The Telecommunication Journal of Australia

Vol. 2, No. 5 | Registered at the General Post Office, Melbourne, for transmission by post as a periodical. | OCTOBER, 1939

CONTENTS

THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

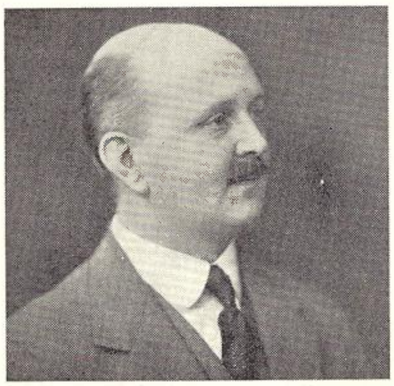
The
Telecommunication Journal of Australia

Vol. 2, No. 5 *OCTOBER, 1939*

SIR HARRY BROWN

K.B., C.M.G., M.B.E., M.I.E.E.

In our June, 1938, issue we had the pleasure of congratulating Sir Harry Brown when he was honoured by His Majesty with the title of Knight Bachelor. In this issue we speak with equal feeling, but in less happy vein, for we of the Australian Post Office now have to say farewell,



at least Departmentally, to one who has been our Chief and our friend for some 15 years.

We feel that every officer of the Department is conscious of the debt which the Australian Post Office owes to Sir Harry, who has done so much to raise its efficiency and enhance its prestige. He did not spare himself—in fact, no officer of the Department has worked harder nor with greater consideration for his officers, all of whom he insisted on regarding as his colleagues in a common enterprise. The splendid spirit of co-operation which he fostered throughout the Service is perhaps his greatest achievement, and he will be remembered for his personal influence in the many activities of the Department.

Appreciation of his ability and his courtesy extends beyond this Department, and the reputation which he has established for the Post Office as a business organization, and for himself as its Chief Executive, is ample evidence of the regard in which he is held by the business community of Australia.

While we regret his going, we are not unmindful of the years of unselfish and successful endeavour which he gave to the Post Office, and all members of this Society will join in extending to Sir Harry their best wishes for success and happiness in the future.

MR. D. McVEY, A.M.I.E. (AUST.)

The Society extends its congratulations to Mr. D. McVey on his appointment as Director-General of Posts and Telegraphs.

To many members of this Society, Mr. McVey is already well known. Born in Scotland in 1892, he arrived in Australia as a youth, and after a short period on the land in Queensland qualified

as a Cadet Engineer. He served in the Great War from 1915 to 1919 and then took up duty as a Cadet Engineer in Brisbane, and eventually rose to the position of Metropolitan Lines Engineer. In 1927 and 1928 he was a member of the Lines Committee which reported on line plant and conditions in all States of the Commonwealth. In 1930 he was appointed Assistant Superintendent of Mails in Sydney, becoming Superintendent in 1933.

He was appointed by the Government in 1937 to the position of second Assistant Commissioner of the Public Service Board in Canberra, and when the National Insurance Commission was formed in 1938 he was appointed Second Member. In 1939 the Government appointed him Chief Administrative Officer of the newly created Supply and Development Department, as Permanent Head of which he has already demonstrated his capacity as an organizer.

Mr. McVey's charm of manner, his honesty of purpose and his broad views have already won for him the friendship of those amongst whom he has worked and lived. We are sure that he will continue to win friends in his new position, and all members of this Society will join in assuring him of their loyal co-operation in carrying out the work of the Department.

THE SYDNEY-NEWCASTLE-MAITLAND CABLE - PART 1.

C. J. Griffiths, M.E.E., A.M.I.E.E., A.M.I.E. (Aust.)

Introduction. This paper is the first of a series dealing with the following aspects of the installation of the Sydney-Newcastle-Maitland Cable:

General Design.
Installation of the Cable.
Equipment.

Under the heading of General Design, it is proposed to outline the development of the existing open-wire route in so far as it influenced the consideration of cable schemes, to set out the salient factors which determined the provision of a cable, to survey the specification requirements and choice of system, and to describe the main features of the system being installed.

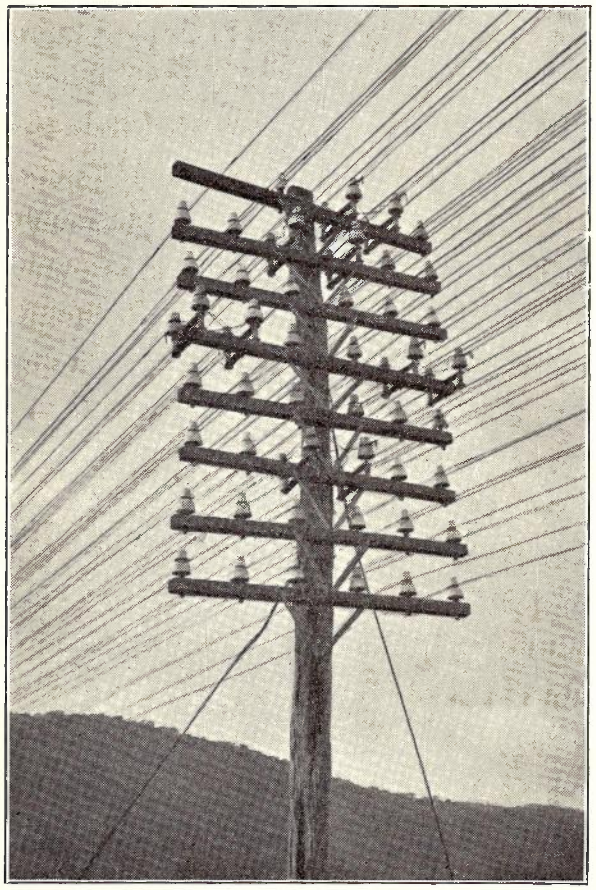


Fig. 1.—Typical pole on open-wire route, Sydney-Newcastle-Maitland.

Historical. The existing open-wire pole route along the railway line was erected over 30 years ago (a typical pole is shown in Fig. 1) and up to 1924 the circuit development was met solely by the erection of copper wires either 100 H.D.C. or 200 H.D.C. At this stage no further arms could be added owing to the limitations of pole height, and consideration was given to the provision of an underground cable to replace the open-wire route, the cable proposed being a loaded 100 pair/40 lb. multiple twin between Sydney and Newcastle and a loaded 50 pair/40 lb. between Newcastle and Maitland. The cable was to be laid mainly along the railway line in wood troughing 6 ins. x 4 ins. inside and supported on 6 ins. x 6 ins. x 4 ft. concrete pegs 15 ins. above ground level. The proposal was the subject of a Public Works Committee examination and report dated 13th June, 1924, and in this report the Committee recommended that the scheme be put in hand as soon as possible. However, late in 1924 the extensive use of carrier systems on open-wire lines, commenced by the A.T. & T. in 1918, had reached the stage of serious consideration in its application to Australian conditions. The Sydney-Newcastle-Maitland open-wire route was the subject of examination by A.T. & T. transposition engineers and, as a result, a scheme was developed and applied in 1928 which provided for the operation of eight three-channel carrier telephone systems. In 1932, because of traffic congestion on the main railway route, the old telegraph route from Sydney to Maitland via Wiseman's Ferry was modified to provide four pairs suitable for three-channel carrier telephone systems. By 1936, fourteen three-channel telephone systems working to 30 kc./sec., a programme carrier system working 34 to 42.5 kc./sec. and a telegraph carrier system working to 10 kc./sec. were in use on the route. The carrier system operating capacity of the route was thus seriously overtaxed, and the early consideration of cable provision or a major reconstruction of the open-wire route was essential to provide satisfactorily for the heavy future development.

Circuit Development. The first step preparatory to an examination of the economic factors involved was a detailed examination of the circuit development involving telegraph, telephone and programme channels, and including the determination of operating characteristics, particularly the question of two-wire and four-wire operation of the telephone channels.

The expected circuit development over a 20-year period from 1938 is set out in Table I., and in the case of the telephone channels shows an increase of slightly more than 100 per cent. in the 20 years. In comparison with English and Continental practice, this figure is conservative, but development conditions are so closely related to tariff rates, the extent of circuit provision in relation to the demand, and other local conditions that direct comparisons tend to be misleading. The higher development rate tendencies for similar conditions overseas were a factor which necessarily weighed as an important advantage of the carrier-on-cable system with its greater flexibility in circuit provision.

Economic Considerations. The three main factors which enter into the consideration of open-wire route replacement by underground cable are the demand for circuit facilities, transmission standards and grade of service, and the combination of capital costs and annual charges. The influence of each of these factors depends largely on the circumstances of each particular case, but in the present initial stage of trunk cable development in Australia the demand for circuit facilities and the capital costs are the basic factors. Practically without exception, the erection of all main open-wire routes throughout the Commonwealth dates from a period when voice-frequency telephone and sub-audio telegraph operation were the only requirements and the transposition pattern and pole spacing were designed accordingly. Up to a point, depending upon the number of pairs on the pole line and the coupling conditions between the voice frequency circuits, it has been found practicable to add a proportion of carrier systems without material additional expenditure on the lines. However, a stage is reached where no further carrier systems can be added without seriously degrading the crosstalk requirements, and it is necessary to consider carrier retransposing, wire respacing and pole respacing on the open-wire line or the provision of underground cable. It is at this stage that the capital costs associated with the aerial route become comparable with those on the cable system. Carrier retransposing of the Sydney-Newcastle-Maitland Route was carried out in 1928 as an alternative to providing underground cable. At the 1936 stage, when the limit of carrier system operation was reached, it was necessary to consider complete reconstruction and further extensive transposing of the existing route (apart from carrier system "saturation" the age of the route necessitated extensive reconstruction) as the alternative to underground cable. Apart from capital costs on the open-wire route of the same order of magnitude as on the cable system, the comparison of all costs on the basis of the Present Value of Annual Charges showed a large saving on the cable scheme. In addition, the latter offered definite advantages from the point of view of transmission standards and grade of service.

TABLE I.
SYDNEY-NEWCASTLE-MAITLAND CABLE — CIRCUIT DEVELOPMENT

Circuit	Telephone				Telegraph				Programme			
	1938	1943	1946	1958	1938	1943	1946	1958	1938	1943	1946	1958
Sydney-Maitland	6	8	9	15	2	2	3	4				
Sydney to beyond Maitland	42	53	66	105	3	3 (Note 1)	3	4	3	4	4	5
Sydney-Newcastle	31	40	49	72	1 3	1 3 (Note 2)	1 4	2 6	2	3	3	3
Sydney-Brooklyn	3	4	4	6								
Sydney-Woy Woy	7	9	10	18								
Sydney-Gosford	12	17	20	33								
Sydney-Wyong	4	5	6	11								
Gosford-Newcastle	3	3	4	7								
Wyong-Newcastle	2	2	3	4								
Swansea-Newcastle	4	4	6	9								
Belmont-Newcastle	4	5	7	10								
Newcastle-Maitland	12	18	21	37	2	3 (Note 3)	4	5	3	4	4	5
Newcastle to beyond Maitland	22	26	32	52								
Intermediate Stations between Sydney and Maitland	16	17	18	24								

Note 1.—Including one special broad band channel for the existing Type B, O.W. telegraph carrier system.
Note 2.—D.C. omnibus telegraph circuits.
Note 3.—D.C. telegraph circuits.
Note 4.—Except where otherwise referred to, telegraph development figures refer to voice-frequency telegraph systems.

Table I.—Circuit development.

Specification Requirements for the Cable

With the rapid developments taking place overseas in the application of carrier to underground cable systems, as well as the question of the relative merits of star quad and multiple twin cable, there was every advantage in preparing the specification in the form of requirements to be met, rather than detail the requirements of a particular system or systems. Based on this arrangement, the important sections of the specification provided for the following:—

Alternative Tenders: In addition to any other tender submitted, a tender was required for a carrier-on-cable system and each tender was to provide for the two main alternatives: (a) the supply and delivery of the material, and (b) the supply, delivery and supervision of the installation. Further alternatives were associated with the circuit development, unarmoured and armoured cable, pure lead and alloy sheath and loading coil types.

Circuit Development: Details of broadcast programme channel, telephone and telegraph circuit requirements at 1938, 1943, 1946 and 1958 were provided. Alternative cable sizes were required to provide for the 1946 and 1958 development and loading coil pots and equipment offers for the 1943 development.

Telephone Circuit Transmission Requirements

Attenuation v. frequency: The variations from a reference axis at 800 cycles/sec. were not to exceed the following limits:—

Frequency band width	Variation
400-2400 c.p.s.	2 db.
300-2500 c.p.s.	3 db.

Transmission equivalent: All intermediate telephone circuits other than between Sydney and Newcastle were to be operated at an equivalent not greater than 6 db. and permit a reduction of the attenuation by 3 db. without causing singing. The Sydney-Newcastle, Sydney-Maitland and telephone circuits extended beyond Maitland were to be operated at zero equivalent.

The equivalent of a circuit was to be the same in both directions with a maximum tolerance of 2 db. at 800 cycles/sec.

Broadcast Programme Channels

Attenuation v. frequency:

Variation from reference axis (800 c.p.s.)	Minimum band width.	Lower point on curve to be below.	Upper point on curve to be above.
Decibels	Cycles/sec.	Cycles/sec.	Cycles/sec.
1	5,000	100	5,000
2	6,000	50	6,000
3	10,000	35	10,000

Transmission equivalent: With an input power level between 6 milliwatts and 10 db. below that level, it should be possible to deliver into a 600 ohm line a power level 2 db. above 6 milliwatts at the output of the channel.

Telegraph Channels: The channels required for hand speed and start stop printer equipment were to be capable of transmitting with not greater than 25 per cent. distortion, speeds up to 50 bauds.

Crosstalk: The guaranteed limits between channels were to be stated.

Route details: The plan and descriptive details of the route conditions included existing conduits, river crossings and nature of country on steel tape armoured cable sections, and the route proposed involved 75,361 yards of unarmoured cable in conduit, 136,646 yards of steel tape armoured cable and 2,884 yards of submarine cable. On the armoured cable sections alternative prices for unarmoured cable were required to permit an economic comparison to be made between armoured cable laid direct in the ground and unarmoured cable drawn into ducts.

Cable Systems: Apart from a general clause permitting special designs to be offered, the following systems were specifically provided for:—

Multi-core cable loaded for voice frequency operation only.

Multi-core cable loaded for voice frequency operation and with single channel carrier superimposed.

Multi-core unloaded cable for voice frequency operation and with direct repeatered open wire type carrier systems superimposed.

Multi-core unloaded cable with special cable type carrier systems.

Cable Types: Depending on the cable types proposed, the following specifications were required to be adhered to:—

Australian Specification 460	Multiple Twin.
British Post Office Specification 448	Star Quad Trunk.
British Post Office Specification 465	Star Quad Trunk type containing Screened Pairs.
Relevant B.P.O. Specification (Now C.W.61)	Carrier-on-Cable type.
British Post Office Specification 494	Steel Tape armouring.

Alternative prices were required for a pure lead sheath and a sheath containing 1 per cent. antimony.

Loading Coils were required to comply with Australian Specification 704, alternative quotations being submitted for manhole and for buried type pots on the armoured cable sections.

Equipment. — General: The initial equipment was to be capable of extension to meet 1958 circuit requirements and consideration was to be given to the extension over the cable of the existing open-wire carrier systems as an alternative to the transfer of the terminals of this equipment to Maitland. Vertical racks 10 ft. 6 ins. in height and 19 ins. in width were to be used.

Signalling: The existing system of signalling provides for 17 cycles/sec. signalling over certain shorter trunk lines, and 1,000 cycles/sec. over all carrier channels and the longer trunk lines, with dialling impulses transmitted over sub-audio channels. When automatic trunk exchanges are eventually installed at Sydney and Hamilton, the change-over to a two-frequency dialling system was to involve minimum alteration to equipment. The signalling equipment was required to respond to the application of ordinary 17 cycles/sec. ringing current applied at the V.F. input, and provide a similar frequency at the V.F. output. Dialling facilities were required to enable certain circuits under 300 miles in length to be used for dialling into the Sydney automatic exchange network from the distant stations, such channels to be equipped also with ringing facilities in both directions.

Power Supply: Provision for the connections from the power supply mains and the erection of a primary power switchboard panel were to be made by the Department. All the remaining equipment including batteries, battery charging equipment, distribution panels and standby supplies was to be provided by the tenderer. Preferably the standby plants were to be brought into operation automatically on the failure of the mains' supply.

Testing Equipment: Although particular requirements would be determined largely by the cable system offered, certain items were specifically required. These were an oscillator (35-10,000 cycles/sec.), volume indicator, attenuator, telegraph distortion measuring set, and trunk test boards at Sydney, Hamilton and Maitland, and a volume indicator, attenuator and trunk test boards at intermediate repeater stations.

Guarantees were required to include:—

Attenuation v. frequency characteristics.

Maximum allowable power levels.

Interchannel crosstalk.

Noise interference.

Overall equivalent.

Volume range (programme channel).

Maximum signalling speed (telegraph channels), and times were required for the delivery and laying of cable, the delivery of equipment and the installation and testing of the complete installation ready for cutover.

Choice of System

The tenders received covered the following types of systems:—

Trunk type star quad containing screened pairs.

25 lb. per mile 16 mH. loaded at 3,000 feet—Broadcast Programme channels.

25 lb. per mile 88 mH. loaded at 6,000 feet—2-wire voice frequency.

25 lb. per mile 22 mH. loaded at 6,000 feet—4-wire voice frequency and single channel carrier (lower side-band of 6 kc/sec.).

Terminal amplifiers at Sydney and Hamilton or Maitland and intermediate repeaters at Gosford.

Carrier type star quad: 40 lb. per mile unloaded with 12-channel carrier systems operating at 4 kc./sec. carrier spacing over the range 12 to 60 kc./sec.

Separate trunk type star quad cables loaded with 88 mH. at 6,000 feet used to provide for short distance intermediate circuits. Repeater stations required at 5 intermediate points between Sydney and Hamilton.

Carrier type star quad: 40 lb. per mile unloaded with 9 and 17 channel carrier systems operating at 8 kc./sec. and 4 kc./sec. carrier spacing respectively over the range 8 to 72 kc./sec.

