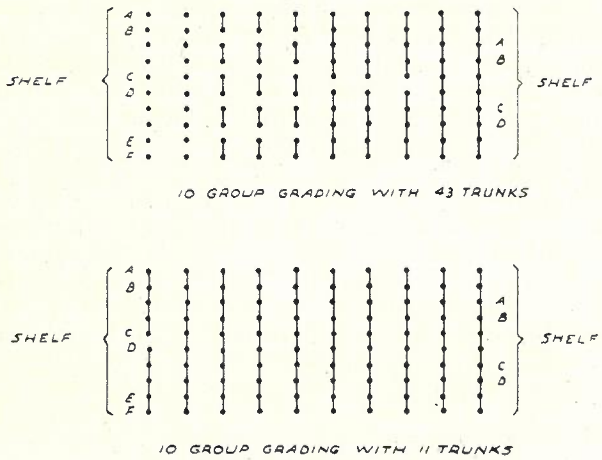
All further values of d are minus and are, therefore, not admissible.

Comparison of results	1	2	3	4
a	3	2	1	1
b	1	3	6	5
c	2	3	0	4
d	4	2	3	0
Sum of differences	5	2	14	9

The best grading of the 4 is No. 2, i.e.—

a = 2 b = 3 c = 3 d = 2

This is shown in Fig. 1. The grading for the 3000 group has only 11 trunks for 10 contacts and is shown in Fig. 1 also.



Q. 6.—Fig. 1.

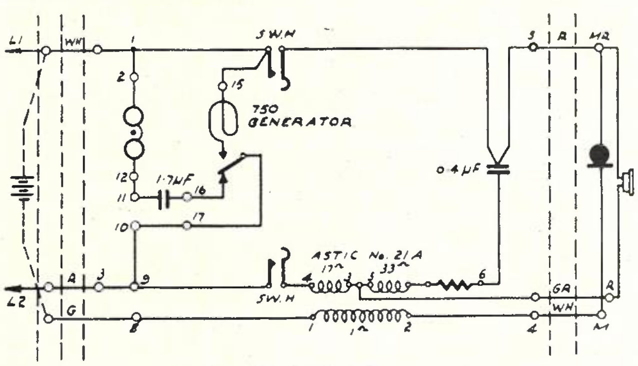
GROUP 3

(Two questions in this group to be attempted.)

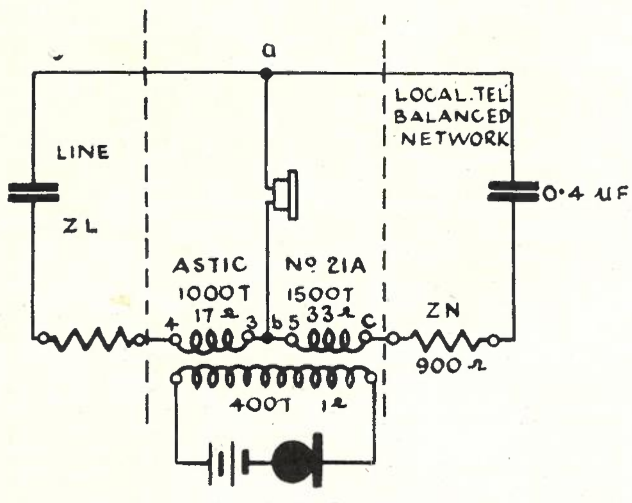
Q. 7.—(a) Explain by reference to a schematic circuit diagram the operation of a magneto handset telephone of the Departmentally designed 300 type.

(b) Dry cells of the type normally used in magneto telephones are purchased direct from the manufacturer by the Department. What tests do you consider should be applied to the dry cells to determine whether they are suitable for the Department's requirements?

A.—(a) The circuit diagram for the 300 type magneto handset is shown below.



Q. 7.—Fig. 1.



Q. 7.—Fig. 2.

The operation is as follows:—

Incoming calls—

The incoming ringing circuit is from Line 1 through the bell circuit, 1.7 µF condenser, generator contacts, to Line 2.

Originating Calls.

(i) **Outgoing Calls.**

The outgoing ringing circuit is from Line 1 through the generator circuit to Line 2. During this time the bell circuit is opened at the generator spring set. This is effected by the driving spindle of the generator moving outwards as the handle is turned.

(ii) **Transmitter Feed Current Circuit.**

When the handset is removed from the switchhook, the transmitter local circuit is completed as follows:—

From the dry cell battery, through the 1 ohm winding of the A.S.T.I.C. to Terminal 4 in the telephone, through handset cord to handset terminal M, through transmitter to handset terminal MR, through handset cord to telephone terminal 5, through switchhook contacts to battery.

(iii) **Sending Circuit and Sidetone Suppression.**

Referring to Figure 2, the operation when transmitting is best understood by considering that the turns and resistance of winding 4-3 are equal to those of 5-C, the impedance of the line is equal to that of the balance network, and that the receiver is disconnected.

Under these conditions we have a simple transformer in which 1-2 is the primary, 4-3 in series with 5-C is the secondary, and the line in series with the network is the load on the secondary.

The alternating current produced by the transmitter is transformed to the secondary and produces a P.D. between 4 and C. The potential at "b" will be at the midpoint of this potential. As the point "a" is at the midpoint of the load on 4-C, its potential will also be at the midpoint of the P.D. across 4-C and, therefore, "a" and "b" have the same potential. It therefore makes no difference whether the receiver is connected or disconnected, and when connected no current will flow through it, that is, no sidetone will be heard.

A.S.T.I.C. No. 21A has unequal turns on the line and network windings (4-3 1000 turns) (5-C 1500 turns). This has the effect of raising the receiving efficiency and lowering the sending efficiency compared with a coil having equal turns, and to obtain a sidetone balance with these unequal turns, it is necessary to use a balance network which has a higher impedance than that which would be used with equal turns.

In practice some sidetone will be heard in all cases, and the amount will vary with different connections. The impedance of the balance network ensures maximum suppression on long lines, and maximum advantage is obtained from the arrangements on connections over which the incoming speech level is low.

(iv) **Receiving Circuit.**

In the receiving condition, the voice currents pass from Line 1 through the switchhook contacts, local telephone receiver, 17 ohm winding of A.S.T.I.C. switchhook contacts back to Line 2.

Under balanced conditions no current flows through the network as the voltage across it is opposed by an equal and opposite voltage induced in the 33 ohm winding by the current flowing in the 17 ohm winding via the receiver.

A.—(b) The general specifications for the dry cell mentioned in this question are as follow:—

(i) **Dimensions.**

The cells shall be circular in cross section and the diameter shall be $2\frac{3}{8}$" and height, excluding terminals, 6⅝". The overall height shall not exceed 7½". The dimensions are those of the completed cell as measured over the cardboard carton.

(ii) **Voltage.**—Not less than 1.5 V.

(iii) **Internal Resistance.**—Not greater than 0.5 ohms measured within one month of delivery.

(iv) **Polarisation.**—The voltage of the cell shall not fall more than 10% when the cell is discharged through a resistance of 2 ohms for a period of 10 minutes.

(v) **Local Action.**—The purity of the materials used in the cell shall be such that no appreciable deterioration or local action will take place during storage for a period of 6 months.

(vi) **Efficiency** (Watt hours).—To be not less than 75 watt hours.

Tests to be applied.

Voltage and Internal Resistance.

In this test, the discharge of the cell through an ammeter or milliammeter in series with a suitable resistance shall be accepted as proving both voltage and internal resistance simultaneously.

The terminals on the cell should be connected to the meter for as short a period as possible, and to achieve this object it is usual to provide means so that the terminals of the cell under test are moved past contacts which are wired to the meter, so giving a discharge of the shortest possible duration.

The minimum permissible deflection of the ammeter or milliammeter shall not be less than the similar reading given by a cell having a voltage of 1.5 volts and an internal resistance of 0.5 ohms.

Polarisation.

The cell shall have a resistance of 2 ohms in parallel with a voltmeter connected across its terminals for a period of 10 minutes, and the reading should not fall below the relative figure given in the table below at any time during the 10 minute discharge.