Side-circuits and phantoms of spare pairs and phantom circuits of carrier pairs to be used at voice frequencies for short distance intermediate circuits. Repeater stations required at 5 intermediate points between Sydney and Hamilton.

Carrier type star quad: 16 to 36 lb. per mile (depending on length of repeater section) unloaded with 12-channel carrier systems operating at 4 kc./sec. carrier spacing over the range 12-60 kc./sec.

Repeater stations required at 5 intermediate points between Sydney and Hamilton.

Carrier type star quad: 16 to 36 lb. per mile (depending on length of repeater section) unloaded with 16 channel carrier systems operating at 3 kc./sec. carrier spacing over the range 12-60 kc./sec. Repeater stations required at 5 intermediate points between Sydney and Hamilton.

Composite conductor and composite type cable with voice-frequency, single channel and three channel carrier systems.

50 lb. per mile screened pairs 16 mH. loaded at 3,000 feet—Broadcast Programme Channels.

20 lb. per mile multiple twin 88 mH. loaded at 6,000 feet—2-wire voice frequency circuits.

50 lb. per mile multiple twin 22 mH. loaded at 6,000 feet—4-wire voice frequency and single channel carrier (lower sideband of 6 kc./sec.).

50 lb. per mile twin 6 mH. loaded at 6,000 feet—three-channel carrier (upper sidebands of 4, 8 and 12 kc./sec.).

Terminal amplifiers at Sydney and Hamilton or Maitland and intermediate repeaters at Gosford.

Such a wide variety of cable and equipment types necessitated a close study in which the more important comparisons required to be considered were:—

(i) Voice-frequency and single channel carrier systems or voice-frequency, single and three channel cable carrier systems v. a full carrier-on-cable scheme involving nine channels and upward superimposed on unloaded cable pairs.

(ii) The relative merits of the various carrier-on-cable types.

(iii) Unarmoured cable in ducts v. steel tape armoured cable.

(iv) Lead-antimony v. pure lead sheath.

To provide a reasonable comparison between widely differing systems, each individual scheme concerned was the subject of detailed costing on the basis of Present Value of Annual Charges including capital costs, maintenance and depreciation, for a 20-year circuit development period. Arising from this examination, an order was placed on 4/4/38 with Philips Lamps (A'asia.) Pty. Ltd. for the supply, delivery and supervision of the installation of a 9-17 channel carrier-on-cable system, the cable and 30 per cent. of the equipment to be manufactured by Siemens Bros. & Co. Ltd., Woolwich, and 70 per cent. of the equipment by N. V. Philips, Eindhoven, Holland. In the following paragraphs some essential features of the cable and equipment respectively will be outlined. More complete details will be included in the subsequent papers in this series.

Feature of Cable Installation

Route Details: Simultaneously with the consideration of tenders, detailed examination of the existing surveyed route and possible alternatives were being investigated. As a result, an important alteration to the route as set out in the specification was made between Kangaroo Point on the south bank of the Hawkesbury River and Gosford. The original route closely followed the Pacific Highway through one of its most hilly sections, and it was feared that continual alteration to the road alignment would be a constant hazard to the cable system. The alternative route adopted passed through Brooklyn, across the Hawkesbury River via Dangar Island, to Patonga Peninsula and Woy Woy, and although it involved a longer submarine cable crossing of the Hawkesbury River, was shorter

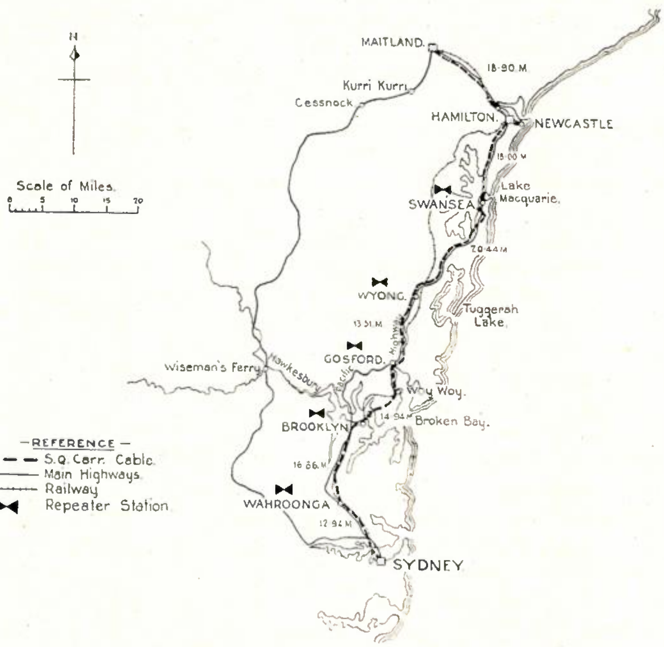


Fig. 2.—Plan of cable route.

and considerably less liable to subsequent disturbance. The final layout including the location of repeater stations is shown in Fig. 2. In this layout, existing conduit was available between Sydney and the Hawkesbury River, but from Wahroonga north alterations to the Pacific Highway either already completed or contemplated, the danger of creepage of cable in unarmoured pipe on hilly sections and possible savings in cable lengths by diversions from the Highway, resulted in 9.22 miles of the distance of 16.86 miles between Wahroonga and Brooklyn being provided with steel tape armoured cable.

From Brooklyn north, except for lengths of conduit at Woy Woy, Gosford, Wyong, Swansea, Belmont, Charlestown, Hamilton and Maitland, steel tape armoured cable laid directly in the ground is used. In the total route mileage of 115.59 miles, 32.67 miles is unarmoured cable in conduit, 80.55 miles armoured cable, and 2.37 miles submarine. Some idea of the nature of the country to be traversed is given by the estimated quantities of excavation of different types, namely:—

	c. yds.
Excavating equipment and ploughing—sand and clay	18,000
Pneumatic drills—mixed rock and hard clay	2,500
Requiring explosive—rock	4,500

The Cables ("Go" and "Return") are 12 quad 40 lb. special carrier type star quad in accordance with B.P.O. Specification 598 (now CW61). The make-up is similar to trunk type star quad, the essential differences being a lower mutual capacity (nominal 0.057 microfarads per mile) and mutual capacity deviation and lower capacity unbalance limits as well as the addition of limits for the mutual impedance, a requirement which necessitates a different stranding lay for each quad. Steel tape-armoured cable is used over the greater part of the route; for severe grades on land sections and easy submarine cable crossings, a light 0.128 in. diameter steel-wire armoured cable is provided. For severe submarine cable crossings such as the Hawkesbury River and Sydney Harbour, a special rubber-protected, 0.272 in. diameter heavily wire-armoured cable is used. Cross-sections of these types are shown in Fig. 3, and the lengths involved in the complete work, including spare cable, are:—

Unarmoured, 119,360 yds.
Steel tape armoured, 289,039 yds.
Light steel wire armoured, 3,780 yds.
Heavily steel wire armoured, 9,373 yds.

The first three types have an inclusion of 0.85 per cent. antimony in the sheath, whilst the heavily armoured submarine cable sheath consists of a ternary alloy of lead, tin, cadmium.

The cables are supplied in drum lengths of 203 yards on steel tape armoured sections, the drums being 4 ft. 4 ins. diameter x 2 ft. 1 in. wide and weighing 18 cwts., and 176-200 yards on unarmoured cable sections, the drums being 3 ft. 9 ins. diameter x 2 ft. 4 ins. wide and weighing 11-12 cwt. Four such drum lengths form a Primary jointing Group, four of which in turn form a Secondary Group. Depending upon the length of the Repeater Section, two, three or four Secondary Groups form a Quarter Repeater Section, four of which form the completed repeater section. The layout of a typical repeater section is shown in Fig. 4. The longest submarine crossings are at Sydney Harbour and the Hawkesbury River, and require lengths of 760, 800 and 1,300 yards, involving drum dimensions of 8 ft. 9 ins. diameter x 4 ft. 7 ins. wide, and approximately 9 tons for the two former, and 9 ft. 7 ins. diameter x 5 ft. 3 ins. wide and 15 tons for the latter.

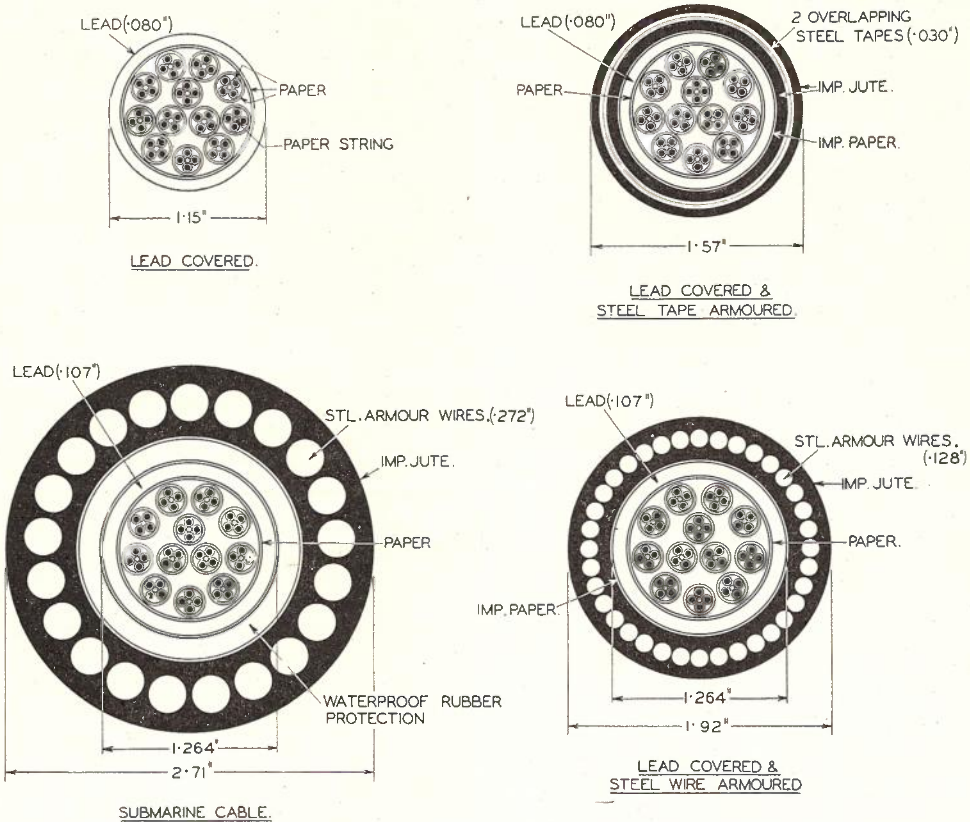


Fig. 3.—Cable cross-sections.

Each drum length is factory tested for:—

Capacity unbalance: (within quad) at 1 kc./sec.	Side to side. Phantom to side. Side to earth.
Mutual capacity at 1 kc./sec.	
D.C. conductor resistance.	

and selection sheets for the jointing within the Primary Groups based on these factory tests form portion of the contract. As these joints represent approximately three-quarters of the total joints, a considerable proportion of the field testing is saved by this arrangement. In this selection it is necessary to take into account all three of the electrical characteristics referred to above. Apart from the reduction of capacity unbalances, it is necessary to keep the resistance unbalance low on account of its increased influence on crosstalk characteristics at high frequencies. Mutual capacity deviations require to be kept to small values as far-end crosstalk arising from reflected currents occurring at such irregularities is not susceptible to neutralization by networks. Field tests on Primary Groups are similar to those made on the individual drum lengths and the selection procedure is also similar.

Field tests on Secondary Groups consist of 1 kc./sec. tests of capacity unbalance within quad on all combinations for side to side, side to earth and phantom to side conditions and mutual capacity at 1 kc./sec. Distant-End Admittance Unbalance is measured at 60 kc./sec. within quads, between adjacent quads and between a limited number of non-adjacent quads. For Quarter and Whole Repeater Sections, Distant End Admittance Unbalance tests at 60 kc./sec. are made on all combinations. (Admittance Unbalance — y — is the generalized unbalance in which leakance as well as capacitance is taken into account where $y = g + jwc$.)

In addition to the reduction of far-end crosstalk by field tests, a further reduction is obtained by the use of neutralizing or balancing networks at the receiving end of each repeating section.

The guaranteed overall repeater section characteristics of the cable are as follows:—

Insulation Resistance ...	10,000 megohms per mile	
Impedance	at 5 kc./sec.	181 ± 9 ohms
	at 60 ,,	140 ± 7 ohms
	at 72 ,,	140 ± 7 ohms
Attenuation	at 5 kc./sec.	1.25 db./mile
	at 60 ,,	2.8 db./mile
	at 72 ,,	3.1 db./mile

Far-end crosstalk	5 to 72 kc./sec.	12 to 60 kc./sec.
90% of all combinations	65 db.	70 db.
All combinations (after adjustment of balancing networks)	60 db.	65 db.

Near-end crosstalk	30	40	60	72 kc./sec.
95% of all combinations				
Same cable	56	53	50	47
Different cable	—	—	135	135
All combinations—				
Same cable	53	50	47	44
Different cable	—	—	125	125

Near-end crosstalk between pairs in the same cable has only an indirect effect on the overall crosstalk characteristics insofar as such near end crosstalk is reflected at impedance irregularities formed by the equipment or by cable conditions, and appears eventually as far-end crosstalk. The far-end balancing networks in themselves tend to degrade near-end crosstalk conditions, thus further necessitating a high degree of impedance matching between the cable and equipment. From random measurements made on the first completed repeater section (Gosford to Wyong) the guaranteed far-end crosstalk values are being appreciably improved even without the addition of the balancing networks.

Supplementary Cables: Simultaneously with the installation of the main cables, provision is being made for the under-grounding of a number of short mixed trunk and subscribers' open-wire routes. By using the same excavation, a considerable saving in the installation cost is possible—the excavation and filling-in costs in laying an armoured cable of the type concerned represent approximately 60 per cent. of the total installation cost. Details of the auxiliary cables, all of which are of local type star quad manufacture (B.P.O. Specification 569) and subject to limited capacity balancing within quads during installation, are as follows:—

Section	Length (yards)	Size
Brooklyn-Kangaroo Point	4,030	28, 38, 54 & 74 pr. 10 lb.
Woy Woy-Gosford (Sydney to Woy Woy circuits are extended through this cable from Gosford.)	9,738	54 and 74 pr. 20 lb.
Gosford-Ourimbah	4,373	54 pair 10 lb.
Ourimbah-Wyong	4,248	54 pair 10 lb.
Wyong-Johns Road	3,610	38 pair 10 lb.
Swansea R.S.-Swansea (Newcastle to Swansea circuits are extended through this cable.)	5,120	38 pair 10 lb.
Mark's Point-Belmont	2,010	38 pair 10 lb.
Adamstown-Charlestown	4,445	38, 54 & 74 pr. 10 lb.
Waratah-Hexham	12,598	28, 54 & 74 pr. 20 lb.

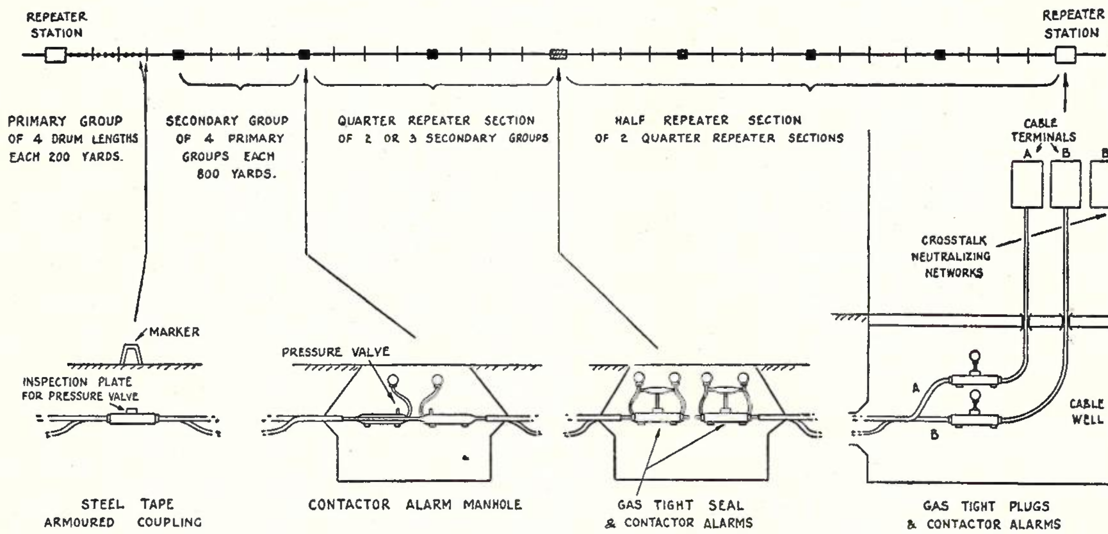


Fig. 4.—Schematic layout of a typical repeater section.

Essential Features of the Equipment

The frequency allocation of 5-72 kc./sec. adopted was determined primarily by the maximum attenuation of the longest repeater section in relation to the requirement that the transmission level should not fall more than 60 db. below a reference volume of 6 mW. speech power. The attenuation at 72 kc./sec. is approximately 3.1 db. per mile, and allowing for a normal transmitting level of 6 db. above the 6mW. reference level, the maximum permissible repeater section length approximates 21 miles. The expected transmission levels (at 72 kc./sec.) are shown in Fig. 5, and the cable attenuation and equalizer characteristics are set out in Fig. 6. The choice of repeater sections necessarily represented a compromise between the ideal "attenuation" layout and the availability of suitable locations along the route in relation to existing sites, buildings, maintenance facilities, power supply and traffic outlet requirements. For maintenance and fault alarm design, Sydney and Maitland are designated terminal stations, Hamilton (Newcastle) a terminal and repeater station, Wahroonga and Gosford attended repeater stations, Wyong a partly attended repeater station and Brooklyn and Swansea unattended repeater stations. Brooklyn alarms are extended to Wahroonga and Swansea alarms to Hamilton.

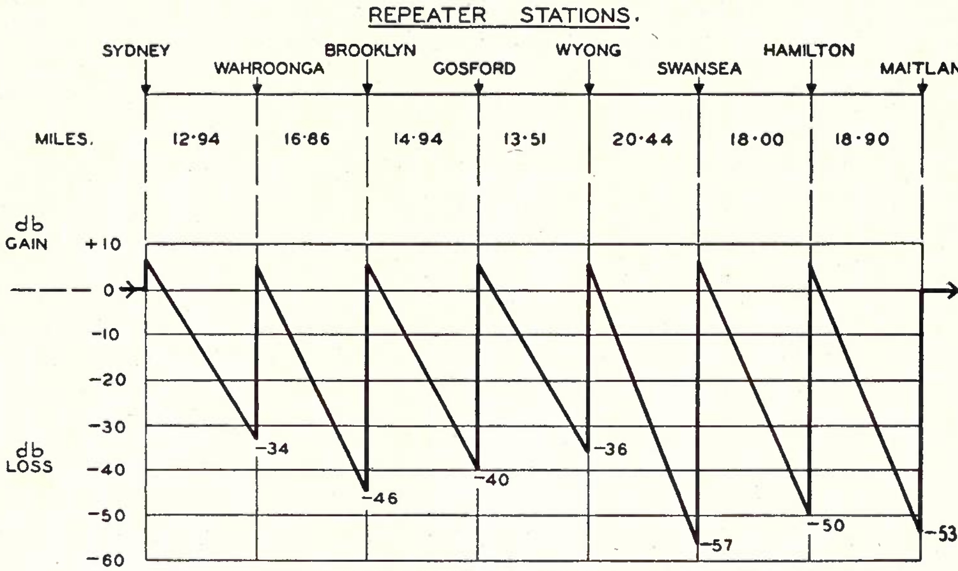


Fig. 5.—Power level diagram.

At Belmont, voice frequency circuits Belmont-Newcastle are led out of the cable—this is the only point intermediate between repeater stations at which such an arrangement is adopted. Only a few circuits are involved and the necessity for providing a separate voice-frequency cable is obviated by this arrangement.

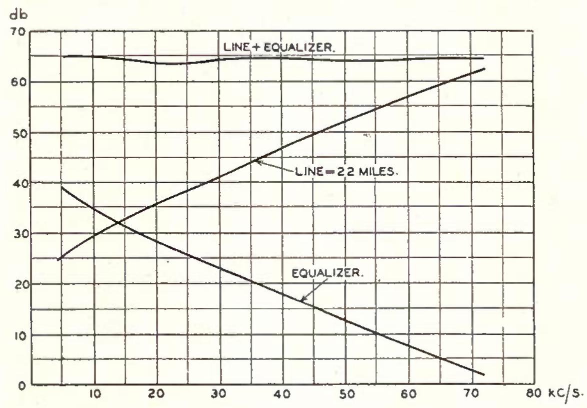


Fig. 6.—Cable attenuation and equalization.

The attenuation of the cable is subject to change with temperature conditions and to prevent a corresponding change in the overall attenuation characteristics, automatic temperature control equipment is used. Investigations of records of soil temperature in Australia showed that variations of the order of 3 deg. C. daily, 6 deg. C. weekly and 20 deg. C. seasonally for a depth of 12 ins.-18 ins. in the ground are not likely to be exceeded. The method adopted is to make a phantom circuit in the cable one arm of a Wheatstone bridge and consequent upon a variation of temperature and consequently resistance, the bridge is unbalanced, a Weston "Sensitrol" relay circuit is actuated and an appropriate adjustment made to a variable attenuator at the receiving end. By this means the overall attenuation of any channel may be maintained within $\pm$ 1 db.

The carrier frequencies of the system are spaced 4 kc./sec. apart from 8 to 72 kc./sec., the lower side-band being transmitted and the "Go" and "Return" channels forming the 4-wire circuit segregated in separate cables. The carrier is normally suppressed. Eleven of the systems in the initial installation provide for nine channels, and five for 17 channels. In the 9-channel system, the alternate carrier frequencies 8, 16, ... 72 kc./sec. are used, enabling considerable simplification and reduction in cost of the filter and modulator design. As traffic increases, the 9-channel system is capable of extension to 17 channels by modification of the band pass filters and modulators and the extension of the carrier supply bay. A schematic layout of the main items of equipment is given in Fig. 7, and a line chart showing the method of provision of the circuit requirements is given in Fig. 8.

Using a special multi-vibrator circuit, the carrier supply for all channels is fed from a common oscillator group controlled from a master oscillator at one end of the circuit. A low level current of 4 kc./sec. is transmitted over the cable for synchronizing purposes.

Ringing and dialling are provided by transmitting pulses of carrier current, the circuit being so arranged that signals can be transmitted simultaneously from both ends without mutual interference.

Two-stage back-coupled amplifiers for each direction of transmission and with a maximum gain of 65 db. are used at repeating stations. For an output power of 1 watt, the proportion of harmonics in the output is less than 0.03 per cent. over the working range. The only gain adjustment consists of attenuating networks as-

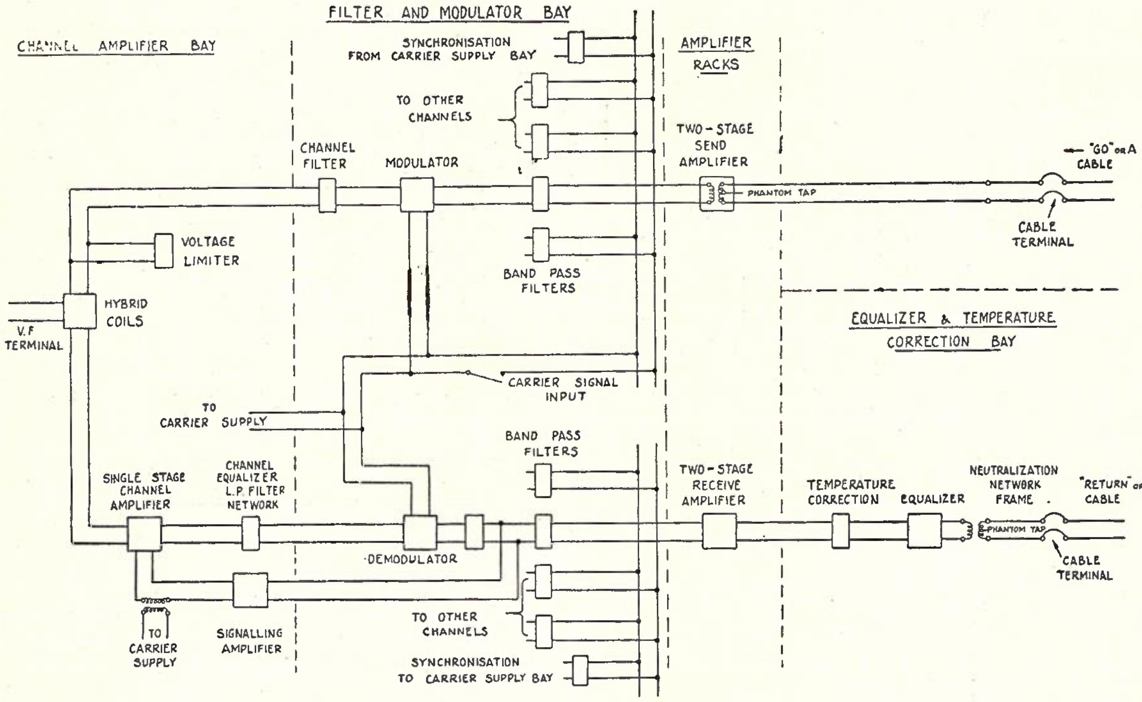


Fig. 7.—Schematic layout of equipment.

sociated with the equalizers, and these are soldered in position after the initial adjustment, when the automatic control takes over. The noise level at the output of the repeater is less than 1.5 mV. for the whole frequency range—only slightly above the theoretical value due to electron noise.

The transmitted band for a telephone channel is practically flat from 250 to 3,200 cycles/sec. and the total harmonic content will be less than 5 per cent.

In certain cases of small circuit groups such as between Sydney and Wyong, Newcastle and Swansea, "dropped" channels are obtained by installing band pass filters up to the number of channels required and appropriate modulators, demodulators and oscillator group. It is not practicable to synchronize the latter with the 4 kc./sec. pilot frequency, and a special designed oscillator with a high degree of stability has been provided for at these points.

Most of the telegraph channels are provided by voice-frequency telegraph systems superimposed on telephone channels. The frequencies are generated by valve oscillators and nine telegraph channels are provided per telephone channel. For the shorter hand-speed telegraph circuits, sub-audio operation on a pair in the cable is used.

Programme channels are provided by replacing the band pass filters on two neighbouring channels on the 9-channel system and three neighbouring channels on the 17-channel system by one broader band pass filter. The expected signal to noise ratio, taking into account noise due to terminal equipment, line amplifier noise, cable crosstalk and noise from sources exterior to the cable, is 71 db.

All telephone channels will accept speech in which the peak levels are 6 milliwatts and the maximum sending level on each voice-frequency telegraph channel is 0.2 mW. at a point of zero reference level.

Power supply will involve 4 volts A.C. to the filaments and 200 volts rectified A.C. for the anode supply. In the event of mains supply failure, diesel-electric generators step in automatically. Should the diesel generator fail to start, a small installation operating from a 200 volt battery normally floating across the output of the 200 volt rectifier will step in and maintain the repeating equipment in operation for approximately three hours, and at the same time permit steps to be taken to bring alternative reserve measures into operation.

Protection: As this cable forms the main link not only between Sydney and Newcastle, but between the Southern and Northern sections of the eastern portion of the Commonwealth, particular attention has been paid to minimizing the possibility of interruption due to cable failures. The most probable sources and types of damage are:—

Mechanical damage—road alterations.

Mechanical damage — itinerant excavators (picks, crowbars, test probes).

Mechanical damage—dislodgment of ground on steep slopes.

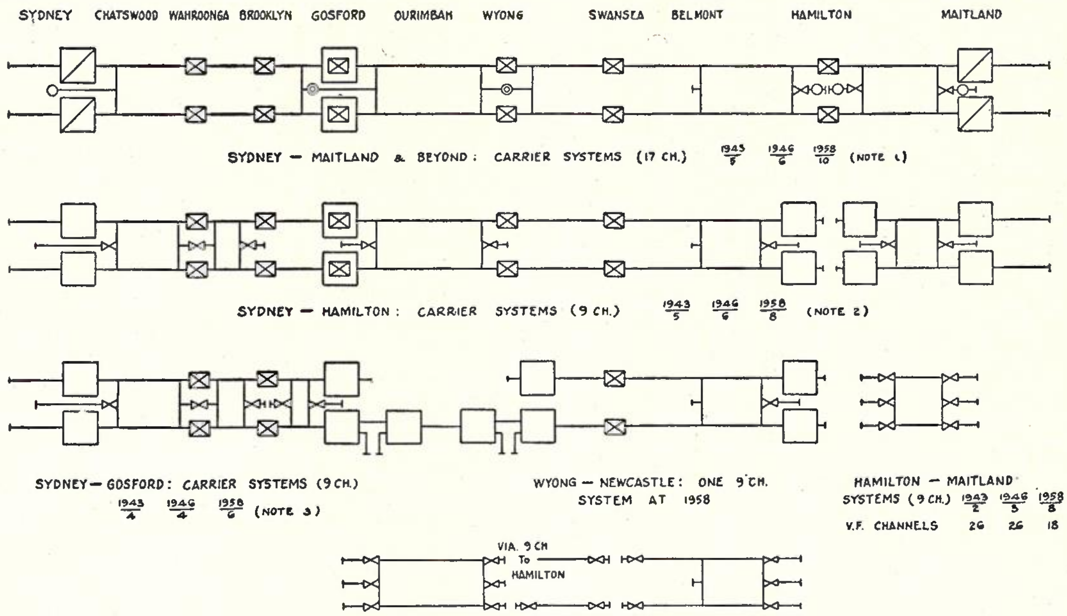


Fig. 8.—Arrangement of circuits.

NOTES.

1. At 1958, 10 "dropped" channels are provided at Hamilton from one 17 channel system.
2. One system terminates at Chatswood.
3. One system is extended to Hamilton and used for "dropped" channels at Gosford and Wyong.
4. Symbols:—
   - Two one-way carrier line amplifiers without temperature control.
   - Two one-way carrier line amplifiers with automatic temperature control.
   - Two one-way V.F. amplifiers.
   - Terminal Equipment 9 channel carrier system.
   - Terminal Equipment 17 channel carrier system.
   - Terminal Apparatus D.C. Telegraph Circuit.
   - Intermediate Apparatus D.C. Telegraph Circuit.
5. The initial installation provides for 1943 development.

Submarine cable failure.

Electrolysis.

(a) Stray traction current.

(b) "Long line" currents.

Chemical corrosion.

Precautions against mechanical damage consist essentially of:—

(a) Care in the choice of initial location for cable, including a study of road development proposals for 10 to 20 years ahead;

(b) Provision of a $2\frac{1}{2}$ in. galvanized iron pipe at main road crossings, under unmade channels, etc., where possibility of future disturbance is high;

(c) Provision of a concrete cover board, 4 ft. x 8 ins. x $1\frac{1}{2}$ ins., where the cable is adjacent to the road shoulder, under gateway entrances liable to future disturbance, etc.

On hilly sections of the route where washaway of the soil around the cable might occur, provision is being made for the concreting in of the cable and surface drainage of the water away from the cable trench. A special detailed maintenance inspection of such points is proposed in the first year following the completion of the installation. Apart from the foregoing, particular attention is being paid to the detailed plotting of the cable on suitable plans and the provision of markers at all jointing points and at all changes in direction of the line of the cable.

The submarine cables on which damage is most likely to occur are the Sydney Harbour and the two Hawkesbury River cables. In addition to the very heavy armouring and special protection adopted (see Fig. 3), adequate marking of the location is to be provided by suitable beacons at the landing points.

Insofar as electrolysis is concerned, the cable passes through stray traction current areas at both Sydney (tramways and railways) and Newcastle (tramways), and in both cases the cable is unarmoured in conduits. The length directly paralleling the traction systems is 19.5 miles, and it is expected that the traction influence will extend over approximately 25 miles altogether. Both the Sydney and Newcastle areas have been the subject of electrolysis surveys, and nine controlled drainage bond feeders to the traction systems have already been installed, and eight more have been designed and are in process of installation. It is expected that these measures will take care of stray traction current conditions. Outside the traction areas consideration has been given to the possibility of "long line" currents (set up by differences in soil conditions through which the cable passes) causing corrosion, as evidence of this trouble has been obtained on existing cables at Gosford and Wyong. To assist in this investigation and the design of suitable remedial measures, a soil resistivity survey using the Gish and Rooney method, and examination of chemical corrosion conditions have been made at regular intervals along the route of the cable.

In addition to the particular measures associated with the different forms of corrosion, provision has been made for the installation of a gas pressure alarm system. Briefly, each repeater section consists of two gas-tight cable sections ranging from 6-10 miles in length, depending upon the repeater section concerned. Each gas-tight section has 5 to 7 equally spaced contactor alarms, which operate a repeater station alarm through a pair in the cable when the normal pressure of 15 lbs./s.in. drops below 10 lbs./s.in. On steel tape-armoured sections, apart from the contactor alarms, pressure testing valves are installed at each cable coupling, the latter being fitted with an inspection plate to facilitate subsequent access to the valve when tracing faults. On unarmoured cable sections with manholes, valves are fitted as and when required.

Conclusion: In conclusion it is desired to express thanks to Philips Lamps (A/sia.) Pty. Ltd. for permission to use certain drawings in illustrating the paper, and to The Institution of Engineers, Australia, for the loan of blocks.

EDITOR'S NOTE:

In Part 2, Mr. W. ENGEMAN, A.M.I.E. (Aust.) will describe the installation of the cable.

SOFT SOLDERS, SOLDERING AND WIPING

G. O. Newton

PART II.

SOLDERING

General. One text book states that there are three rules which govern successful soldering and they are cleanliness, cleanliness and cleanliness. This largely sums up the requirements for good soldering. Clean and properly tinned bits with clean solder and clean surfaces which have to be soldered together with the use of the most suitable flux are the requisites of good soldering work. A good workman will also use the minimum of solder and flux necessary to give a neat and clean finish and operate at the temperature which permits the solder to run freely, and quickly wet the surface, and complete the operation in a minimum of time and labour. This applies whether one is making an electrical connection or performing a heavier soldering operation. Proficiency at the work is usually acquired very quickly with a little practice.

Wherever possible, it is advisable to tin (i.e., coat thinly with solder) joint members before the final soldering. It is naturally simpler to ensure perfect cleaning, fluxing and wetting of surfaces when the members are separate than when assembled. In those cases where the parts are separated by thousandths of an inch when joined, it ensures satisfactory soldering in the confined space. In such cases the solder follows the flux by capillary attraction, and a previous tinning ensures that it will take in all parts. In addition, in the case of copper and brass members at least it ensures stronger joints. (See Fig. 8.)

Recently the tinning of brass and copper parts ready for soldering has been replaced to a large extent by cadmium plating. Since manufacturers are preferring this practice it is evidently cheaper. So far, except where there is evidence of faulty workmanship in regard to the plating,

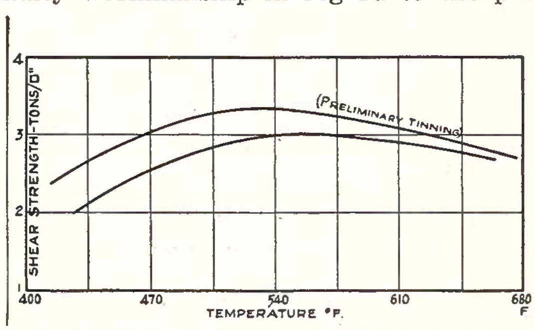


Fig. 8.—Variation in shear strength of copper joints with soldering temperature.

it has not proved inferior to the former practices. In view of the comparatively short period of trial and the facts that cadmium is a rare metal, and there is a very considerable call for its use for other purposes, at present it is perhaps unsafe to form an opinion in regard to the permanency of the practice.