Int. Res. of Cell	V.M. reading immediately after application of 2 ohm load.	V.M. reading immediately prior to removal of 2 ohm load.
0.1 ohms	1.45	1.3
0.2 ohms	1.35	1.25
0.3 ohms	1.3	1.2
0.4 ohms	1.25	1.15
0.5 ohms	1.2	1.10

Efficiency.

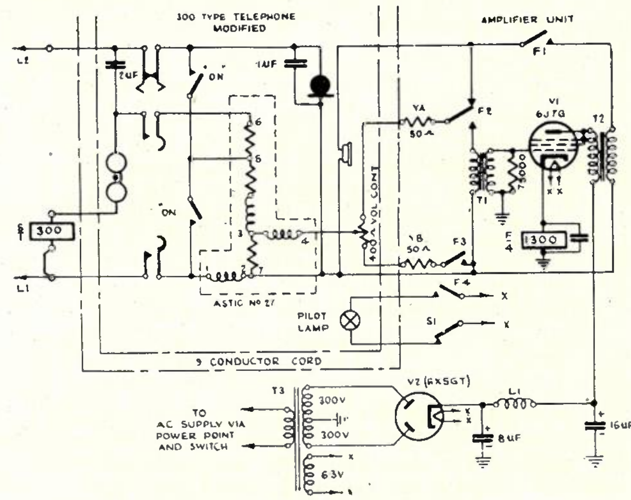
The cell or cells under test shall be discharged at 50 milliamperes for 7½ hours per day on five successive days. On the remaining two days of the week the cells will stand idle. The voltage will be determined weekly until the voltage falls to 1.2 V, and after that it will be determined daily.

During the period that the voltage is determined weekly it will be the average of the readings taken before the commencement of the test, say, on Monday morning, and after the completion of the test on the following Friday. When the voltage is determined daily it will be the average of the readings obtained before the commencement and after the completion of each day's discharge. When either the voltage falls to 1 volt or the internal resistance increases to two ohms, the cell shall be considered to have completed its life, and the tests shall be discontinued.

Q. 8.—A subscriber has defective hearing and applies to the Department to have a suitable amplifier supplied for association with the automatic hand set telephone at his residence.

Draw the circuit of the type of amplifier which should be supplied, and explain the operation.

A.—Fig. 1 shows the amplifier which should be supplied, and also the modifications necessary to the standard 300 type telephone to permit of its use.



Q. 8.—Fig. 1.

The amplifier consists of a single 6J7G valve (VI) connected as a triode, with input and output circuits coupled by means of transformers T1 and T2 respectively. Power supply is obtained from the household mains by means of power transformer T3 and full wave rectifier valve V2 (type 6X5 GT), the output of which is smoothed by means of the filter choke L1 in conjunction with two electrolytic condensers.

On switching on the A.C. the filaments of both valves are heated by current from the 6.3 volt winding of T3, and plate current commences to flow in the plate circuit of V1. This plate current flowing through relay F causes it to operate; and the voltage drop across this relay provides the grid bias for V1. Contacts of F relay prepare the amplifier circuit and F4 completes the circuit of the pilot lamp which glows to indicate that the amplifier is ready for operation. An incoming ring now operates relay S in series with the telephone bell and contact S1 causes the pilot lamp to be extinguished in synchronism with the periods of incoming ringing current. This gives a visual as well as an audible indication of an incoming call.

The operation of the telephone circuit is unaltered, except for the fact that instead of the receiver being connected to terminals 7 and 4 of the A.S.T.I.C. No. 27 as is usual, this circuit is connected to the input of the amplifier via the 400 ohm volume control, resistors YA and YB, contacts F3 and F2 (operated) and the primary winding of T1. Incoming speech currents are thus amplified by V1 and passed via transformer T2 to the receiver. The telephone transmitter circuit is not altered, and the addition of the amplifier in the receiver circuit does not affect its operation.

If the amplifier is not switched on, or is faulty, F relay does not operate. Under this condition the telephone can still be used, as the receiver is connected back in its normal circuit (but in series with YA and portion of the volume control) so that it is capable of receiving speech at normal unamplified level. Contact F3 (normal) prevents the receiver being shunted by YB, and contacts F2 and F1 (normal) open the input and output circuits of the amplifier respectively.

Q. 9.—(a) Explain the advantages of an inductor type tone generator compared with any other type of tone generator with which you are familiar.

(b) What factors determine the frequency of the tone produced by the inductor type tone generator?

(c) Explain, by means of schematic circuit diagrams, how the tones are supplied to subscribers line circuits at 2000 type exchanges.

A.—(a) The advantages of an inductor type tone generator over the previously used drum interrupter type are as follow:—

(i) Lower maintenance costs. The tones in the inductor type generator are induced into a stator winding by a toothed, soft-iron wheel, rotating in a magnetic field. Hence there are no slip rings, commutator or brushes required as there are no electrical connections to the rotor. Maintenance is thus reduced to a minimum, as the main item of maintenance on the drum interrupter type tone generator consists in cleaning the interrupter drum and changing worn brushes.

(ii) Reduced fault liability. The most frequent faults on the drum interrupter type tone generator are due to dirty interrupter drum, or worn, sticking or dirty brushes. These are eliminated in the inductor type as above.

(iii) Radio Interference. The possibility of radio noise interference, due to sparking at the brushes of the drum interrupter type, is eliminated as above in the inductor type tone generator.

(iv) Output Control. The volume of the tone output from the inductor type tone generator can be readily controlled by variation of the current through the exciting winding. This is achieved on this type of generator by provision of a number of resistors which can be included in series with the exciting winding as required. No such simple method of volume control is available on the drum interrupter type machine.

(v) Constant Output. In the inductor type generator, which does not require a transformer in the output circuit, the output voltage remains substantially constant under all load conditions. However, due to regulation effects of the transformer used with the drum interrupter type, the voltage varies considerably under different loads.

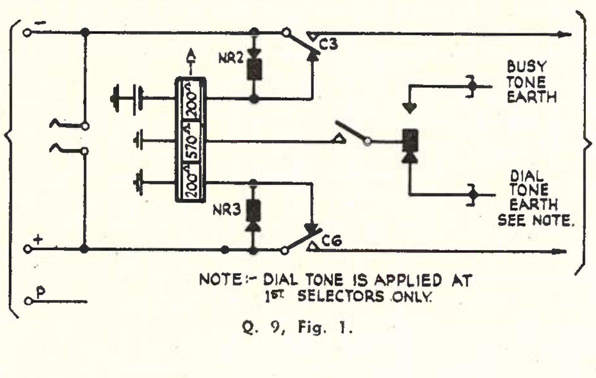
(vi) Better Quality Tones. The tones produced by the inductor type generator are generally purer and more pleasing to the ear than those from the drum interrupter type.

(b) The frequency of tones generated by the inductor type tone generator is determined by the following factors:—

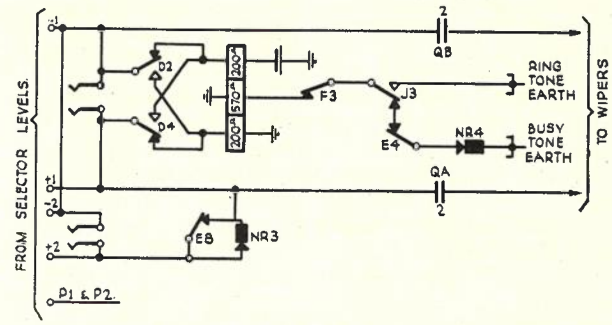
(i) The speed of the rotor (r.p.m.).

(ii) The number of teeth in the rotor.

(c) The standard service tones are applied to the calling subscribers' lines at 2000 type automatic exchanges as shown hereunder:—

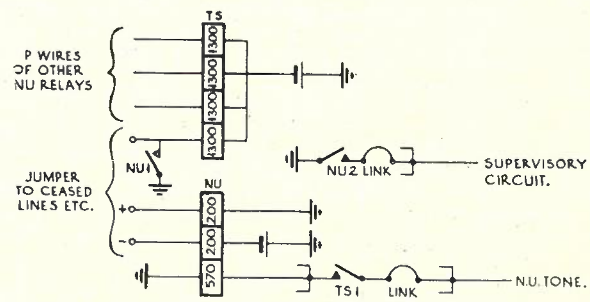


Q. 9, Fig. 1.



Q.9, Fig. 2.

Fig. 1 applies to the A relays of first selectors (busy tone and dial tone) and other group selectors (busy tone). Fig. 2 applies to the A relays of final selectors (busy tone and ringing tone). The tones are returned to the calling subscriber, depending on the operation of the appropriate relays. The 570 ohm winding of the A relay serves as the primary of a transformer, and the tones are induced into the two 200 ohm line windings which act in series as the secondary. N.U. tone is fed via a special relay to the banks of unallotted numbers and levels, thence via the switch wipers to a calling subscriber. Fig. 3 shows the relay connections.



Q. 9, Fig. 3.

EXAMINATION No. 2824—SENIOR TECHNICIAN TELEPHONE

J. Hardie

TELEPHONY 1

Q. 4.—(d) Until recently shunt field relays were included in repeaters (relay sets) and discriminating selector repeaters—

(i) What is the function of the relay in these circuits?

(ii) In later circuits an alternative arrangement is provided. Describe briefly the alternative.

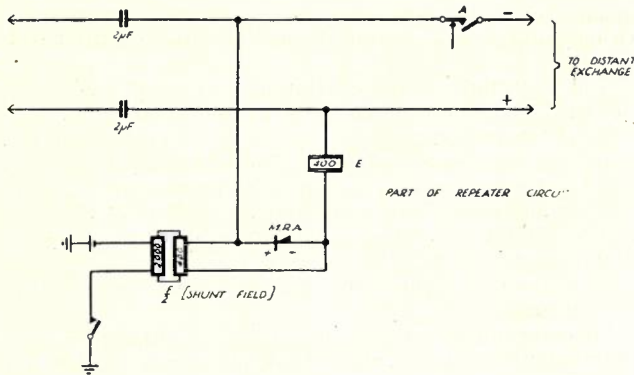
A.—(d) (i) The function of the shunt field relay is to operate when the called subscriber answers, so that battery will be reversed to the calling line to operate subscribers' registers, relays in public telephones and for supervisory purposes.

When current is reversed in the 400 ohms winding of the shunt field relay F, the alteration of polarity in this coil causes the armature to be attracted. Fig. 4.

As an additional safeguard, the 400 ohms coil of F is s/c. by a metal rectifier until reversal occurs. The rectifier also prevents "pick-up" troubles.

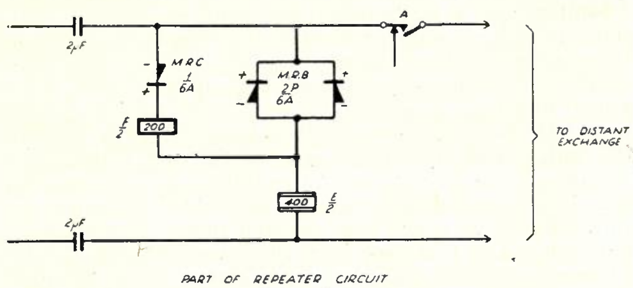
4. (d) (ii) In later circuits the shunt field is replaced by a standard 3000 type relay in conjunction with metal rectifiers.

Relay F has a 1/6A rectifier connected in series with it. F relay will not operate until current is reversed over the junction. On reversal, current will then flow



Q. 4.—Fig. 4.

through the rectifier in the forward direction and allow F relay to operate. The relay then performs the same functions as the shunt field type. See Fig. 5.



Q. 4.—Fig. 5.

Q. 5.—(a) A group selector of any type is to be subjected to a Routine Examination. Explain briefly how you would check the mechanical adjustments to determine whether re-adjustment is necessary. (State the type of selector to which your answer refers.)

A.—To check a 2000 type group selector—

1. Check that hub is not loose on tube.
2. **Vertical stroke.** Operate "B" relay and exert pressure on carriage. There must be no vertical "play."
3. Operate vertical magnet. There must be a minimum of forward or backward play between levels 1 to 0.
4. Observe that there is no play in detents.
5. Observe for damaged shaft washers.
6. Observe for broken magnet residuals.
7. **Rotary stroke** with magnet operated there must be no rotary "play" with pressure exerted on carriage.
8. Operate rotary magnets over levels 1, 5 and 0 step by step. There must be no forward or backward "lash."
9. Rotary disc must cut in on comb plate without rise or fall (undercut disc).
10. Carriage must latch on rotary detent projection with slight play.
11. Check carriage restore tension from level 1.
12. Check clearance on extended lug.
13. Check that rotary armature projection is locking and interrupter not breaking on restore.
14. Check that shaft is firm in top bearing by exerting pressure on bridge plate.
15. Check interrupter adjustment carefully with gauges.
16. Check that carriage will cut in off vertical pawl and NR lever. (This is important as it is a source of many alarms.)
17. Check that vertical ratchet does not foul vertical pawl on restore.
18. Observe movement on all mechanically operated spring sets.

Q. 5.—(b) After cabling a new building for subscribers' services, what tests would you apply to prove the wiring?

A.—Each cable pair terminated shall be tested for—

(i) Continuity.
(ii) Correct sequence.
(iii) Reversals, A and B wires in correct position at each termination.
(iv) Transpositions between pairs of wires.
(v) Where the total number of internal cable pairs terminated at M.D.F. or box does not exceed 100, a test of insulation from the exchange test desk will suffice unless a 500 volt megger is available.
(vi) If a tester is available, test one pair in each branch cable, if enamelled cable is used, and 25% of pairs in each branch if unenamelled.
(vii) In installations of over 100 internal pairs, test one pair in each branch of enamelled cable and 25% of pairs in branches of unenamelled cable, using a 500 volt insulation tester.
(viii) Insulation tests on every pair shall not be imposed unless—

1. With enamelled cable, the I.R. of any pair is lower than 10 megohms.
2. With unenamelled cable the resistance is lower than 5 megohms.
3. Due to damage or some other reason, the condition of the cable is suspect.

(ix) With enamelled cable, an I.R. value of below 5 megohms and with unenamelled 2 megohms, should be rectified or the cable replaced unless the good pairs are sufficient in number to meet development.

Reference:—Installation Circular No. 4.

Q. 5.—(c) In connection with trunking in an automatic exchange explain the following terms:—
(i) Full availability.
(ii) Traffic Unit.

A.—(i) The term "Full Availability" in a trunking scheme means the condition where a selector has access to the whole of the trunks on a given route.

(ii) A Traffic Unit is a unit employed in estimating the amount of switching equipment required in Automatic exchanges to carry the traffic. The Traffic Unit may be defined as the traffic flow in one circuit continuously occupied, and the traffic flow in traffic units for a period, usually the busy hour period, would be the number of calls originated during the period multiplied by the average holding time of a call, holding time being expressed in terms of the period. Examples:—

1 call of 1 hour's duration = 1 TU
4 calls of 15 min. duration = 1 TU
30 calls of 2 min. duration = 1 TU

Q. 5.—(d) What equipment is mounted on a composite finder rack in a 2000 type exchange?

A.—On a composite line finder rack, provision is made for two finder groups consisting of:—

(i) 2/25 800 contact bank multiples.
(ii) Positions for 25 finders per group.
(iii) 400 L and K relays.
(iv) Positions for 3 control sets per group.
(v) 6 allotters and banks per group.
(vi) 2 start sets one per group.
(vii) Bus bars and fuses.
(viii) Routine testing equipment.
(ix) Alarm and pulse relays.
(x) Marking relays.
(xi) Bank terminal strips.
(xii) Miscellaneous terminal strips.
(xiii) Supervisory lamps and jacks.