Strengths of Joints. Fig. 9 shows a number of types of metal joints. (i) is the weakest since it depends solely on tensile strength over a very small cross-section. (ii) is one often used for butt seams in lead work, and is a slight improvement since there is a heavier section of solder. The strength of (iii) is dependent on the angle of the joint and the resultant combination of shear and tensile strengths. It is naturally a little stronger than (i) and (ii).

The remaining types of joints, however, are the most satisfactory from the aspect of strength, especially where there is considerable difference between the strength of the metal parts to be joined and the solder. In the case of these types it will be noticed that (except

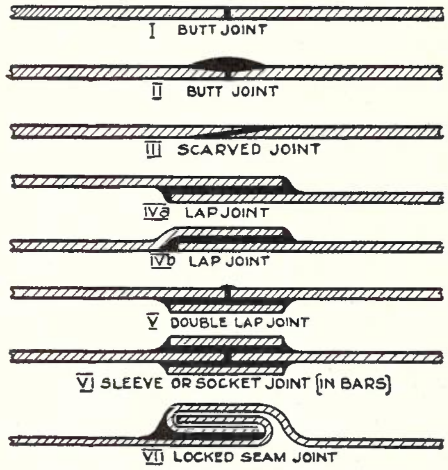


Fig. 9.—Types of soldered joints.

for the lock seam where the solder mainly makes the joint air- or water-tight and plays little part in the strength) the strength of the joint depends on the shear strength of the solder. For this reason all the discussion on strengths of joints will have reference to shear strengths. The fillets shown in the diagrams of Fig. 9 give increased strength to the joints, but care must be taken that they do not conceal voids in the solder in the confined space between the members.

The factors which enter into the strength of joints are:—

(i) Material of which joint members are made.
(ii) Constitution of solder.
(iii) Use of suitable flux to obtain complete wetting of surface and the removal of surplus flux after soldering where it is of the corrosive type.
(iv) Soldering temperature.
(v) Thickness of solder film between members.
(vi) Temperature at which joint exists in service.

The free use of solder gives no advantage as regards strength and, therefore, there is no necessity to use a greater amount than will adequately fill the joint. This also applies to electrical connections where strength is not a consideration, since it is only necessary to use sufficient to give an efficient electrical connection and any additional solder used is waste.

Prolonged contact between the joint members and the molten solder does not appear to affect the final strength of a joint to any extent except in the case of copper or copper alloys, where the tendency of copper to dissolve in and mix with the tin causes heavy alloying of surfaces, which has a weakening effect on the strength of the joint. Prolonged application of heat may cause the tin-rich portions of the solder to be drained away, and so bring about a weak joint due to the low tin content of the remaining solder.

Of the factors listed, (i) needs little comment, and (vi) should be self-evident, whilst (ii) and (iii) have been covered in previous discussion (see Part I.).

Effect of Soldering Temperature (iv.). Fig. 8 shows the effect of soldering temperature on the strength of copper joints with and without previous tinning. This shows that the optimum temperature is between about 520°-540° F. in the former case and between about 540° and 570° F. in the latter. The optimum temperature for most metals and for most grades of solder appears to be round about 540° F. With higher temperatures, except for extremely close joints, there is a tendency for joints not to fill with solder, apparently due to the fluidity being too great to obtain the capillary effect. Higher temperatures are necessary for extremely close joints to obtain the necessary fluidity for the solder to run in. When dealing with hard-drawn copper which is under strain, as in the case of span wires, it is essential to avoid using excessive heat owing to the annealing and therefore weakening effect on the wire itself.

Effect of Thickness of Solder Film. Provided the solder completely wets the surfaces to be joined, thin joints are stronger than thick ones. Opinions re the optimum thickness seem to differ a little, but for copper, brass and steel, it appears to be of the order of 4 to 5 mils. Below 3 mils the strength falls off rapidly as it does above 6 or 7 mils, but if the effect of soldering temperature is taken into consideration also, there is a variation in that the thinner joints improve with higher soldering temperatures, e.g., with a thickness of about 1 mil, a soldering temperature of 750° F. gives a joint of similar shear strength to one about 4 mils thick at the recognised optimum temperature of 540° F. This, of course, assumes that the metal of the members to be joined is not affected by the higher temperature.

Applications. One of the most common uses of soldering within the Department is for the purpose of providing good electrical connection between wires and terminal tags or between wires of cables (except light gauge P.I.L.C. cable), for which resin cored solder is used. In such cases strength is not a consideration. Wires and tags should be clean (preferably tinned) and a close firm contact provided between the two before soldering. The amount of solder used in the former case should be just sufficient to form a good metallic bond by filling up all spaces between the wire and the tag, and between turns of the wire on all sides. In the case of cable conductors the complete bonding of the twists in the wires for about one-quarter inch at the tip is sufficient. Where the wire is insulated by enamel it is necessary that care be taken to remove all traces of it at the soldered connection. It is of interest to note that a type of enamel insulation is now available which is removable by the heat of the bit during the soldering process. This class of insulated wire has been tried by the Department, but results to date indicate that further improvement is necessary before it can be regarded as satisfactory for general adoption.

The other common use of soldering is on open line wires where normally stick solder (Grade F) with a Zinc-Ammonium Chloride flux is used. Acid cored solder which has been used at times and found entirely satisfactory, usually contains a similar flux (often with an addition of resin) in paste or solid form. Drip points are in the same class as tag connections since a good electrical connection is the chief essential. In the case of the well-known Britannia joint (see Fig. 10), strength is a serious consideration. When an analysis of faults due to broken wires on an important trunk route was made some time ago it was found that about 30 per cent. of them

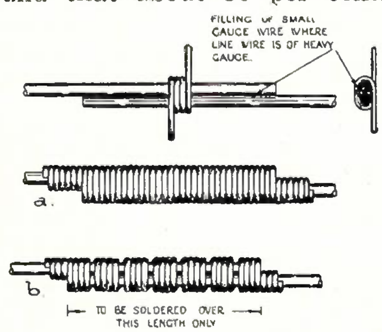


Fig. 10.—Britannia Joint.

(a) Present recognised method of making a Britannia Joint.
(b) Suggested variation in method of making a Britannia Joint.

were due to failure of Britannia joints, most of which had been inserted in copper wires some years ago when apparently metal jointing sleeves were not available. These faults are of two types:—

(i) Where the wire breaks at or adjacent to the end of the joint.

(ii) Where the wires pull out of the binding without breaking.

The first is mainly due to the excessive application of heat, resulting in the copper wire being annealed and causing early tensile failure. A typical case of this is shown in the photomicrograph, Fig. 11. It is quite common to find that, although the wire has been annealed at the end where the single wire is covered with the binding wire, the solder within the bindings covering the two wires has not taken properly on both wires.

The second class of fault may be due to one of several causes or, as appears to be mostly the case, a combination of these:—

(i) Wires not properly cleaned, preventing the solder taking on the line wires.

(ii) Soldering bit not hot enough and resulting in surface of binding wires only being soldered or line wires only partially soldered on surfaces adjacent to the bit.

(iii) Improper use of flux as a result of which line wires beneath bindings are not wetted with solder.

(iv) Combined effects of low heat and flux residues (see Fig. 7).

Corrosion is in evidence in a very large number of cases of this class of fault and is very likely due to flux residues which were not removed readily by rain after soldering, or which became embedded in the solder through the heat being insufficient to melt it properly and allow it to run clear of the molten solder.

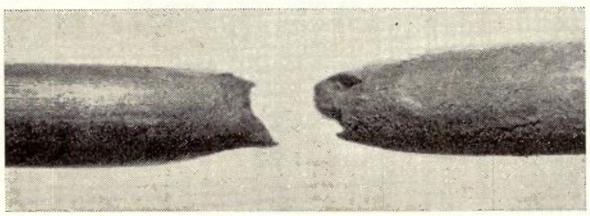


Fig. 11.—Photomicrograph of ends of broken copper wire due to tensile failure.

Britannia joints in span wires should be avoided wherever possible (especially where copper wire is concerned), but when used the following precautions appear necessary:—

(i) Thoroughly clean line and binding wires with fine emery paper, and tin line wires prior to binding. Do not overdo the cleaning on copper wire.

(ii) Add light gauge filling wires around line wires where the larger gauge wires are concerned.

(iii) Ensure that the flux and solder can reach the line wires below bindings by leaving a little space between the turns of the binding wire at intervals. [See Fig. 10 (b).]

(iv) Use the proper degree of heat to give the solder sufficient fluidity to penetrate to and fill all spaces between wires and to complete soldering operation as quickly as possible without any danger of annealing line wires.

(v) With the object of avoiding annealing of the line wire at the single wire portion, omit the soldering at this point. In these circumstances there appears to be no necessity for the turns of binding wire on the single wire portion, except as a means of finishing off the turns on the double wire portion. [See Fig. 10 (b).]

(vi) Withdraw the bit immediately soldering is complete.

(vii) Wherever possible, wash the completed joint, when cool, to remove all trace of flux residue.

In areas where atmospheric conditions are likely to give rise to corrosion, it is advisable to cover the joint completely with bitumastic paint or varnish. The amount of soldering suggested in (v) is quite adequate if the soldering is properly done. The strength of a number of Britannia joints soldered in this way was found to be greater than that of the wire.

The soldering of line wires has been considerably facilitated of late years by the use of the well-known Mox type of soldering bit, which is heated by special briquettes capable of giving suitable temperatures to the bit in a matter of seconds and in a very convenient and clean manner. The advantage of this over the old plain type of bit heated in a firepot needs no explaining.

WIPING

General. Wiping is a special method of soldering which differs from other methods in that it calls for a greater degree of skill, efficiency only being acquired after considerable practice and experience. It is the process by which it is usual to unite sections of lead pipe or one section of lead pipe to a pipe of some other metal on which the solder will take. In such cases it is usually essential that the joint be water and air-tight, and having in mind also the size of the metal members to be joined and considerations of strength, a considerable mass of solder is usually necessary. These factors and working conditions usually necessitate that the soldering be done by the wiping process rather than by ordinary soldering with a bit or blowlamp.

When dealing with telephone and electric power cables, the process is still more difficult than with empty pipes. In the former case the lead pipe forming the cable sheath surrounds a very considerable mass of copper which readily conducts away the heat, and so quickly cools the solder. In addition to this, the plumbing of cable joints has very often to be carried out in confined spaces such as small or congested manholes, under floors of buildings, etc., where working conditions are decidedly difficult. For these reasons the practices found to be the most suitable when plumbing cables will not always be identical with those followed on other classes of plumbing work.

Requirements of Solders for Wiping. The essential properties of a wiping solder are:—

(i) The melting point must be sufficiently below that of materials to be joined to provide a safe margin against any melting of these.

(ii) The solder should have a sufficient plastic temperature range to permit of the metal being worked into shape with a minimum use of the blowlamp or torch. A range of at least about 90° Fahrenheit seems necessary. (See Fig. 1, Part I.)

(iii) It must form a strong non-porous joint.

To obtain the last property the tin content must be such that there is an adequate amount of eutectic (see page 244-6, Part I.) to permit of the complete "wetting" of all surfaces to be soldered together with the surfaces of the particles of lead in the plastic metal.

A tin lead solder with a plastic temperature range of 90° F. has a tin content of a little over 40 per cent., so that this appears to represent the maximum tin content, whilst (i) and (iii) combine to make the lower limit about 30 per cent. A composition of 38-40 per cent. tin appears to find favour in America on account of its better non-porous properties, but having regard to the rapid conduction of the heat by the copper wires it is very desirable that the widest permissible plastic temperature range be provided, and for this reason, coupled with the economic aspect, a coarser solder is preferable. Another disadvantage of a wiping metal containing a high percentage of tin is the greater tendency for the eutectic to drain out during wiping.

A composition of 30 per cent. tin, when the only other constituent is lead, on the other hand, cannot always be relied upon to give a non-porous joint, even when used by a skilled man and in the hands of the unskilled the finished joint—to use the words of a Lines officer when discussing the matter—"often looks like a piece of pumice and is about as porous." These considerations point to the advisability of using an intermediate composition, and standard practice therefore at present adheres to a composition containing 34 per cent.-36 per cent. tin. Where the "pot" method of wiping is the general practice, some authorities prefer the larger figure since it permits the operator to reduce the percentage by adding lead to suit his particular desires, and allows a margin for the loss of some of the tin through oxidization in the metal pot.

Some years ago one of the companies associated with the American Telephone and Telegraph Co. carried out a comprehensive series of trials among skilled cable jointers and found that the average composition of the wiping solder preferred contained about 38 per cent. tin (see Bell Lab. Record, Oct., 1932). Apparently, on the result of this test a standard of this order was adopted. Such a test seems to leave too much to individual prejudice for the composition to which the parties concerned have been accustomed. A plumber's hands very soon become accustomed to the feel of the particular composition of solder which he uses, and develop a sensitiveness to even minor changes in the composition. If given a wiping solder of slightly different composition he will invariably complain that there is something wrong with it, notwithstanding the fact that another man may make an equally good non-porous wipe in the same time with this composition if he is accustomed to using it. It is significant in connection with the American tests that the standard composition previously in use contained 40 per cent. tin, whilst in some cases 50-50 solder was provided and modified by the jointers by the addition of scrap lead. Presumably the general practice was to use the "pot" method for wiping.

In opposition to the inclination towards a high tin content in America, the British Non-Ferrous Metals Research Association, in a Research Report, No. 28, published in 1926, claimed that a solder containing 30 per cent. to 31 per cent. tin was the most satisfactory, and that solders containing 35 per cent. tin were more difficult to work owing to the tendency of the eutectic to drain out. As far as is known, these lower percentages of tin have not been brought into general practice anywhere, and except where antimonial solders are used, general British practice adheres to the standard composition of 34-36 per cent. tin.

Standard and Special Compositions of Wiping Solders. The Australian Standard Specification (see Part I.) provides for two types of wiping solders, Grades D and H. Grade D contains a maximum of 1.7 per cent. antimony with tin and lead in somewhat similar proportions to Grade H. As far as is known, little use is made of Grade D in this country, and normal practice seems to confine itself to either Grade H or 34-66 solder made direct from commercially pure lead and tin. The British Standard Specification varies from the Australian Standard in that Grade D only contains 29-31 per cent. tin, and one authority claims that in a comprehensive series of tests covering all classes of wipes this composition was less difficult to work than Grade H, and gave a good lack of porosity owing to its small grain size and good adhesion between the lead and solder. The suitability of antimonial solders for wiped joints seems to be borne out by recent investigations of the British Post Office. Following experiences with explosions in the underground systems in certain city areas in Great Britain, the need for some "flameless" method of sealing cables became apparent. With this object tests were carried out using standard Grade H solder, but these proved rather disappointing.

Trials with Grade D solder (British composition) gave better results, and finally it was found that with a composition of 31.5 per cent. tin, 1.8 per cent. antimony and the remainder lead, 100 per cent. non-porous wipes could be obtained when using the "pot and ladle" method without a blowlamp. The chief feature of the technique in making such wipes appears to be speed, whilst another is cessation of work on the solder before it reaches its final set. Any attempt to prolong the forming of the wipe to obtain a neat finish is likely to result in a faulty joint.

The B.P.O. tests proved that the composition was also quite satisfactory for blowlamp joints, and as the composition is slightly cheaper than the standard Grade H solder it has now been adopted by the B.P.O. as their standard composition. The lower tin content provides an increased plastic temperature range, whilst the addition of the antimony more than offsets any tendency to coarseness due to the lower tin content. Some tests with solder of this composition have already been made by the Department, but at the present date have not advanced sufficiently to form any definite opinions.

Whilst dealing with wiping solder compositions, it is of interest to note that, during and just after the Great War, when tin was at an exceptionally high price and cadmium comparatively cheap, the A.T. & T. Company of America made trials of a composition of 9 per cent. cadmium, 24 per cent. tin and 67 per cent. lead—this composition producing a wiping solder equivalent to their 38-62 tin lead solder. (See Bell System Technical Journal, January, 1932, and Bell Laboratory Record, October, 1932.) As a result of later variations in prices of constituent metals, the economic advantage of such a composition ceased and the experiment also ceased. This composition has a larger plastic temperature range (451°-293° F.) and a lower melting point than standard tin lead wiping solder, and it is claimed that it also has the advantages of excellent lack of porosity and easy working. In view of these claims, a solder of this composition would require serious consideration if the price of tin increases to any great extent in the future.

Note: The final article of this series will appear in the next issue of the Journal. In addition to a discussion of methods and practices associated with wiping, it will cover other aspects of plumbing of lead-covered telephone cables.

Strength of Porcelain Insulators and Cement Joints

R. A. Turner

In the construction of large radiators, both mast and tower types, where insulating units are incorporated with the steelwork and have to withstand definite loads, it has been found that electrical porcelain is the most satisfactory insulating medium owing to its weathering ability and the permanence of its insulating properties.

The mechanical performance of porcelain varies greatly and it is difficult to decide on the ultimate strength of the material per unit area and in designing to apply a definite stress to any cross-sectional area or to expect constant results from similar units when tested to failure. Information on the mechanical performance of porcelain insulators and their associated cement joints is not generally available and it is considered that the tests tabulated herein may serve as a guide to designers as to what strength to expect from these materials, as well as indicating some of the limiting factors in deciding on shapes or form of porcelain units. Electrical

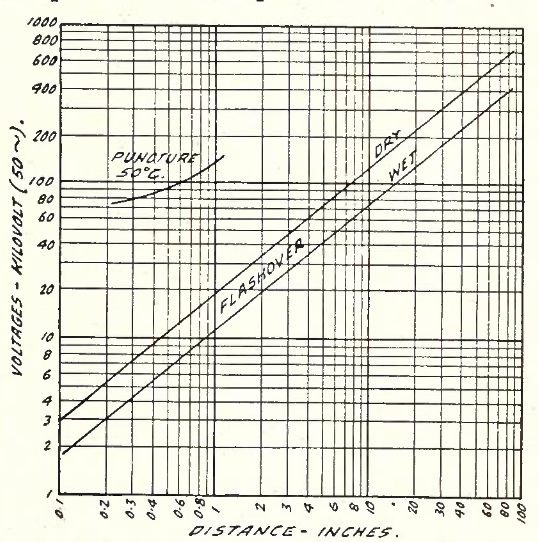


FIG. 1. GLAZED PORCELAIN. FLASHOVER & PUNCTURE VOLTAGES.

design considerations are not covered by this article, but for the information of readers a graph, Fig. 1, is shown, setting out the flashover and puncture voltages to be expected for electrical porcelain, when tested with 50 cycle per sec. A.C. supply.