EXAMINATION No. 2817—ENGINEER—LINE CONSTRUCTION

F. C. L. Taylor, B.Sc., A.M.I.E.(Aust.)

PART B—CONDUITS AND CABLES

Q. 4.—Explain the advantages gained from the use of pillar terminals for distributing cable pairs in exchange networks and describe how you would determine suitable locations for them and dilineate the area to be served by each one.

Under what circumstances would you consider the use of larger cross-connecting facilities between the pillar terminals and the exchange?

A.—Chief advantage of the use of terminal pillars in a cable distribution system is the greater flexibility obtained between main or branch pairs and subsidiary pairs, which leads to more economic use of main pairs and deferring of relief, particularly on routes with a slow rate of development. In a main cable multipled through small pole distributing boxes, a large number of boxes each serving a relatively small area is unavoidable, as in the city and inner suburban areas difficulties associated with heavy aerial routes and economic considerations limit the size of pole boxes in general to 10 pair. This system is insufficiently flexible to cater for unanticipated growth which inevitably occurs in numbers of the small areas served by the pole-boxes, and without continuous and expensive re-arrangements to provide spare pairs at required boxes, experience has shown that the use of main cable pairs is limited to approximately 75%. Such re-arrangement work is wasteful in effort and must, in time, deteriorate cable joints and increase the fault liability. The use of pillar terminals on which main pairs may be terminated and jumpered to any one of a number of distribution pairs serving the pillar area increases the overall availability of main pairs in most cases to well over 80% with a consequent saving in main cable provision. Main cables are usually laid to meet eight year requirements, and branch cables for 8 or 20 years, depending on facilities for future relief and economic considerations. Cables up to and including 300 pair are installed to meet 20 year requirements. The shorter subsidiary cables which serve definite small areas are always less efficient due to variation of growth within such areas from survey figures. These cables generally have a maximum occupancy of the order of 66%, and even with a well-planned layout the subsidiary pairs at junction points will exceed the available main or branch pairs, and direct jointing and multipling of main pairs leads to maintenance and recording difficulties which are greatly decreased by the installation of pillar terminals at such points. If pillar terminals are provided at suitable points along main and branch cables, a high degree of flexibility is obtained with no multipling of main pairs between pillars. In the original installations of terminal pillars 10 links were frequently provided in each direction from the pillar. These link pairs served a useful purpose in providing access between pillars or to directly route non-exchange lines required to extend between pillar areas, but it was found in practice that there was always a tendency to abuse the use of link pairs such as connecting a subscriber through as many as seven pillars, and the increased recording difficulties outweighed the advantages. Most pillar terminals are now planned without links, particularly where larger cross connecting cabinets are also installed. The use of these large cabinets is discussed below. In other cases a compromise scheme using five links only in each direction may be used, e.g., in industrial areas where groups of extensions between buildings are common. Other advantages arising from the use of pillar terminals are:—

(i) Facilitate direct routing of extension and other non-exchange lines wholly within a pillar area.

(ii) Allow direct leads to be readily disconnected from the main cable when services are cancelled.

(iii) Provide properly identified groups of pairs for testing purposes along main and branch cables.

(iv) Simplify cabling and jointing operations and the planning of future relief.

(v) Facilitate the provision of party line services if required.

In determining suitable locations for pillar terminals, detailed development plans showing survey figures and existing construction along main, branch and subsidiary routes are essential. The pillar areas are then selected as areas which can be most economically and conveniently served from a pillar terminal, which should be located as close as possible to the groups of subscribers which the subsidiary cables are to serve. The subsidiary, or distribution pairs will exceed the main pairs in number and consequently should be as short as possible. Pillars are preferably located on the pavement and as near as practicable to the manhole in which jointing is to be effected. The size of a pillar area will be limited by the exchange line capacity of the pillar, e.g., in the case of a 120 pair pillar with 50 main pairs, an area should contain a 20 year development of approx. 40. It is also advisable to ensure that an area will be capable of further subdivision should a pillar become full, without the necessity of altering adjacent pillar boundaries. An exchange area should be taken as a whole when the subdivision is being made, and the proposed boundaries clearly marked on the exchange area development plan. In the case of a new cable installation it is usually simpler and more economical to instal the pillar terminals at the outset than to instal them later on working cables. With existing cables there is no necessity to instal pillars while direct leads will meet all service requirements without re-arrangements.

The primary reason for installing a large-sized cross-connecting cabinet in an existing cable layout is to allow the deferring of large scale relief of main cables by increasing the availability of existing main pairs. When all main pairs of a cable are connected through a large sized cabinet an availability of 90% to 95% can be expected on the exchange side of the cabinet, and in the vicinity of 85% on the secondary side if distribution to subsidiary cables is via terminal pillars. If actual development closely follows the forecast on which the cabinets are provided, higher efficiencies approaching 100% may be obtained between the cabinets and the exchange. It would be wise, however, to plan for an occupancy not exceeding 95%. The installation of cabinets at the main distributing points on a congested cable may free a considerable number of pairs and also greatly facilitate their use for future services by simple alterations to jumpers within the cabinet. For the installation of the cabinets to prove economical under these conditions the expenditure saved in copper provision between the cabinets and the exchange by increasing the pair availability outweigh the costs of the pillar, each considered over the period for which further relief is deferred by installing the cabinets.

Similarly, where a new installation of pillar terminals is in mind, it is quite possible that further economies in main cable provision may be effected by installing a number of controlling cabinets which would increase the availability of main pairs between the exchange and the cabinets. The presence of the cabinet would then almost certainly facilitate still further the connection of additional subscribers and extensions without the necessity of jointing operations.

Q. 5.—A section of an existing subscriber's cable route consisting of a single 4-in. pipe and a 200 pair 10-lb. cable is to be developed also as part of a junction cable route. Survey figures are—

	Subs. lines 10 lb.		Junctions 10 lb.		20 lb.
Present	**180**	....	....	....	....
8 year	**600**	....	**600**	....	**400**
20 year	**1,200**	....	**1,400**	....	**1,000**

How many ducts would you lay and how would you plan immediate and ultimate cable installations, giving your reasons?

Give a list of items of material and approximate quantities for 1 mile of the size and type of conduit you propose.

A.—Duct requirements would be as follow:—

10 lb. subscribers' cables	2
10 lb. junction cables	2
20 lb. junction cables	2
Spare and unforeseen	2
Total	8
Existing	1
New ducts required	7

Under these circumstances it would be economically sound to lay two four-way ducts, particularly as the provision of a third duct for unforeseen purposes on such a route would not be unreasonable.

Cable Provision:

(i) 10 lb. Subscribers.—Based on a pair occupancy of 90%, which could be readily obtained between the exchange and large-sized distributing cabinets, an 800/10 would meet eight year subscriber requirements and would be installed initially. The existing 200/10 would be withdrawn ultimately but initially may be used for subscriber distribution. On a new route such as this it would be desirable to provide separate cables for subscriber and junction purposes. This allows a gas pressure alarm system to be fitted to a junction cable more easily than on a cable which also serves subscribers' terminals. The danger of interference to junction pairs arising from operations on the subscribers' pairs is also minimised. In some instances, e.g., on an existing route where remaining duct space is at a premium, it may be more economical to provide a 1200/10, the maximum size cable, and utilise the minor 600 pairs as junctions pending the ultimate installation of a second 1200/10 for junction purposes only. In this case, however, separate subscriber and junction cables would be installed. A second 10 lb. subscriber cable would be required some time after the eight year period and would be either a 600/10 or larger depending on revised survey figures which would be available at the time. Two ducts must therefore be provided for 10 lb. subscriber cables.

(ii) 10 lb. Junctions.—Presumably miscellaneous circuits have not been included in the figures given, and an allowance of at least 10% on these figures must be made for such services. For industrial areas this ratio would be considerably higher, but by examining the existing ratio of miscellaneous and junction lines a reasonably accurate idea could be obtained of the allowance which must be made. It would be necessary to plan for at least 1540 10 lb. pairs, for junction and miscellaneous purposes at the 20 year period, and an 800/10 would be required initially to meet requirements for at least eight years. A relief cable, probably a second 800/10, would then be required. Two ducts must, therefore, be provided for 10 lb. junction cables.

(iii) 20 lb. Junctions.—Allowance must be made for at least 440 circuits at the eight year period and 1100 at the 20 year period. A 600/20 is the largest cable that can be installed in a 4 in. duct, and to ensure that two ducts will meet 20 lb. requirements for 20 years it would be advisable to make the first installation a 600/20. The size of the relief cable would be influenced by any revised survey figures available at the time, but would be, in all probability, another 600/20 or possibly a 540/20. It might be observed that insofar as cable provision is concerned a slight economy would be gained by providing the 20 lb. cable in three stages of 400/20. This economy would, however, be more than outweighed by the cost of the extra duct that would be required. Also, if it were assured that 1140 pairs would meet 20 year requirements, the initial provision of a 540 pair cable would be slightly more economical than providing a 600 pair initially followed by a 540 pair relief cable. The economy would be only very slight, however, of the order of £100 in £13,000 per mile total P.V. of costs involved, and it would be preferable to gain maximum duct use by installing a 600/20 initially in case survey figures at the time should dictate a second 600/20 as the relief cable.

Conduit material for one mile of route:—

Conduits E.W.S.A. 4 way 4 ins. x 24 ins.	5200
Packing sand	25 c. yds.
Acetylene gas	500 c. ft.
Manhole covers and frames, 4 ft. x 4 ft.	25
Cement	350 bags
Coarse sand	50 c. yds.
Screenings	75 c. yds.

Pipes E.W. 4 ins. x 24 ins. untested, as required for drainage purposes. Manholes would be drained where ready access was available to storm-water channels, etc.

Gratings for manhole sump	25
Anchor irons	25
Manhole steps	50
Cable bearers, moveable 3 joint	100
Channel iron supports—4 way	25

Q. 6.—A large cable has failed completely and the trouble has been localised to a section between two manholes.

Discuss the considerations which would lead to a decision as to whether you would replace the faulty section of cable or would excavate at the point of failure and dry out and repair the cable.

Describe the procedure you would adopt for replacing the faulty section of cable if there were no spare duct.

A.—The following are the main factors which must be considered in such a case:—

(i) Whether location tests from each manhole reconcile sufficiently to enable the exact location of the fault to be confidently determined. If an accurate location is not available, much time can be lost in excavating, particularly if other conditions as discussed below are also difficult.

(ii) The nature of the fault.—If the fault has occurred in a known electrolysis area it is likely that the length would contain other incipient faults and should be replaced. The primary objective in such a case is, however, to get subscribers working as quickly as possible and, if the cable is easily accessible, e.g., in a single pipe close to the surface and safely located on a footpath, it may pay to excavate and dry out to the point where even a sub-standard service is possible while operations to replace the length are in progress. The type of cable, the length of time the fault has been on, and the amount of water present will also have an important bearing. If, for instance, a loosely packed cable such as twin or M.T. has been wholly or partially submerged for some time by a heavy downpour or burst water main it is likely that moisture will have seeped some distance into the cable and drying out under these conditions would be difficult.

(iii) Accessibility of the fault.—If the fault is within a short distance of a manhole it would almost certainly pay to extend the manhole bell mouth and dry out if at all possible. If the cable is on a multi-duct route the position of the cable in the ducts and the number and size of other cables would have an important bearing. If the cable is in a top duct it will usually be possible to repair the broken four or 6 way duct with split pipes. If the faulty cable is in a lower duct and extensive damage to the whole nest of ducts will be necessary to reach it, the construction of an intermediate manhole at the location of the fault may be necessary when repairs to the faulty cable have been effected. Generally speaking it would be preferable under these conditions to replace the length at the outset.

If the cables are housed in single pipes, the process of breaking down will be much simpler and duct repairs more easily effected. There are still other factors which must be considered, however, e.g., the depth of the ducts. A deep and lengthy excavation can cause considerable disruption to pedestrian traffic on a footway and can cause much more serious dislocation on a roadway, even in a suburban area, particularly if the initial excavation does not expose the fault, which is always a possibility. If the fault is located in a busy shopping section or on a fairly busy roadway and the ducts are deep it will be preferable in most cases to replace the length, particularly if electrolysis or corrosion is suspected. If tram lines are present, road excavation can cause serious traffic bottle-necks even when ducts are at normal depth only, and replacement of the length would be advisable. The type of surface and soil likely to be encountered will also be a consideration, as will the presence of other obstructions at the position of the fault.

To summarise, it will be preferable to break down and dry out if the above considerations suggest with reasonable certainty that quick access to the fault can be obtained, and that the trouble may be removed by drying out once exposed. The larger the size of the faulty cable the more desirable will it be to break down. With cables of 300 pair or less it will usually pay to replace the length without attempting to uncover the fault.

In the event of replacement being unavoidable and no spare duct available, an emergency cable of sufficient capacity to take all essential services would be run, probably in the gutter. Fuses would be removed on the exchange M.D.F. and two **skilled and experienced** jointers placed at each manhole. Each wire in the faulty cable would then be identified and tagged in both directions. A wet cable test set would be used for this identification. During the process the more important lines would be transferred to the emergency cable, the wires of each pair being cut over individually. The identification of these lines would be checked by simple buzzer tests from the M.D.F. After full identification the faulty length would be cut away, withdrawn, and a new length drawn in, identified and jointed. The working pairs in the emergency cable would be transferred to the new cable in the process.

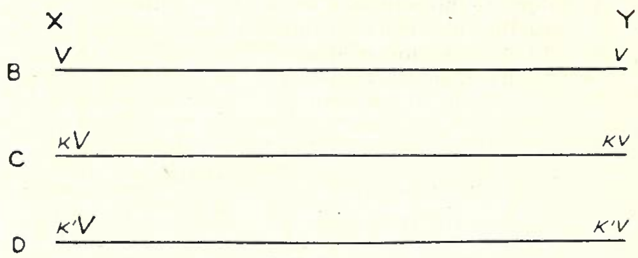
PART C—AERIAL WIRES

Q. 7.—Explain the following terms and their association with the transposition design of aerial trunk routes:—

Fundamental types.
Extra transpositions.
Transposition intervals.
Irregularity crosstalk.
"K" factors.
Absorption.

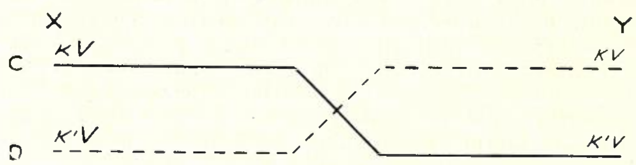
What is the normal design limit for crosstalk between two pairs of trunk telephone wires for carrier operation?

A.—The following simple but qualitative explanation of the cause of cross-talk and the effect of a transposition may be helpful in considering transposition types and their application. Take the case where wire B of a circuit AB is disturbing an adjacent circuit CD. (See Q.7, Fig. 1.)