Manufacture of Porcelain

Porcelain being a manufactured product, it may be of interest to outline the process of manufacture and this may serve to explain limits of design such as the thickness of cast forms and the inside shapes of some articles.

Porcelain is a mixture of quartz, kaolin and felspar and perhaps other materials according to the manufacturer's methods. The solid constituents are ground in ball mills, water being added during the process. The resulting mass is passed over a magnetic separator which extracts any steel fragments that may have accumulated during grinding and is then stored in pits. The material is next processed in filter units where excess water is extracted, leaving it in the form of a pug or plastic state. The pug is formed into the ultimate shape of the insulator or other item by one of three methods, which are as follows:—

(1) By spinning in a metal mould under pressure of an inside die which is stationary. This can only be achieved in circular objects and where the inside die can later be withdrawn, such as telephone line insulators.

(2) By pressing in dies a pug which has been granulated or powdered by blowing through a wire screen or by treatment in a dust mill. This is used for items of irreguar shape, where both inside and outside have to fit definite conditions or where repetition manufacture of small articles is necessary, such as fuse-mounting blocks.

(3) By reducing the pug to a liquid state, the consistency of separated cream, and casting in plaster moulds. The moulds are formed to provide the outside shape and the liquid porcelain is poured in and allowed to stand. The plaster mould being in a dry state absorbs the moisture from the outer surface of the liquid porcelain forming a shell. When the desired thickness is attained, the remaining porcelain in a liquid state is poured out. The result of this process can be seen in a teapot or the like, where the outer shape is moulded and the inside surface casts itself in conformity with the outside form. The drawback to this method is that the manufacturer cannot vary the thickness of the shell in any location, though later on it may be trimmed in the green stage as hereinafter explained. The limit of thickness of the shell in this process is about one inch, but this may be increased where it is possible to insert an inside plaster cast which will also absorb the moisture, but must be capable of withdrawal from the finished form. A thickness of shell up to three inches is possible under this system of manufacture.

It will be appreciated that of the three methods of manufacture the porcelain resulting from the spinning under pressure should give the most homogeneous porcelain free from air pockets and porosity when it has dried out, and would probably give the most constant results when the completed article is submitted to mechanical tests. Large insulators, even when of the cylindrical type, are generally of the cast type owing to the costs of metal moulds and the size required of spinning presses.

After the material is formed into the desired shape, it is dried out on racks in drying rooms, where it reaches the green stage, which is a hard, dry state with the appearance of chalk. In this condition it can be machined and trimmed, and reduced to any desired shape.

Where a small number of special insulators is required, it is possible to cast them in plaster moulds or to form them out of a blank in the green stage, thus obviating the necessity of moulds, dies or plaster casts.

After the final shaping the article is dipped in glaze, which may be of any desired colour. When dried, it is placed in fire-brick saggars in the kiln, where it is fired at a temperature in the vicinity of 1400° C. for a period of about three days, the porcelain being thoroughly vitrified. During firing in the saggars the insulator must be supported on a surface free from glaze, otherwise it will adhere to the saggar and eventually have to be broken away. This difficulty is sometimes overcome by sprinkling a glazed surface with quartz chips; these latter support the insulator during firing and can be readily removed later on. Unfortunately this arrangement mars the appearance, though not the performance, of the completed insulator. On removal from the kiln the insulators are submitted to a visual inspection; those that are passed are subjected to electrical and mechanical proof tests before being placed on the market. Where insulators require true fitting surfaces they may be machine ground after firing.

The glaze assists an insulator to remain clean and retain its appearance; it is also claimed that it improves the strength of porcelain units, especially when they are stressed in tension. Failure generally occurs by the extension of invisible surface cracks and the provision of the glaze tends to fill these minute crevices and provide a smooth outer surface for the insulator.

It will readily be seen that a material, such as porcelain, subject to so much processing in manufacture by individual proprietary methods, even when supplied by the same manufacturer, the strength of articles may be affected by the constituents, the individual treatment, the weather conditions operating at the time of processing, or even the position in the kiln when firing, therefore constant mechanical performance or strength cannot be expected, and it is reasonable to allow a fair margin for safety when designing insulators to be incorporated in structures and subject to definite stressing.

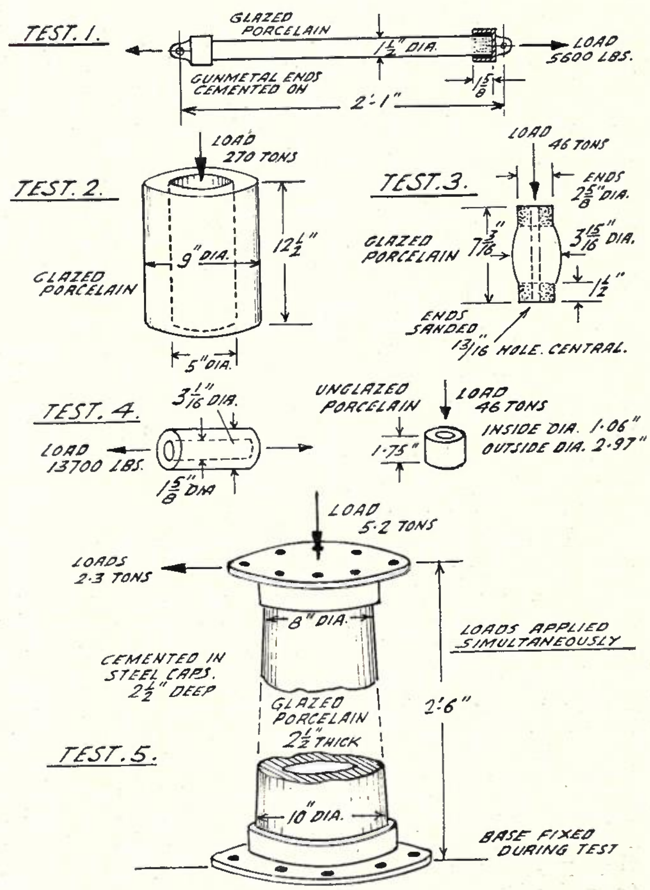
Cement Joints

As many insulators are a combination of porcelain units cemented in metal caps or fittings, investigation has been made into the strength of cement joints and the results are tabulated herein.

Where the insulator is cemented in a metal socket, the best practice appears to be to rib the inside of the socket, and the end of the porcelain is covered with quartz chips which adhere to the glaze before the firing stage. The chips are generally covered with bituminous paint, which permits a slight amount of expansion or contraction in the socket. The actual cementing process is a proprietary secret, but a good cement can be made out of a 1 to 1 mixture of Portland cement and clean quartz sand, which should be steam cured. The potteries have a special plant for this work, the cement being placed in the joint during vibration. Where porcelain is to be attached to metal fittings, it is good practice to have the metal fitting on the outside, then any expansion of the intervening cement joint will not tend to burst the insulator.

Tests on Insulators

The performance of insulators as listed in this article is not a report of an investigation over a large number of test pieces, but rather records



the results of mechanically testing specimens or insulators used in structures erected for the

Postmaster-General's Department or the National Broadcasting Service. Information is given by the tests as to what strength may be expected of electrical porcelain and cement joints, and the diverse results indicate why designers should be conservative in proportioning porcelain to withstand definite loads. Wherever possible, porcelain should be stressed in compression and the material should not be subject to impact or sudden shock.

The various tests are listed in the same order as the drawings are numbered. The method of loading is described and the basis of arriving at the stress imparted to the material is also indicated. Table A (shown later) records in general form the results of the tests from which a fair average strength of the materials can be decided on. Unfortunately, on some occasions, owing to the limit of the testing plant, the ultimate strength was not attained. The following is the range of tests:—

Test 1—Porcelain in Tension; Cement in Shear.

This insulator is a tension unit used in the aerial of the 6WF broadcasting station. Glazed porcelain.

The test on the porcelain was not conclusive as the eye of the gunmetal socket failed with a tension of 5600 lbs. without any effect on the porcelain.

The tension stress applied to the porcelain was 3180 lbs. per sq. inch.

The shear stress applied to the cement, on $1\frac{5}{8}$ inch diameter, was 675 lbs. per sq. inch.

Test 2—Porcelain in Compression.

This base insulator is the type used in the Grafton radiator, there being a group of six supporting the structure. Glazed porcelain.

The applied compressive load without failure was 270 tons (the limit of the testing machine).

The cross-sectional area is 44 sq. inches and the compressive load was approximately 6.1 tons per sq. inch.

Based on the result of this test and other investigations, the later radiators erected, such as Sydney and Melbourne, are supported by one insulator.

Test 3—Porcelain in Compression.

This item was a preliminary design for guy insulators, glazed porcelain.

The unit would eventually be mounted in metal ends overlapped at a distance by metal rods of opposite polarity. Advantage was taken of the diameter of the metal ends to barrel the porcelain unit; this did not decrease the air gap, but it is doubtful whether it added much strength to the porcelain. In testing in compression, the first failure appeared by chipping at the ends and the barrelling tended to flake off. The primary failure was the crushing of the ends. The first fracture was noted at 46 tons load and complete disintegration occurred with a 77 tons application. The area of the ends was 5.4 sq. inches. As an insulator may fail with its first crack, the ultimate load is taken as 46 tons and the ultimate compressive stress would be 8.5 tons per sq. inch. It might be noted that recent investigations show that cylindrical compression units can be strengthened by providing a concave outer surface on the vertical axis.

Test 4—Porcelain in Tension; Porcelain in Compression; Porcelain in Shear.

These tests were on samples and were carried out for the potteries. Unglazed porcelain.

The specimen for tension had a cross-sectional area of 5.3 sq. inches and the ultimate load was 13,700 lbs., the ultimate tension stress being 2585 lbs. per sq. inch.

The specimen for compression had a cross-sectional area of 6.05 sq. inches. The first crack occurred with a load of 46 tons and the disintegration at 73.3 tons.

Using the 46 tons as the ultimate load, the porcelain had an ultimate compressive strength of 7.6 tons per sq. inch.

The shear test was carried out on a solid specimen with a cross-sectional area of 12 sq. inches. It failed with a load of 3780 lbs., therefore the ultimate strength in shear was 315 lbs. per sq. inch.

Test 5—Porcelain Subject to Bending; Cement in Shear.

This insulator was similar to the type supporting the armature on the Grafton radiator. It was of glazed porcelain and cemented in metal ends.

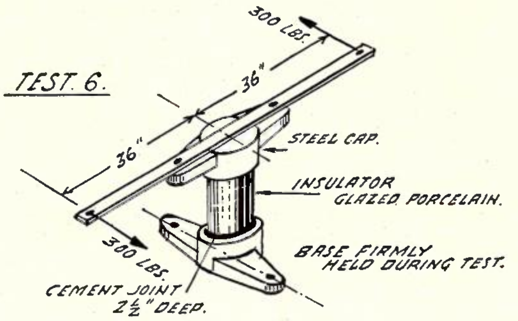
The insulators were tested with loads of four times the calculated maximum working loads and they were applied as shown in the drawing. The insulator satisfactorily withstood the tests applied. The direct compression and shear loads were light, but the combination of the bending load and the compressive load gave a stress of 1917 lbs. per sq. inch on the compression side, and 1437 lbs. per sq. inch on the tension side of the insulator.

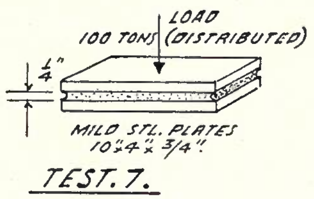
The insulator was cemented in for 2.5 inches and taking a strip 1 inch wide on the tension side of the insulator the shear stress on the cement joint would be $1437/2.5 = 575$ lbs. per sq. inch.

Test 6—Porcelain in Shear; Cement in Shear.

This test was carried out on a guy insulator unit to arrive at a stress in shear. In its position in a guy an insulator is compressed owing to the tension of the guy; it is subject to bending owing to its weight slung between the socket ends and also to a torsional stress imparted by the twist in the rope, which operates as the tension is varied. The twisting effect of the rope was arrived at by test and calculation, and the insulator was tested to observe its resistance to torsional shear.

The arrangement of the test and loads applied without failure are shown on the drawing. The load applied to the insulator was 600 lbs. on a 36-inch lever giving a torsional moment of 21,600





inch lbs. The section modulus about its axis of a 5-inch diameter insulator is 24.5, the shear on the porcelain being, therefore, 880 lbs. per sq. inch.

The insulator was cemented in the socket for a depth of 2.5 inches; therefore—

$$\frac{TM}{\pi D \times d \times .5D} = \text{Shear per sq. inch of cement.}$$

TM = Torsional moment.
D = Diameter of insulator.
d = Depth in socket.

The shear on the cement was 220 lbs./sq. inch.

Test 7—Cement Joint in Compression.

This test was carried out to arrive at a bearing pressure on pins where an insulator is transversely loaded, such as in the reel type, the pin being cemented in the insulator.

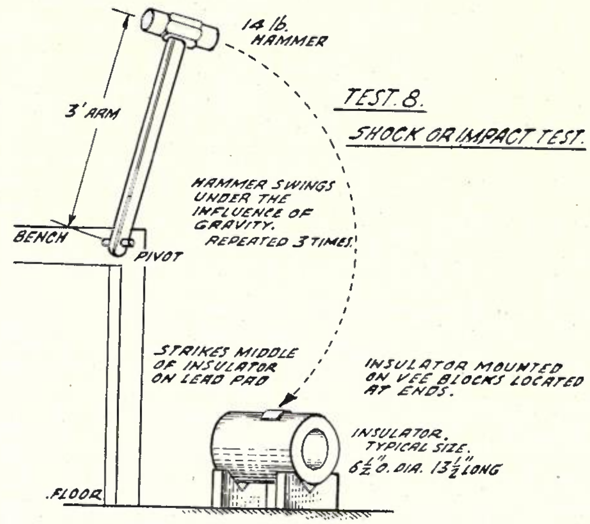
The cement seam was arranged between two plates, as shown in the drawing. The inside surfaces of the plates were roughened by countersunk holes made by the point of a ½-inch drill on 1½-inch centres in all directions.

The cement seam was ¼ inch thick; it was provided and steam cured by the potteries. The edges of the cement were hollowed out so that the cross-sectional area of the cement was 9⅝ inches x 3⅝ inches, or 34.9 sq. inches.

The cement was subjected to the required unit stress, applied at intervals, but eventually the limit load of the machine, 100 tons, was applied without damage. This gave a compressive load of 2.8 tons per sq. inch on the cement.

Test 8—Impact or Shock Test.

In handling and assembling large insulators it has been found that occasionally an insulator is broken across; the primary crack or may be internal weakness has not been noticed in a visual inspection and may not show in a proof compression test where a light load is applied. It has proved good practice to submit all insula-



tors to a shock test. While it might be considered that a shock may start a failure, experience has shown that the policy is effective in getting rid of faulty insulators. The arrangement of a test on cylindrical guy and base insulators is shown on the drawing, the insulator being supported horizontally on two Vee blocks

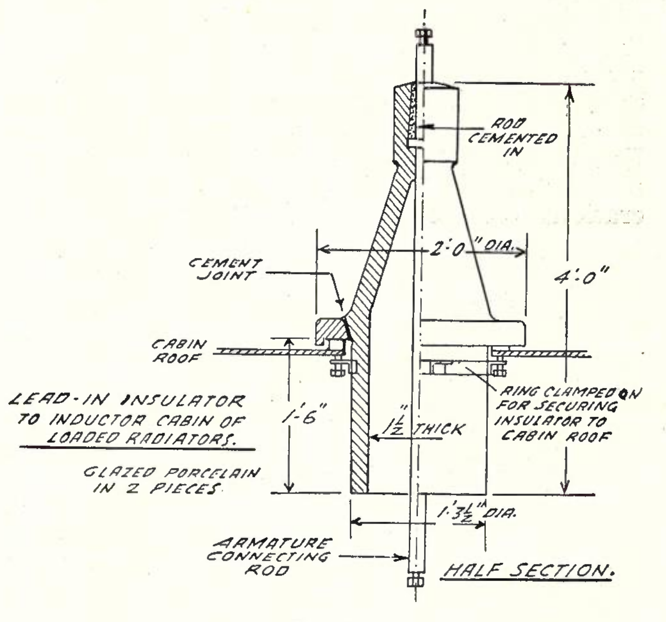


Fig. 2.

which are located at the ends. The middle of the insulator is then struck three blows with a hammer as illustrated, the thin lead pad being there to absorb the harshness of the blow and prevent local shattering of the glaze, but it will be appreciated that a severe shock test is administered under this arrangement.

After testing, the insulator is submitted to a further visual examination.

The results of tests 1 to 7 inclusive are tabulated on Table A, and the reader is directed to the stresses shown on that table. A warning to anyone mechanically testing insulators may not be out of place. They should only be viewed through a protective screen or otherwise covered with leather or stout fabric during the process, as the material whilst it may have preliminary chipping or cracking, eventually flies to pieces and sharp-edged fragments are scattered around, a positive danger to the person. Unfortunately with the test specimen covered it is difficult to note the cause of early failure; cracking can be heard, but unless the load is removed the cause should not be investigated.

Size of Insulators Available in Australia.—To give some idea of the size of insulators which have been manufactured in this country, an outline sketch is shown in Fig. 2 of the lead-in insulator to the tuning cabin at the top of the mast of the loaded radiators at Dooen, Wagin and Cumnock. These insulators, whilst subject to practically no external stresses apart from their own support, are of the size shown for electrical reasons. They are manufactured in two sections, the body and the surrounding ring, which is cemented on. This insulator is located in the cabin roof on the structure and is held in position by a clamped ring.