Q. 7, Fig. 1.

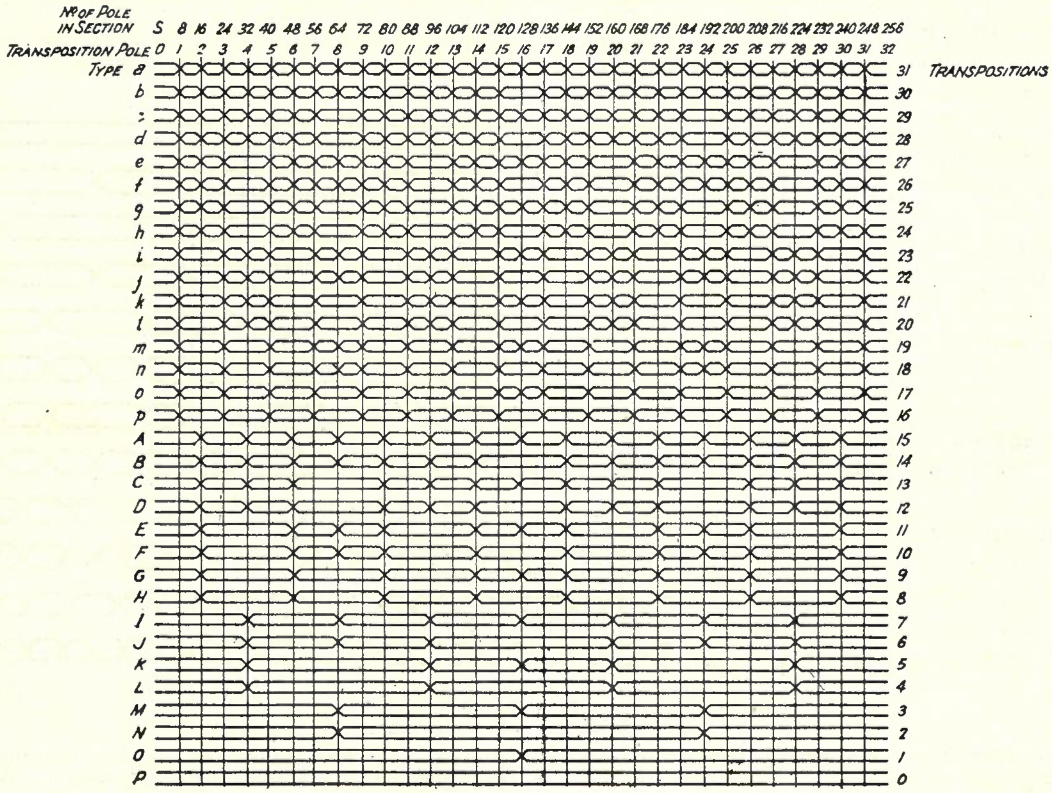
Induced potentials in wires C and D at points X and Y will be as shown, where k and k' are constants. The potential differences between the wires of circuit DC will be V(k—k') and v(k—k') and will be of similar polarity. If now a transposition is placed at an intermediate point in the circuit CD, induced voltages will be as shown in Q.7, Fig. 2.



Q. 7, Fig. 2.

The same potential differences will exist between the wires at X and Y but they will be of opposite polarity. If V(k—k') = v(k—k') there will be no resultant voltage between the wires over the section XY. For this to be so the magnitudes and phases of V and v must be closely approximate, and the section under consideration must be sufficiently small for this to hold. The higher the frequency of the working circuits the greater will be the change in magnitude and phase along the line, and transposition schemes for such circuits must contain more transpositions with smaller spacing between.

Fundamental Types.—To facilitate the design of transposition schemes a number of arrangements of transpositions have been standardised. These arrangements are known as fundamental types and are abitrarily designated by the letters a, b, c, . . . p, and A, B, C, . . . P. In a scheme employing fundamental types only there is a maximum of 32 transposition poles in an E section of 256 spans. Typical examples of fundamental types are—



Q. 7, Fig. 3.

Transposition schemes for voice frequency circuits normally involve fundamental types for all classes of section. These types provide sufficient transpositions within a section to render the phase and magnitude change in the V.F. circuits negligible between transposition points.

Extra Transpositions.—The fundamental types do not meet this requirement for longer sections when carrier frequencies are in use and types employing more transpositions have been built up by the uniform addition of "extra transpositions" to the fundamental types. Each of these derived types is definitely related to a fundamental type and is designated by—

ⓐ, ⓑ, ⓒ ---- ⓟ, and

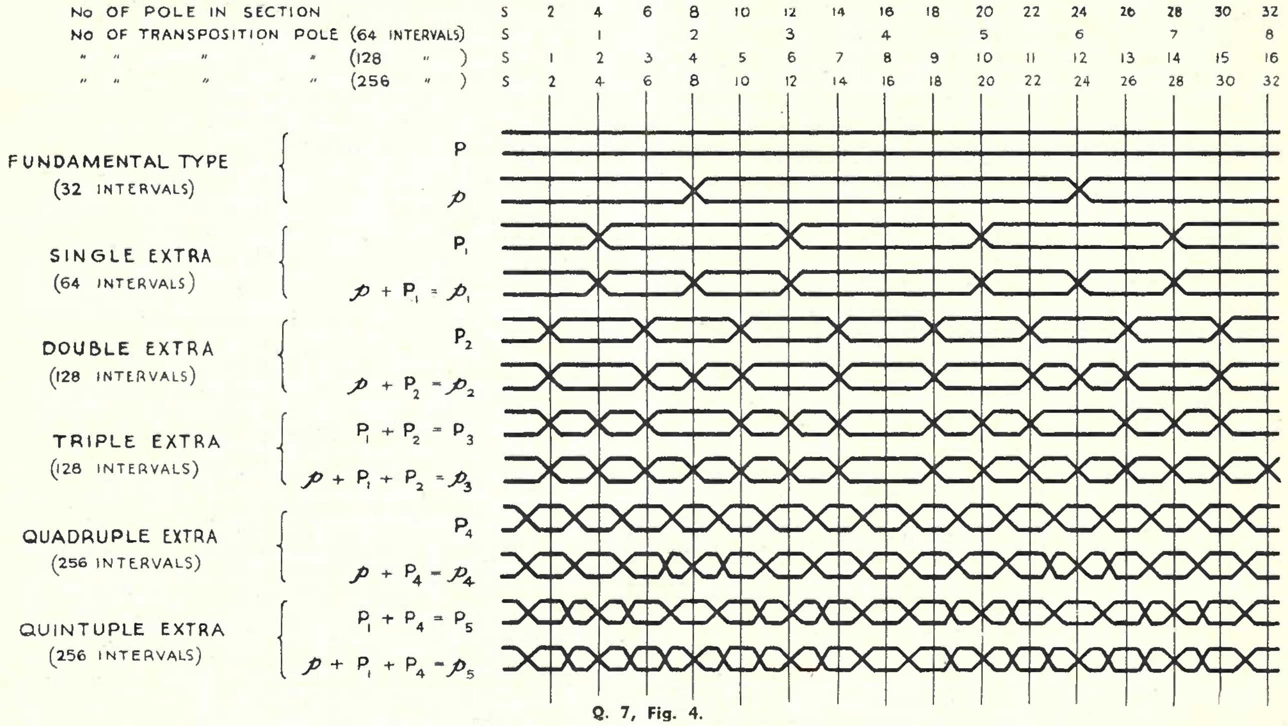
Ⓐ, Ⓑ, Ⓒ ---- Ⓟ, or

((a)), ((b)), ((c)) ---- ((p)), etc.

depending on the extent to which the fundamental type has been subdivided. Schemes for carrier operation require "extra" types of all E sections and in certain cases for L and R sections. The derivation of extra types from fundamental p and P types is shown in Fig. 4.

Transposition Intervals are the intervals between successive transposition poles. In the fundamental scheme shown in Fig. 4 the transposition interval would be 16 spans for capital letter types and 8 spans for small letter types. In the single extra scheme, it would be 4 spans, giving 64 intervals in the E section, and in the double extra scheme, 2 spans, giving 128 intervals, etc. The minimum transposition intervals in a scheme employing fundamental types would be eight spans, while in a scheme intensively transposed for a number of 12 channel systems every pole may be a transposition pole and every span a transposition interval.

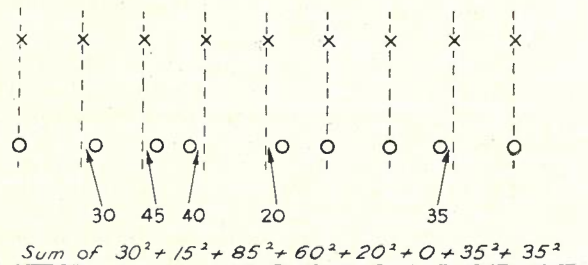
Irregularity Crosstalk is cross-talk arising from irregularities in construction. The most important irregularities are inaccurate location of transposition poles and differences in sag between the wires of a pair. Variations in arm or wire spacing and proper impedance matching of entrance cables to the open wire line are also very important. Wire spacing may, for instance, vary at a heavy angle, and such cases should be specially treated and longer arms fitted if necessary. The total effect of cross-talk values is given approximately by the square root of the sum of the individual components, and the cross-talk characteristics of a line are controlled by the worst sections. The effect of one badly located transposition pole can thus be very serious, and a carefully planned transposition scheme nullified. Impedance irregularities in a line arising from sag differences, poor matching of cables, variation in arm or wire spacing, etc., have the effect of reflecting near-end cross-talk currents which then add to the far-end effect. Near-end currents are not important as such on carrier lines as the receiving filters on adjacent systems will not pass them. If reflected at impedance mismatches, however, their effect can be serious. It is important when erecting new wires to ensure that the sag is as uniform as possible and the maximum difference in sag between the two wires of a pair should not exceed one inch. Regular check tests should be made to ensure that subsequent differences do not exceed two inches. In addition to careful construction and uniformity of sag a close check must be kept on carrier routes of the cumulative effect of pole-spacing irregularities. A useful and uniformly used criterion for



Q. 7, Fig. 4.

checking the degree of pole spacing irregularity is the "K factor."

The K Factor is the sum of the squares of the irregularities in transposition intervals divided by the length of the section, all values expressed in feet,



$$K = \frac{\text{Sum of } 30^2 + 15^2 + 85^2 + 60^2 + 20^2 + 0 + 35^2 + 35^2}{\text{Length of section}}$$

Q.7, Fig. 5.

Note that the K factor is **not** concerned with the distances of individual poles from their correct locations, but with irregularities in the lengths of **transposition intervals.** For 12 channel carrier routes, the K factor for each transposition section should be less than one, and the transposition poles at the 1/4 and 1/2 points of all E sections placed as close to their theoretical locations as possible. The distance of these poles from their correct location should in no case exceed 100 feet. In each 12 channel repeater section the value of K for the section as a whole should be less than 0.33. On new routes these limits are easily obtained. On existing routes retransposed for carrier working a K factor over a transposition section of less than three is sufficient in the initial stages to avoid extensive re-poling. This usually involves locating transposition poles within ± 45 ft. of their correct location.

Absorption causes attenuation peaks at certain frequencies due to loss of energy by induction into other circuits. The presence of these peaks is governed largely by the transposition scheme and types of other circuits present. A pair transposed for low-frequency working only can for example cause absorption from an adjacent J12 circuit. A heavy iron wire pair can have a similar effect.

The normal **design limit** for cross-talk between two pairs designed for carrier operation is 60 db. between wanted and unwanted signals. When direct cross-talk occurs between channels at different levels, e.g., between the output of one repeater and the input of another, the repeater gain must be added to the design limit. If the repeater gain is 15 db., then cross-talk limit would be 75 db. as the cross-talk currents would undergo an amplification of 15 db. Special precautions must always be taken, therefore, to eliminate cross-talk in entrance loops to repeater stations.

EXAMINATIONS NOS. 2860 AND 2861—TECHNICIAN, BROADCASTING

SECTION A

N. S. Smith, A.M.I.R.E.

Q.1.—Explain the terms:—

Instantaneous value,
Maximum value,
R.M.S. value,
Average value,

as applied to an alternating current. What do you understand by the term "three phase 50 cycle A.C. Supply"?

A.—The instantaneous value of an A.C. is its value at some specified instant of time.

The maximum value of an A.C. is the highest value reached during a cycle, it may be either positive or negative.

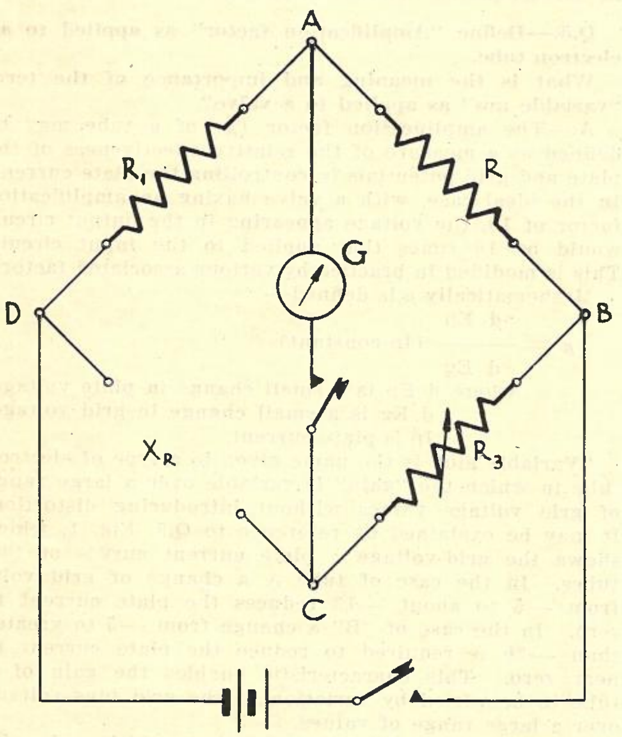
The Root-Mean-Square value of A.C. is the square root of the mean value of the squares of the instantaneous values taken over one complete cycle. It approximates maximum value X 0.707, and is equal to the value of D.C. which would produce an exactly similar heating effect in a circuit.

The average value of A.C. is the average of the instantaneous values over a half-cycle (over a whole cycle would be zero). It is equal to the R.M.S. value divided by 1.11.

The term "3-phase 50 cycle A.C. supply" indicates a power supply utilizing Alternating Current having a frequency of 50 cycles per second made up of three alternating voltages displaced in phase with regard to one another by 120 degrees.

Q.2.—Explain with a circuit diagram the principle of a Wheatstone Bridge and show how such a Bridge can be used to measure a wide range of resistance values.

A.—



Q. 2, Fig. 1.

A Wheatstone Bridge as illustrated schematically in Fig. 1 consists of two resistance arms R_1 and R_2 (known as Ratio Arms) each of which may be adjusted to 10 ohms, 100 ohms or 1000 ohms, and a continuously variable calibrated resistance R_3 (known as the Variable Arm). The fourth arm X_R is where the unknown resistance to be measured is connected. A voltage is applied across D and B and a galvanometer is connected across A and C. A key is connected in the battery circuit and in the galvanometer circuit. Assume that both keys are closed. When points A and C are at the same potential no current flows through the galvanometer. Under this condition the Bridge is said to be "balanced" and the value of resistance R_1 multiplied by R_3 equals the value of X_R multiplied by R_2, i.e., $R_1 \times R_3 = X_R \times R_2$ and $X_R = (R_1/R_2)\ R_3$ so that when R_1 and R_2 are equal $X_R = R_3$

For high resistances let $R_1 = 1000$ and $R_2 = 10$, then at balance $X_R = (1000/10) R_3 = 100R_3$.

For low resistances let $R_1 = 10$ and $R_2 = 1000$, then at balance $X_R = (10/1000)\ R_3 = R_3/100$.

Thus by altering the values of the Ratio Arms resistances of high and low values may be determined readily.

Q.3.—What do you understand by the terms:—
Coulomb,
Farad,
Dielectric?

Given two condensers having capacitances of 6 microfarads and 4 microfarads respectively, what would be their capacitance when connected (a) in series, and (b) in parallel?

A.—Coulomb is the unit of quantity of electricity or a measure of the rate of flow. One coulomb is the quantity passing in one second when the mean current is one ampere.

Farad is the practical unit of electrostatic capacitance. A capacitance has a value of one farad when a charge of one coulomb causes a difference of potential of one volt between the surfaces of the capacitance.

Dielectric is material which offers relatively high resistance to the passage of an electric current, i.e., an insulator. In a more general sense it is the material separating the plates of a capacitor.

When condensers are connected in parallel the total capacitance is the sum of the capacitances of all condensers so connected; in this instance $6 + 4 = 10$ microfarads.