TABLE A.

Test No.	Material	Applied stress per sq. inch (without failure)			Ultimate stress per sq. inch		
		Tension	Comp.	Shear	Tension	Comp.	Shear
1	Porcelain Cement	3,180 lbs.		 675 lbs.			
2	Porcelain		6.1 tons				
3	Porcelain					8.5 tons	
4	Porcelain (Unglazed)				2,585 lbs.	7.6 tons	315 lbs.
5	Porcelain Cement	1,437 lbs.	1,917 lbs.	 575 lbs.			
6	Porcelain Cement			880 lbs. 220 lbs.			
7	Cement		2.8 tons				

Many proof tests have been carried out with much lighter loads than those tabulated, but as they withstood the tests without failure they have not been recorded.

Conclusion.—All the insulators described in this article were supplied by Sunshine Porcelain Potteries Pty. Ltd., of Victoria.

GENERAL RADIO TRANSMISSION MONITORING ASSEMBLY

E. W. Anderson

Papers in previous issues of the Journal have made mention of General Radio equipment, and as this monitoring assembly has now become standard in all broadcasting stations installed and operated by the Department it is the intention of this paper to describe this equipment and also to give some idea of the measurements it is possible to make by using it.

The General Radio Monitoring Assembly, Type 730A, consists of three A.C. operated self-contained units:—

(A) **731 Modulation Monitor.** This performs two functions—it gives a continuous indication of percentage modulation on either positive or negative peaks and an indication of over-modulation peaks in excess of any pre-determined modulation level.

Percentage modulation is indicated on a high speed meter whose scale is calibrated from 0 per cent., to 110 per cent., modulation. An additional db scale is provided to facilitate adjusting the transmitter input. Positive or negative peaks as desired are selected by means of a switch. The overall accuracy of measurement at 400 c.p.s. is within 2 per cent. at modulation percentage of between 0 per cent., and 100 per cent., while the frequency response is linear within less than 0.5 db between 40 c.p.s. and 15,000 c.p.s.

The over-modulation indicator is a lamp which flashes whenever the percentage modulation exceeds the value at which the **"Nominal Modulation Peaks"** dial is set.

Provision is made for extending both the modulation percentage meter and the over-modulation lamp to any external point.

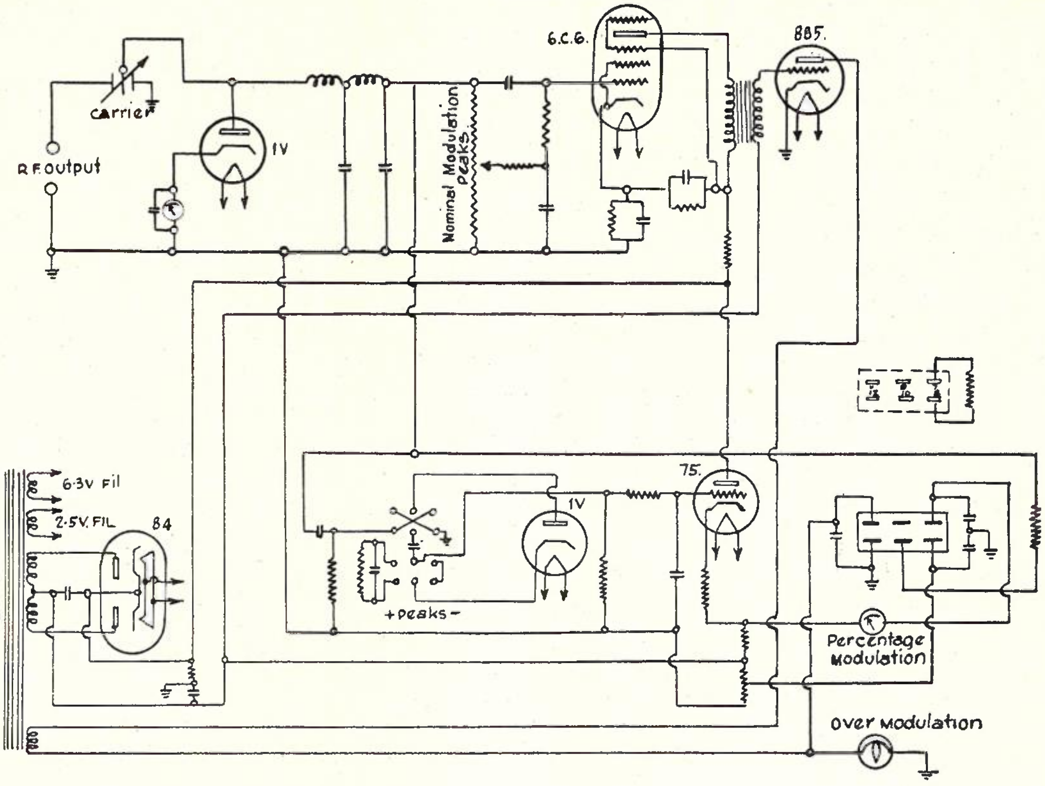


FIGURE 1 Schematic Wiring Diagram of Type 731-A Modulation Monitor

(B) **732A Noise and Distortion Meter.** This meter is designed for measurements of total harmonic distortion (with 400 c.p.s. modulation) and of the noise level present in the output of a broadcast transmitter. Means are also provided for making distortion and noise measurements on the audio-frequency system above, and, if a wave analyser is available, for analysing the components of distortion at any audio-frequency. To permit corresponding measurements in audio-frequency circuits simple means are provided for removing the radio-frequency rectifier and connecting the equipment directly to the audio system.

(C) **733A Oscillator.** This oscillator is a source of audio-frequency voltage of good waveform at a frequency of 400 c.p.s. It is intended for use in modulating the radio transmitter when measurements are to be made with the Type 732 distortion and noise meter.

Principle of Operation

(A) **731 Modulation Monitor.** Fig. 1 is a schematic circuit of the set. A modulated radio-frequency is applied to the input terminals. This is applied to the diode rectifier and the level adjusted to a specified value by means of the condenser type voltage divider and the D.C. meter in series with the diode. The positive half of the modulated radio-frequency wave is demodulated by the diode and passed through a filter which removes the radio-frequency components.

The filter output voltage consists of an A.C. component (corresponding to the varying envelope of the original modulated signal) superposed on a D.C. component produced by the rectification of the carrier. The ratio of amplitudes of the A.C. and D.C. components is identical with the radio of the amplitudes of the A.C. components of the envelope and average carrier in the original signal.

The D.C. component E_0 is used to supply a negative grid bias for the amplifier tube 6C6. The A.C. component is applied directly to the amplifier grid. The grid bias is variable between zero and the full value of E_0 and is controlled by the **"Nominal Modulation Peaks"** dial, given fractions of E_0, corresponding to the same values of fractional modulation—that is, half scale corresponds to 50 per cent. modulation.

Whenever the peak value of the A.C. component exceeds the grid bias, the grid becomes positive, and plate current flows, tripping the Type 885 gas-filled triode and flashing the overmodulation lamp.

The percentage modulation meter is fed from the output of the R.F. filter through a phase reversing switch, for selecting either positive or negative peaks, to a diode detector. The A.C. voltage is rectified, and its amplitude indicated by a vacuum tube voltmeter device on a meter calibrated in percentage modulation.

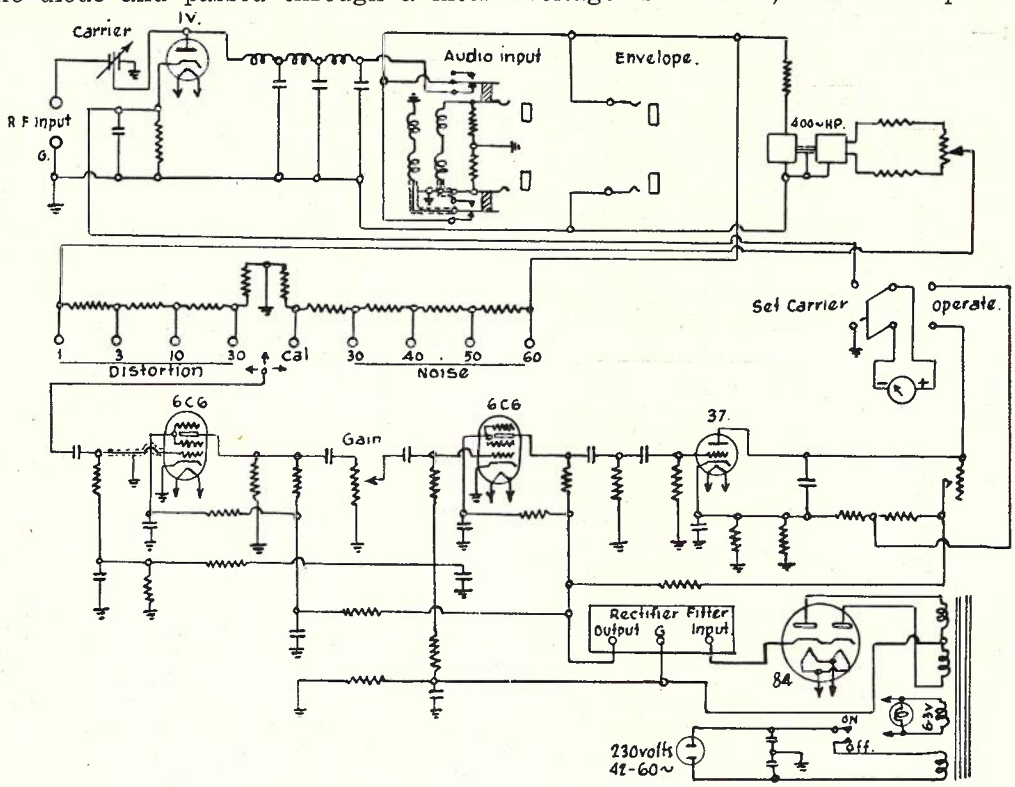


FIGURE 2. Schematic wiring Diagram of Type 732-A Distortion & Noise Meter

(B) **732A Distortion and Noise Meter.** Fig. 2 is a schematic diagram of the distortion and noise meter. The input circuit is similar to that of the 731A modulation monitor. A meter for reading carrier amplitude can be switched in series with the R.F. diode—this same meter is used as the indicator in the vacuum tube voltmeter. The 400 cycle modulated carrier is demodulated by the diode. The output passes through the radio-frequency filter, which removes the R.F. component.

For measurements of harmonic distortion, the output of this R.F. filter is passed through a 400 c.p.s. high pass filter, removing the 400 c.p.s.

fundamental of the audio-frequency, but leaving all its harmonics. These are then amplified by the amplifier and the amplitude indicated by the attenuator and output meter. The attenuator dial is provided with a calibrating position which is used to standardise the meter scale in terms of the original 400 c.p.s. amplitude before making the measurement. This setting is made by adjusting the amplifier gain for a full scale deflection on the meter, when a known fraction of the envelope amplitude is applied to the amplifier.

For noise and hum measurements the output of the R.F. filter is applied directly to the attenuator. The calibration adjustment is made with the transmitter modulated at the level with which it is desired to compare noise. With the modulating voltage removed from the transmitter the noise level in decibels below the modulated signal level is indicated on the meter.

(C) **733A Oscillator.** Fig. 3 is the complete circuit diagram of this oscillator. The oscillator is of the Hartley type, and the final output is an audio-frequency voltage of good waveform at a frequency of 400 c.p.s.

A filter is used in the output to eliminate harmonic voltages.

Transmitter Performance Tests

In making complete measurements on a transmitter the normal procedure is to measure:—

(i) Modulation capability;
(ii) Distortion;
(iii) Noise;
(iv) Frequency Response.

It is possible to make these measurements in less than 15 minutes with the G.R. 730A assembly for the first three measurements and a beat-frequency oscillator in conjunction with the 731A set for the frequency response measurement.

Before the installation of this G.R. equipment much time was necessary to get accurate measurements of the performance of audio or radio equipment, but with the G.R. 730A assembly these measurements can be readily taken by the normal operating staffs of the stations concerned, and this is a very desirable feature.

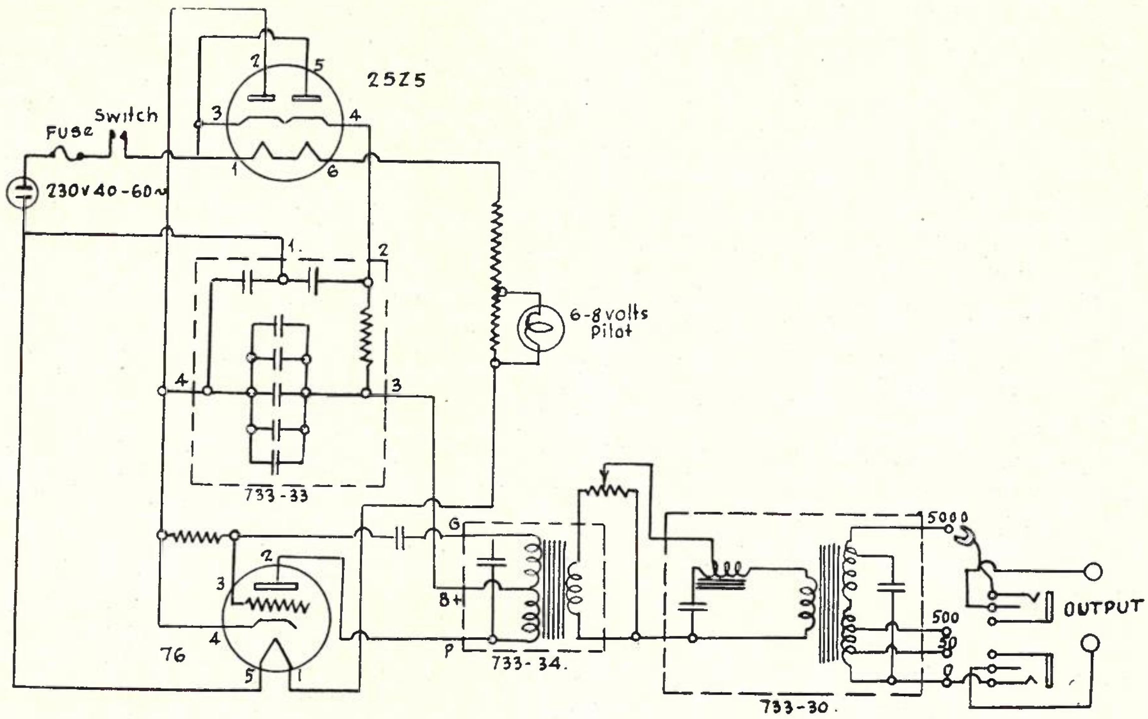


FIGURE 3. Schematic Wiring Diagram of Type 733-A Oscillator.

The modern radio transmitter and associated equipment, studio and station, having a large number of controls and using a large number of valves, needs constant supervision, and measurements should be taken at least every week and, if possible, daily. As the time taken in making the measurements is less than 30 minutes this is not as impractical as at first glance it might appear, the extra time involved to make the measurement being amply repaid by the knowledge of the correct operation of the entire audio and radio plant being used.

THE NEW MELBOURNE TRUNK EXCHANGE

C. McHenry, A.M.I.E. (Aust.)

The main features of the new trunk exchange were described in the June, 1939, issue of this journal. In the present and subsequent issues the more interesting features of the installation will be described in greater detail.

Number of Positions

The new trunk exchange, when completed, will include 97 operating positions and 24 miscellaneous service positions as follows:—

(a) **Main operating suite:**

Demand	58
Interstate	24
Through	7
Suspense	3
Trunk Inquiry	5
	97

(b) **Service positions:**

Delay Supervisor	2
Traffic Officer	1
Monitors' Posts	12
Routing	1
Pneumatic Tube Distribution	2
Pricing	6
	24

Figure 1 shows two typical positions of the main suite. All positions, externally, are similar, but there are differences in the equipment arrangements, as explained later.

Demand Positions

These positions receive all calls for trunk line service from metropolitan subscribers. Each incoming circuit terminates on a "demand line circuit" which consists of a 24-outlet homing type uniselector and associated relays, the uniselector having graded access to "demand distributors."

The demand distributor switches are the Siemens motor-uniselector type. The banks of these switches have 200 outlets, of which approximately 180 will be used for routing calls to the demand positions and 20 for the call queueing.

The outlets from the demand distributors each terminate on a "connecting circuit" on the positions. Each position is equipped with six connecting circuits and theoretically 180 outlets could be distributed over 30 positions, but in practice the actual number of positions is about 28 on account of the need for equalising loads and for concentrating traffic during periods of light load.

Incoming calls are not routed directly to idle connecting circuits. The demand distributors test over the bank contacts reserved for call queueing and having found a queue position cause a waiting call lamp to display on all demand positions to which the demand distributor has access. Waiting calls are indicated by a strip of lamps mounted vertically on the face of each position, the number of lamps displayed indicating the number of waiting calls. The order of glowing is from bottom upwards, i.e., one call waiting—lamp No. 1 displays; two calls waiting—lamps Nos. 1 and 2 display; three calls waiting—lamps Nos. 1, 2 and 3 display, and so on. As calls are answered, the lamps are extinguished from the top downwards, i.e., assuming three calls are waiting and no fresh calls arrive, lamp No. 3 will be extinguished when the first call is answered, lamp No. 2 when the second call is answered, and so on. The vertical strip of lamps, therefore, functions as a load indicator, the height of the lamp column increasing when calls are arriving at a rate greater than they are being answered and vice versa.

Incoming calls are queued in the order of arrival and answered in the same order.

To answer a waiting call a free telephonist selects an idle connecting circuit (as described later), and this releases the call at the head of the queue, and causes the demand distributor switch to search for the outlet associated with the marked connecting circuit.

During periods of light load the connecting circuits can be set by the telephonists to receive incoming calls although no calls are waiting. Under these conditions, a call, when it arrives, will not be queued, but will be routed directly to a marked connecting circuit.

The lamp strip referred to comprises 11 lamps, the first 10 of which are used for indicating queued calls; should nine lamps display, nine calls are waiting, but should the 10 lamps display there may be more than 10 calls waiting. Normally, the maximum number of queued calls should not exceed four or five. As stated earlier, the first 20 contacts of the demand distributor switches will be used for queueing, and an indication up to 20 queued calls will be given on the Delay Supervisor's position, but there is no point in going beyond 10 on the demand positions. The remaining or top lamp of the strip has a dual function:—

(a) To flash on all positions when the call at the head of the queue has remained unanswered for a predetermined period;

(b) To display steadily when a demand position has been set to receive an incoming call and no calls are waiting. This allows the monitor to keep a check on the telephonists.

Figure 2 shows the arrangement of the lamps and how they function under five different conditions. It will be understood, of course, that there is only one lamp display strip on each position. In the photograph the same strip has been repeated for purposes of direct comparison.

later—and when a call is reverted the calling subscriber must be connected to the answering side, so that the call can be timed. The connecting circuits on the demand positions have been designed, therefore, that by appropriate manipulation on the part of the telephonist incoming calls are answered and reverted calls set up on the answering side; and outgoing calls set up on the calling side.

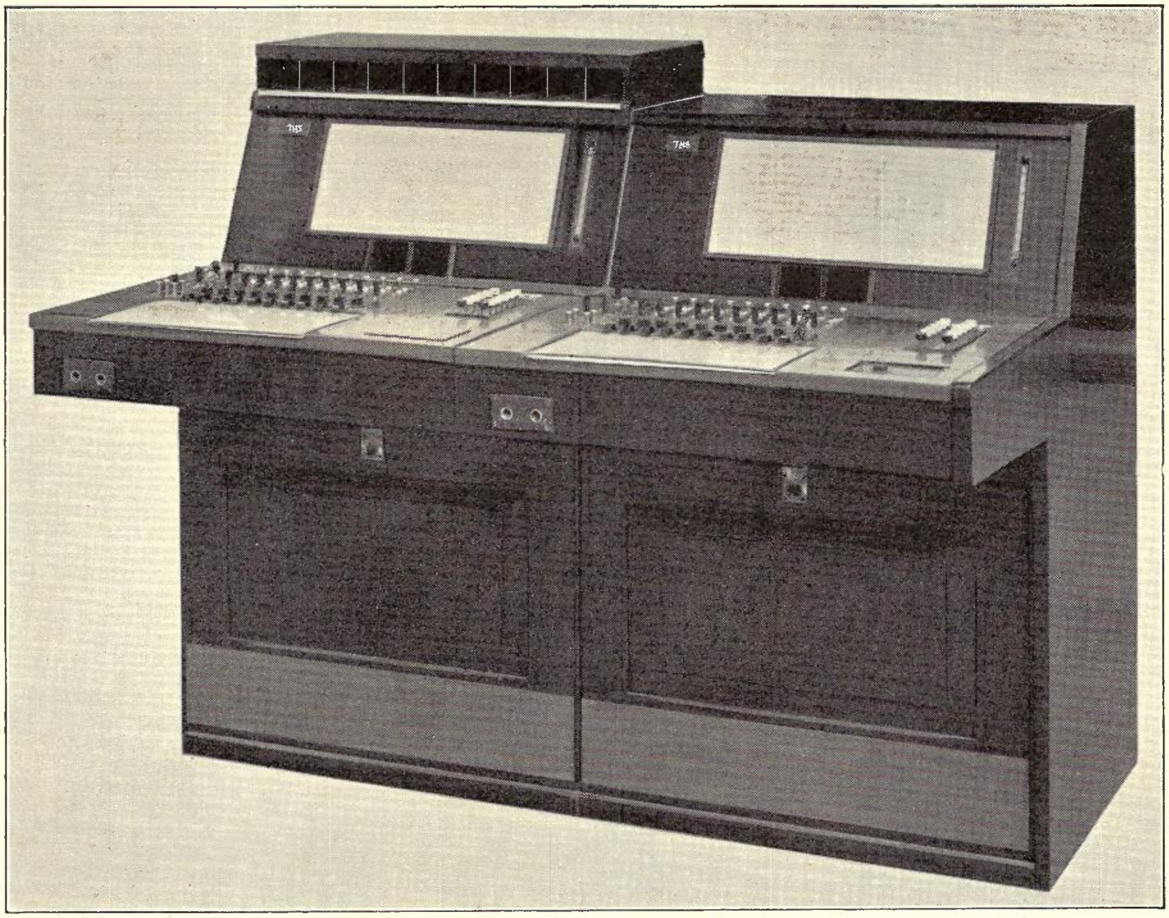


Fig. 1.—TYPICAL POSITIONS IN THE MAIN SUITE.
Note: The top on the left-hand position is removable and is used for ticket storage when a demand position is used for delay working.

To complete a demand call from a Melbourne subscriber to another Victorian subscriber—Ballarat, for example—the demand telephonist couples a sender to the position circuit. The telephonist then sets up a 3-digit code on the keystrip, this code being recorded by the sender and translated suitably to route the call to the required trunk group. The first code transmitted by the sender operates a "first trunk selector," and this is followed by codes which direct a "second trunk selector" to a free line in the trunk group required.

Should the demand telephonist be unable to complete a call on demand, the caller will be informed of the probable delay and advised that he will be called when service can be given. Timing of calls is effected from the answering side of a connecting circuit—with the exception of the suspense positions, which will be described

Figure 1 shows the panel arrangements: the pneumatic tube outlet to the position can be seen on the left of the panel and to the right of this, portion of the bulletin space, and also the display lamp strip. Two lamps are placed behind the bulletin frame and are invisible until they glow; these lamps are:—

(a) Pneumatic tube alarm lamp at the lower right-hand corner, which displays when the inlet valve is not to be used, due to a blockage, for example;

(b) Monitor call lamp at the upper right-hand corner.

Key Shelf Equipment for Connecting Circuits

Referring now to Figure 3, which shows the layout for a demand position, the key shelf equipment of each connecting circuit consists of:—

(a) **Release Key (REL.).** The release keys will be seen adjacent to the hinge. These keys are numbered 1 to 6 consecutively, to distinguish each circuit. These keys are of the order wire type and are non-locking. The momentary operation of a release key will completely clear the connecting circuit.

(b) **Engaged Lamp (ENG.).** This lamp glows immediately a connecting circuit is taken into use and is not extinguished until the circuit is cleared. Gives a visual indication to the telephonist of busy circuits.

(c) **Answer and Call Supervisory Lamps, respectively (ANS. SUPY.) and (CALL SUPY.).** These lamps indicate call conditions at various stages by glowing steadily, flashing, flickering or by being extinguished. The indications are:—

(i) **Steady Glow.**—The called subscriber or the distant country telephonist has not answered, or the called subscriber has cleared. On incoming calls indicates that the caller has cleared.

(ii) **Flashing.**—On incoming calls, denotes that the caller has sent a recall signal. When a telephonist "camps" on a line, flashing occurs when the line becomes free. Flashing ceases when the speak key is thrown.

(iii) **Flickering.**—Takes place only on outgoing stored calls when congestion lifts. Pending a trunk becoming free the steady glow is interrupted once every six seconds.

(iv) **Extinguished.**—This is the normal condition when the connecting circuit is free, but when the engaged lamp is displaying, both supervisory lamps out indicate that the call is proceeding normally.

(d) **Time Check Lamp (TIME CH.).** After the timing circuit has been started this lamp glows steadily for 12 seconds immediately prior to the expiration of 3, 6 and 9 minutes provided, of course, the caller is still holding the connection. At the end of the 3- and the 6-minute periods the lamp goes out, but at the end of the 9-minute period the steady glow changes to a flicker to indicate to the telephonist that further registration cannot take place, and that resetting is required, assuming the call continues. When the lamp commences to glow just before the end of each 3-minute period, the parties receive three short pulses of tone to advise that another 3-minute period is about to commence.

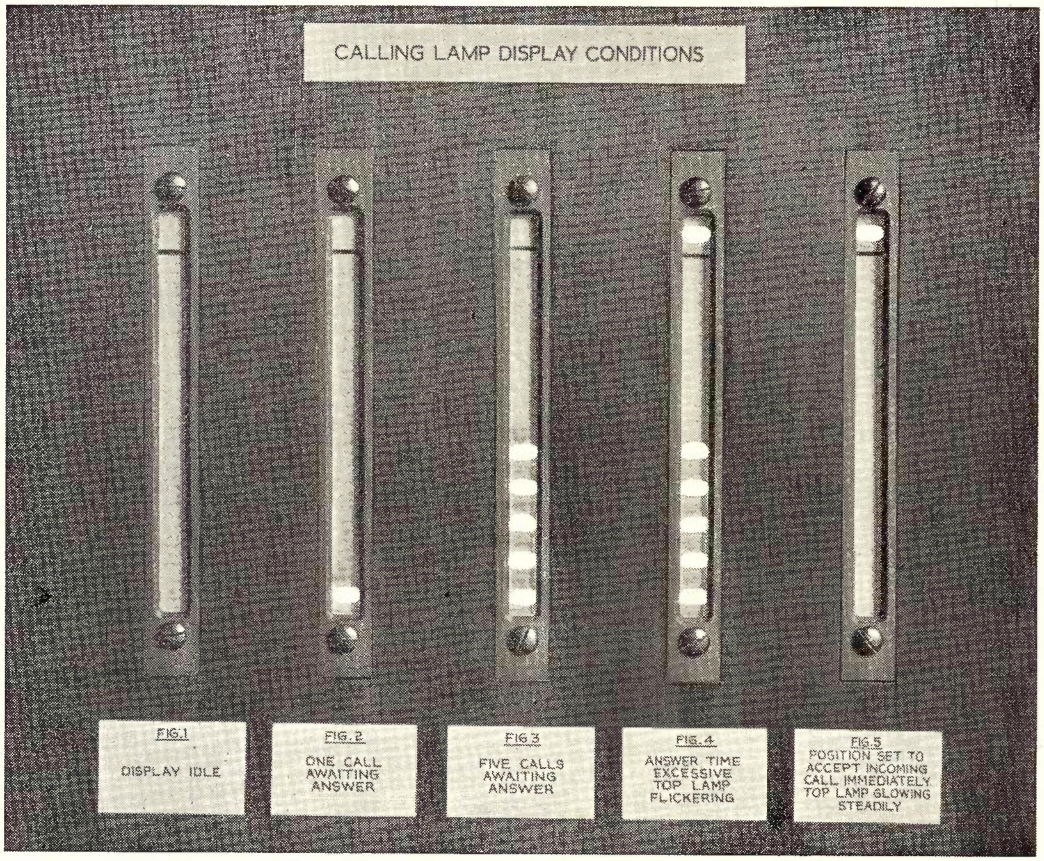


Fig. 2.—Calling Lamp Display Conditions.

(e) **Speak and Monitor Key (SPK.) and (MON.).** This is a three-position locking type lever key. In the "speak" position—away from the telephonist—the connecting circuit is associated with the position equipment and can be used to answer incoming calls or set up outgoing calls, and on established calls the telephonist can speak to both parties on the connection. In the "monitor" position—towards the telephonist—the telephonist can listen without impairing transmission. Excepting for one operating feature the operation of a key either to speak or monitor, automatically cuts out the remaining keys; for example, if No. 3 key is operated, followed by No. 6, the operation of the latter key has no effect; the key first operated takes priority. The exception comes about in this manner: Assume that No. 3 circuit has a call in storage and that congestion lifts at a moment when the telephonist is speaking on another connecting circuit, the telephonist by operating No. 3 key can take the call out of storage without interruption to what she is doing, and immediately she is free she can attend to No. 3 circuit. Connections, therefore, cannot be cross-switched by the operation of two or more keys.

(f) **Time Check.**—Timing of calls is affected by the use of the B.P.O. Clock No. 44. This component records the chargeable time in minutes and decimal parts of a minute. It is started by the telephonist and continues to record as long as the caller holds the line. Timing ceases when the caller clears. Registration up to 9 minutes is provided for, after which resetting and restarting is necessary. If the call exceeds 9 minutes the telephonist makes a suitable note on the ticket so that when the call is completed no confusion can arise as to the correct chargeable time. The time check is started by rotating the black rectangular key—not very clear in the figure—through 45 degrees in an anti-clockwise direction: the telephonist can stop timing by restoring this key. The recording mechanism is restored to normal by depressing the reset but-

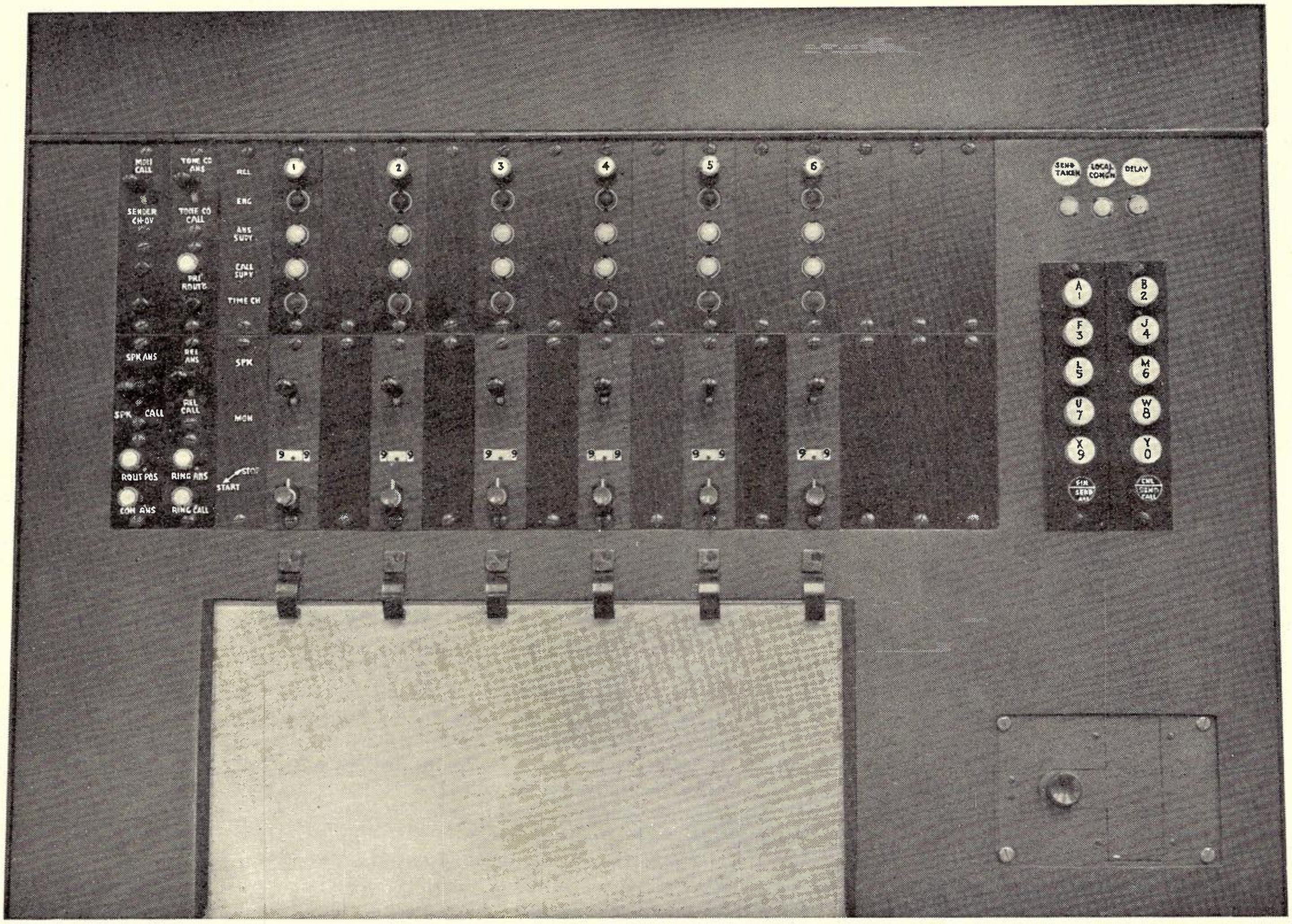


Fig. 3.—Key shelf of a demand position.

ton downwards with the start key normal. In the normal position the time check registers 9.9 minutes, and the first impulse brings up 0.0. Impulses occur at 6-second intervals. As these pulses can occur at any instant within one-tenth of a minute after the start key is operated, the subscriber is given the benefit of this preliminary variable period.

(g) **Ticket Clip.**—While a call is in progress the ticket is held under this clip to identify the connecting circuit being used.

Common Equipment on Key Shelf

(a) Pneumatic tube inlet—seen at front right corner.

(b) Rhodoid covered space for notices, instructions, etc.

(c) **Monitor Call Key (MON. CALL), and Sender Changeover (SENDER CH.-OV.).**—This is a three-position locking key. In the monitor call position—away from telephonist—this lights the monitor call lamp located behind the bulletin frame on the position, or the adjacent position, as one monitor call lamp serves two positions. A pilot lamp also lights on the relevant monitor's post and a buzzer operates as well. The buzzer and the pilot lamp attract the monitor's attention and the lamp on the position indicates the location of the call. Although the bulletin space on a position may be covered by notices, the monitor call lamp shows clearly when glowing. In the sender changeover position the telephonist is given another sender as first choice; senders are coupled to a position in a fixed order of choice and during slack periods the same sender will always be assigned to a position. Should the telephonist encounter a faulty sender this key gives an alternative choice. When the sender changeover key is operated a lamp displays on the nearest monitor's post, and the monitor can investigate the reasons for the key being operated.

(d) **Speak Answer and Speak Call (SPK. ANS. and SPK. CALL).**—This is a three-position locking key and allows the telephonist to speak on either side of a connection without the other party hearing the conversation. The speak key on the connecting circuit must be operated, of course.

(e) **Routing Position (ROUT. POS.).**—This is a non-locking key of the order wire type. Operation of this key gives the telephonist access to the routing position from which information can be obtained regarding routings not covered by the information available on the position.