When condensers are connected in series the relationship between the joint capacitance K, and the capacitances of the separate condensers K_1, K_2, K_3 . . ., etc., is as follows:

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} \ldots, \text{etc.}$$

In this instance

$$\frac{1}{K} = \frac{1}{6} + \frac{1}{4} = \frac{2+3}{12} = \frac{5}{12},$$

and $\therefore K = 12 \div 5 = 2.4$ microfarads.

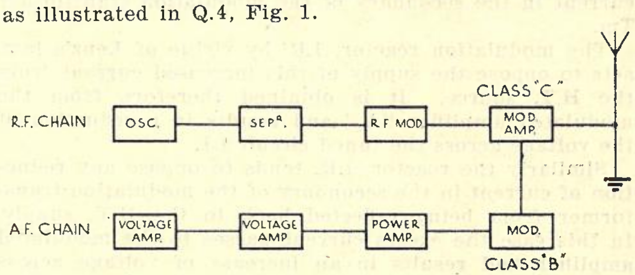
SECTION B

Q.4.—What is meant by high level modulation of a radio transmitter?

Describe with the aid of a diagram a method of modulating a transmitter in this manner.

Why is it necessary to maintain as high a depth of modulation as possible?

A.—A transmitter is said to be high-level modulated when modulation is effected in the final R.F. amplifier as illustrated in Q.4, Fig. 1.

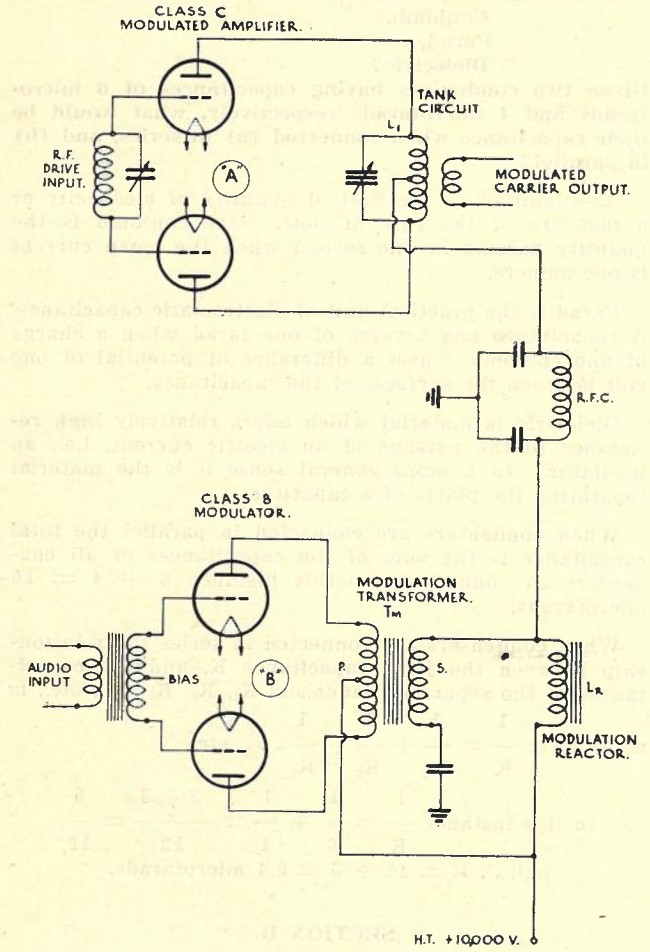


Q. 4, Fig. 1.

Q.4, Fig. 2, illustrates a method of achieving high level modulation.

The R.F. carrier is fed to the push-pull class C amplifier "A," and the audio input to "B."

The H.T. supply to "A" and "B" is from a common source.



CLASS B HIGH-LEVEL MODULATION CIRCUIT.

Q. 4, Fig. 2.

The operation is briefly:—

The instantaneous amplitude of the R.F. carrier in tank circuit depends on the H.T. voltage at any instant, and will be constant with no audio signal applied to "B." Consider an audio signal applied to "B," of such polarity and amplitude as to require an increase of current in the secondary of the modulation transformer Tm.

The modulation reactor, LR, by virtue of Lenz's law, acts to oppose the supply of this increased current from the H.T. source. It is obtained therefore from the modulated amplifier "A," and results in a reduction of the voltage across the tuned circuit L1.

Similarly the reactor, LR, tends to oppose any reduction of current in the secondary of the modulation transformer from being reflected back to the H.T. supply. In this case the excess current passes to the modulated amplifier and results in an increase of voltage across the tuned circuit. Thus an audio wave of varying amplitude applied to "B" causes the voltage across the tuned circuit, L1, of "A" to vary in a similar manner. Since this tuned circuit is supplied with a radio frequency wave, the amplitude of this R.F. wave will vary according to the audio signal level. The R.F. wave is thus said to be "amplitude modulated" by the A.F. wave.

The sidebands produced by the process of modulation contain the modulation frequencies (i.e., the programme) and consequently the greater the power in these sidebands the stronger the output signal in a radio receiver. At 100% modulation, the sideband power is only half the carrier power and under general programme conditions the average modulation depth is about 30%, with a consequent reduction in sideband power. Thus it is essential to keep the modulation depth as high as possible to preserve a satisfactory signal-to-noise ratio.

Average modulation depth may be improved by employing "peak" limiters or compression amplifiers which enable the average modulation depth to be increased without fear of overmodulation on the programme peaks. The characteristic of these amplifiers is that beyond a certain adjustable limit an increase of input produces no corresponding increase in output.

Q.5.—Define "Amplification factor" as applied to an electron tube.

What is the meaning and importance of the term "variable mu" as applied to a valve?

A.—The amplification factor (μ) of a tube may be defined as a measure of the relative effectiveness of the plate and grid potentials in controlling the plate current. In the ideal case, with a valve having an amplification factor of 10, the voltage appearing in the output circuit would be 10 times that applied to the input circuit. This is modified in practice by various associated factors.

Mathematically μ is defined—

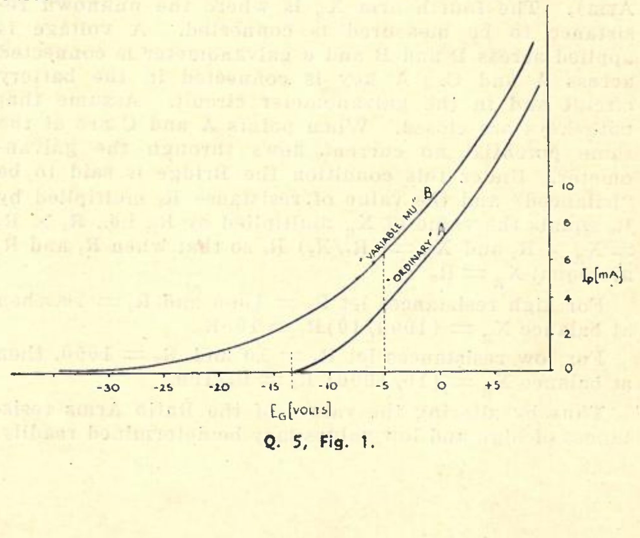
$$\mu = \frac{d\,Ep}{d\,Eg} \quad \text{(Ip constant)}$$

where d Ep is a small change in plate voltage,
d Eg is a small change in grid voltage,
Ip is plate current.

"Variable mu" is the name given to a type of electron tube in which the "gain" is variable over a large range of grid voltage values without introducing distortion. It may be explained by reference to Q.5, Fig. 1, which shows the grid-voltage : plate current curves of two tubes. In the case of tube A a change of grid volts from —5 to about —13 reduces the plate current to zero. In the case of "B" a change from —5 to greater than —30 is required to reduce the plate current to near zero. This characteristic enables the gain of a tube to be varied by variation of the grid bias voltage over a large range of values.

By deriving this bias from a circuit which makes its value dependent on the signal strength of a received carrier wave, the gain of a receiver may be kept reasonably constant for relatively large changes of signal input to the receiver.

The application of this principle to radio receivers enables the effects of fading to be considerably minimised.



Q. 5, Fig. 1.

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