(f) **Connect Answer (CON. ANS.).**—This is a non-locking key of the order wire type. This key gives discrimination when the answering side of a connecting circuit is to be used to answer an incoming call. With the connecting circuit speak key already operated, momentary operation of the connect answer key sets up the conditions required to answer an incoming call. If calls are waiting, a call will be released from the queue, and if no calls are waiting the operations already described will cause an incoming call to come straight through without being displayed in the queue. If a connecting circuit has been set to receive an incoming call and the speak key restored before a call is connected, the answering conditions are cancelled.

(g) **Tone Cut-off Answer and Tone Cut-off Call (TONE C. ANS.) and (TONE CO. CALL).**—This is a three-position non-locking key. This key is used to cut off discriminatory tones received by the telephonists. Special tones, as distinct from the ordinary services tones such as busy, overflow, etc., are used to assist the telephonists. The tone cutoff key has no effect on the ordinary service tones.

(h) **Primary Routing (PRI. ROUTG.).**—Under the zoning scheme described in the previous issue, it will be appreciated that a call may be completed over a secondary or alternative route. When the route selections involve automatic selecting equipment at all stages, calls go into storage on the primary route should the primary and the alternative routes be congested. In the early stages of the system many of the primary and the secondary routes will terminate on manual exchanges, and conditions can arise which prevent automatic operation of the call storing arrangements. An example will make this clear: Assume that a group centre exchange "A" with direct lines to the main trunk exchange is in a zone in which the zone centre exchange is manually operated. The alternative route to "A" via the zone centre exchange must be completed manually at the zone centre and, therefore, should the direct route be congested the call will be diverted to the zone centre exchange, and so far as the switching equipment in the trunk exchange is concerned, the call has been completely routed. The Melbourne telephonist, as soon as she finds that the call has been diverted to the zone centre, asks to be connected to exchange "A." If a line is available the call goes through, but if the tie trunks are congested service cannot be given and the only thing to do is to call later. The Melbourne telephonist, therefore, releases the call and sets it up again, this time depressing the primary route key instead of the last digit "0." This action prevents the call taking the secondary route, and if the primary route is still congested the call then goes into storage on the primary route.

(i) **Release Answer and Release Call (REL. ANS.) and (REL. CALL).**—This is a three-position non-locking key and with the speak key of a connecting circuit operated, enables the calling or the answering side of a connection to be released. The operation of the connecting circuit release key, as already stated, completely clears both sides of a connecting circuit. Release of either side of a connection, whilst still retaining the other, is required in certain circumstances, such as a wrong number being obtained, or several calls being worked off in succession, and so on.

(j) **Ring Answer and Ring Call (RING ANS.) and (RING CALL).**—These are non-locking keys of the order wire type and are used for recalling the telephonist at the distant end on main trunk lines. The initial calling signalling is given automatically.

(k) **Digit Key Strip and Associated Lamps.**—The key strip consists of 12 keys, ten of which have white tops and carry in black the standard dial designations A1, B2, F3, etc., whilst the two remaining keys have red tops and carry in white the designations FIN./SEND ANS. on one, and CNL./SEND CALL on the other—(Finish/Send Answer and Cancel/Send Call) respectively. For brevity the two latter keys will be referred to as FSA and CSC respectively, using the first letter of each word. The three lamps are SEND. TAKEN (Sender Taken), LOCAL CONG'N. (Local Congestion) and DELAY.

A sender is coupled to a connecting circuit by the telephonist operating the associated speak key and momentarily operating the FSA or the CSC key, depending on whether sending is required on the answering or the calling side of the connecting circuit. The SEND. TAKEN lamp glows steadily immediately a sender has been coupled to a connecting circuit, and is not extinguished until the sender has been freed.

When the number has been completely keyed up, on calls to metropolitan subscribers and on supplementary numbers over main trunk lines, the FSA key is operated momentarily to signal the sender that the set up is complete. The FSA key is also used under delay working conditions, as will be described later.

The CSC key is operated after a sender has been associated with a connecting circuit whenever it is necessary to cancel the set up when a mistake occurs during the setting up. If sending has been completed, the call must be released by release key operation as described.

Excepting as described below, a sender automatically releases on completion of call routing, this being indicated by the SEND. TAKEN lamp going out. The exceptions are:—

(a) **Incomplete Set Up.** — A sender releases after a period of 30 to 60 seconds.

(b) **Trunk Group in Delay.** — When the required trunk group happens to be in delay the SEND. TAKEN lamp continues to display, but the DELAY lamp functions as follows:

(i) Flickering—delay up to 15 minutes.

(ii) Flashing—delay between 15 and 30 minutes.

(iii) Steady glow—delay 45 minutes or more.

The sender is released by the operation of the CSC key, but failing this the sender will be released automatically as in (a).

If the SEND. TAKEN lamp remains alight and the LOCAL CONG'N. lamp displays, this indicates congestion within the trunk exchange itself. The sender is released by operation of the CSC key or as in (a).

Where a call has been steered automatically over an alternative route, which means that the call will be answered by a telephonist different from the one the Melbourne telephonist expects to answer, she is so warned by the SEND. TAKEN lamp commencing to flash. Flashing continues until the CSC key is operated as conversation cannot take place until the sender is freed.

Delay Working

The state of the various trunk line groups is indicated on the Delay Supervisor's Position. A trunk line group, under normal conditions, will be worked on a demand basis even though periods of congestion occur. When a group has become congested to such an extent that delay working is necessary this is introduced—

(a) automatically: when the number of stored calls has reached a predetermined figure depending on the size of the group;

(b) manually: at the discretion of the Delay Supervisor.

The introduction of delay working either automatically or manually is controlled by keys on the Delay Supervisor's Desk. When the conditions for delay working have been set up for any trunk line group the demand telephonists cannot obtain access thereto, and on receiving the delay indication described earlier will suitably inform the caller and send the ticket to the pneumatic tube distribution position (PDP), from where it is routed to the position allocated to operate the trunk line group on a delay basis.

The delay positions, by operating the FSA key after receiving the delay signal, can force entry into groups in delay, this facility being under the control of the Delay Supervisor. The delay positions can hold the trunk lines if the distant end is manual, the necessary action of raising the distant telephonist being effected by operation of the ringing key: if the distant end is automatic, a trunk line must be released after each call.

The delay ticket trays, one of which is shown on the left-hand position of Fig. 1, merely rest on the tops of the positions. If it is necessary to change to another position, the tray complete with tickets can be moved easily. The ticket trays also identify the positions which are being used for delay working.

Interstate trunk lines are accessible only from the Interstate positions. During normal periods the interstate lines, as will be described later, will be worked on what is virtually a delay basis. Subscribers requiring interstate service will be answered from the demand suite and the telephonist, after taking particulars, informs the subscriber he will be called later. The ticket is then sent to the PDP and from there to the interstate suite, where the call is dealt with in its order.

Demand Link Positions

It has been stated earlier that the number of outlets from a demand distributor to the demand positions is 180. The total number of outlets from the demand distributors is more than twice this number and this means that the multiple must be broken and initially these outlets will be arranged in three groups, each group handling approximately the same volume of traffic. The traffic incidences during busy periods will not occur simultaneously in each group and one of the purposes of the demand link positions is to meet these unequal incidences of traffic.

Four link positions are being provided and each one will be arranged so that it can deal with the traffic from two groups. Normally each link position will deal with the traffic from one particular group of the two to which it has access, but when the other group receives a preponderance of traffic the calls dealt with will be from that group.

The group which a link position serves is determined automatically, and this arrangement permits the telephonist to operate under the same conditions as the ordinary positions. Each link position has a calling lamp display, which indicates the number of waiting calls in the group to which it happens to be switched.

The manner in which a link position operates will be described. Assume that group 2 has three calls waiting and group 1 has two. If the first call in each group has not been waiting for an unduly long period, the link position will remain in its normal state of serving, say, group 2, which happens to be the one with the greater number of calls. If the first call in group 1 has been waiting for an appreciably longer period than the first call in group 2, then, although there are fewer calls in group 1, the link position will be switched automatically to this group. When both groups have calls which have been waiting attention for an unduly long period, the switching of the link positions is determined on a call quantity basis. Likewise, when calls are being answered at what may be termed a normal rate, the link position will be switched to the group which has the greater number of waiting calls. The period referred to as "unduly long" can be set to a value lying between 10 and 20 seconds approximately; furthermore, the period set for each group need not be the same. Group 1, for example, could be set to 15 seconds and group 2, if a smaller number of positions had to be served, might be set to 20 seconds. These are the periods at which the top lamp of the lamp display commences to flicker.

Another function of the link positions is to concentrate the traffic during periods of light load. Without these positions night traffic would need to be answered from three separate positions, i.e., one for each group. With the link position arrangements being provided, night traffic can be answered from two positions.

The ordinary demand positions become inactive when the positions are vacated. The link positions always function, whether the positions are staffed or not, and this ensures that when the staff is at a minimum the arrival of calls will still be indicated.

(To be continued.)

Tungar Rectifiers For Battery Charging

W. Gray

Introduction. The use of vacuum valves as rectifiers of alternating currents is well known and considerable use is made of high vacuum diodes for the supply of D.C. power at comparatively small current values.

Such valves are generally of the "hot cathode" type, i.e., a heated filament (the cathode) is utilized as an electron emitter. Referring to Fig. 1, the cathode "C" is heated by A.C. from a filament tapping on the mains transformer. If the voltage applied by the secondary of the transformer be such as to make the potential anode (A) to cathode (C) positive, then the electrons will be attracted to the anode and a current will flow through the secondary winding of the transformer, the battery and the valve as shown by the arrow I. When the applied voltage is such that this potential is negative, the emitted electrons will be repelled by the anode and no current will flow. Thus, the alternating E.M.F. developed in the secondary of the transformer will result in pulses of unidirectional current in the secondary circuit. The current is said to be rectified. At all times electrons exist in the space between the heated cathode and the anode and these electrons constitute a strong negative charge or "space charge" which must be overcome by the positive anode potential before current will flow. Fig. 1 depicts a half wave rectifier—one in which anode current flows only during alternate half cycles of the applied voltage.

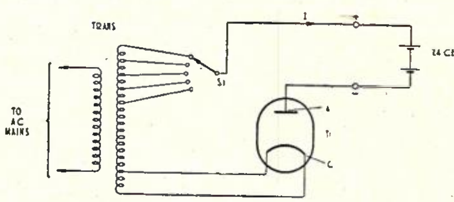


Fig. 1.—Half-wave rectifier circuit.

Valve Action. Due to the "Space Charge" effect the high vacuum diode has a large internal resistance and requires the application of large anode potentials. The heat generated at an anode is proportional to the anode voltage multiplied by the anode current. With high vacuum valves considerable anode heating takes place, and if large current values are required the anode and consequently the whole valve must be made large in order that this heat may be satisfactorily dissipated.

The detrimental effects of the "space charge" may be eliminated by the introduction of an inert gas to the tube. Tungar valves are of the gas-filled type. During manufacture the valves are exhausted to a high vacuum and then filled with purified argon gas. This gas is an element and is one of those known as "rare gases" which are very stable and do not enter into chemical combination with other elements.

In general, an atom consists of a central portion — or nucleus — positively charged — around which one or more electrons revolve. The positive charge of the nucleus and the negative charge of the electrons are equal so that the atom as a whole is neutral. If some or all of the electrons are dislodged, the balance is upset and the atom becomes positively charged. Such action occurs when the gas atoms become ionized by collision.

The action of a gas-filled valve may be described, briefly, as follows:—At low anode potentials the anode or space current is small and the detrimental effects of the space charge are in evidence. With increase of anode potential this current slowly rises until a potential is reached (approximately 13 volts in the Tungar), at which the anode current rises quickly. At this stage the anode potential has reached such a value that the velocity of the electron stream is sufficient to cause ionization of the gas atoms. The electrons set free are attracted to the anode while the positively charged nuclei, because of their weight, are repelled slowly (comparatively) towards the cathode and come into the space charge region. By reason of their low velocity the nuclei remain longer in the "space charge" region and constitute a positive charge neutralizing the negative space charge and allowing greater anode current with a given anode potential than in the case of a high vacuum valve.

Because of the low anode voltage in the case of a gas-filled valve the heat generated at the anode is less than in the case of a high vacuum valve.

A disadvantage of a gas-filled valve is that it may pass a current in the reverse direction, i.e., when the anode is at negative potential it may act as a cathode, setting up a glow discharge which may merge into an arc discharge. The "Maximum Peak Inverse Voltage" of a rectifier valve is the maximum negative potential which can be applied to the anode without the flow of reverse current. In a 6 ampere Tungar valve this potential is approximately 375 volts.

The use of an anode material which does not readily emit electrons is one method of preventing such reverse current. In the Tungar valve the anode is graphite, which is a very poor emitter of electrons compared with such a material as tungsten, which is used for the cathode.

The reverse current may also be kept low by the use of an anode of comparatively small dimensions. This consideration is met in the Tungar valve since being a gas-filled valve with low anode voltage, considerations of heat dissipation do not require an anode of large surface area.

The cathode is the source of electrons which comprise the anode or space current and the efficiency and life of a valve depend upon the choice and use of cathode material. In the Tungar, the cathode is a coiled spiral of tungsten worked at a high temperature which enables a high efficiency of electron emission, since the rate of emission increases considerably for small increases of temperature.

In a high vacuum valve, the use of a cathode at high temperature results in its vaporization and gives a short life. If, however, the cathode is surrounded by argon gas at a pressure of about 5 m.m.'s of mercury, such vaporization does not take place and, therefore, in the Tungar valve high cathode temperature is used without fear of vaporization. High efficiency as well as long cathode life is obtained. However, impurities in the argon gas will cause disintegration of the cathode, so during manufacture of the Tungar, magnesium is introduced to the valve. This reacts chemically with the impurities and keeps the gas in a pure state practically throughout the life of the valve. The silvery appearance of the inside of a Tungar valve is due to the magnesium.

The 6 ampere Tungar valve is used extensively. The technical details of this tube are listed below:—

Max. Output—Volts, 90; Amperes, 6.
Filament Volts—2.2.
Filament Current—18A.
Pick-up Voltage—11-18; 13 average.
Arc Voltage—6-11; 8 average.
Max. Peak, Inverse Volts—375.

The "pick-up voltage" is that anode voltage at which ionization takes place, after which an arc discharge continues and the anode voltage drops to 8 volts (arc voltage).

Fig. 2a and 2b show approximate voltage and current curves for the typical half wave rectifier shown in Fig. 1. From the curve of Fig. 2a it will be seen that the instantaneous E.M.F. of the secondary of the transformer must be such as to overcome the voltage of the battery and apply to the anode a positive potential equal to or greater than the pick-up voltage. The peak inverse voltage is considerable (in this case approximately 150 volts). Fig. 2b indicates approximate current curves and three facts are clearly illustrated:—

(i) That pulses of current occur only during a small portion of each alternate half cycle of input voltage.
(ii) That a choke coil considerably smoothes the output.
(iii) That the maximum peak plate current is reduced when a choke coil is used in the output.

In Fig. 2c are current curves which apply to the rectifier shown in Fig. 3. It is seen that output current flows for a small portion of each half cycle of applied E.M.F. and that the output current is substantially flat when a choke coil is used.

Typical Circuit. Fig. 3 shows a typical power

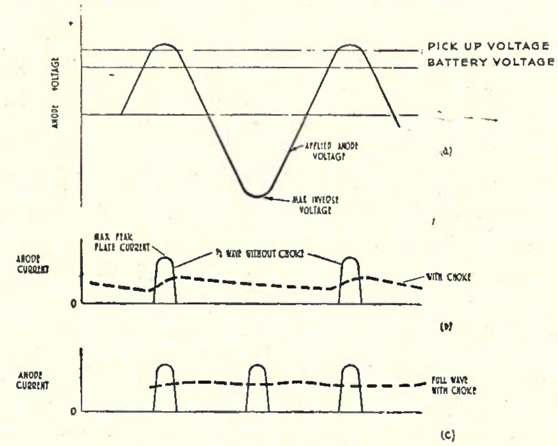


Fig. 2.—Voltage and current curves.

circuit for a Private Automatic Branch Exchange installation. Full wave rectification is employed since when used with a suitable choke coil the output D.C. is substantially flat and permits "floating" without the introduction of noise. Adjustment of the D.C. output is achieved by means of the switches S1 and S2, which vary the value of the applied anode voltage. The ammeters shown in the anode leads are D.C. moving coil meters and give the average value of current—the output of the rectifier being the sum of the two ammeter readings.

The D.C. output of the rectifier is rated at 65 volts 10 amps. and two six ampere Tungar valves are used.

An interesting feature of this circuit is that whereby a normal charge rate is reduced to a "trickle charge," the switches S1 and S2 are adjusted to provide a normal full charge with the rectifier functioning as a full wave rectifier. Relay "B" provided with a mercury tube contact is operated. Release of relay "B"—brought about when the battery voltage rises to 52V—opens the anode circuit of one valve. The rectifier now functions as a half wave rectifier and without further adjustment of the switches S1 and S2 the charging rate is reduced to a small trickle charge. By adjustment of the preliminary settings of S1 and S2, the trickle charge rate may be increased or decreased.

A charging circuit is thus obtained such that the rectifier in the full wave connection supplies heavy loads, while at other times a trickle charge (in half wave connection) maintains the battery in good condition. Regular overcharges with consequent rise of busbar voltage is thus avoided.

The operation of the circuit is as follows:—

Assuming that the battery voltage is less than 52 volts and greater than 48 volts, then relay B is operated and closes the anode circuit of the first valve. The rectifier (operating under full wave conditions) supplies normal charging current to the battery and load via relay C, which is connected across a shunt in the main charging circuit. Relay C operates and at contact C2 closes the circuit of relay D which, however, will not operate until the battery voltage rises to 52 volts. When this occurs, relay D operates (the contact arrangements at D2 being to ensure quick and reliable operation) and at contact D1 closes a circuit for relay A, which is energized and locks through contact A1. The operation of relay A causes the release of relay B which opens the anode circuit of one valve and converts the rectifier to half wave operation. A small trickle charge current now flows. Relay C is adjusted to release when trickle charge flows and releasing restores relay D. When the battery voltage drops to 48 volts, relay A releases. A releasing, operates B. Subsequently C operates as the full charging current is applied when B operates. The full charge continues until the voltage again rises to 52 volts.

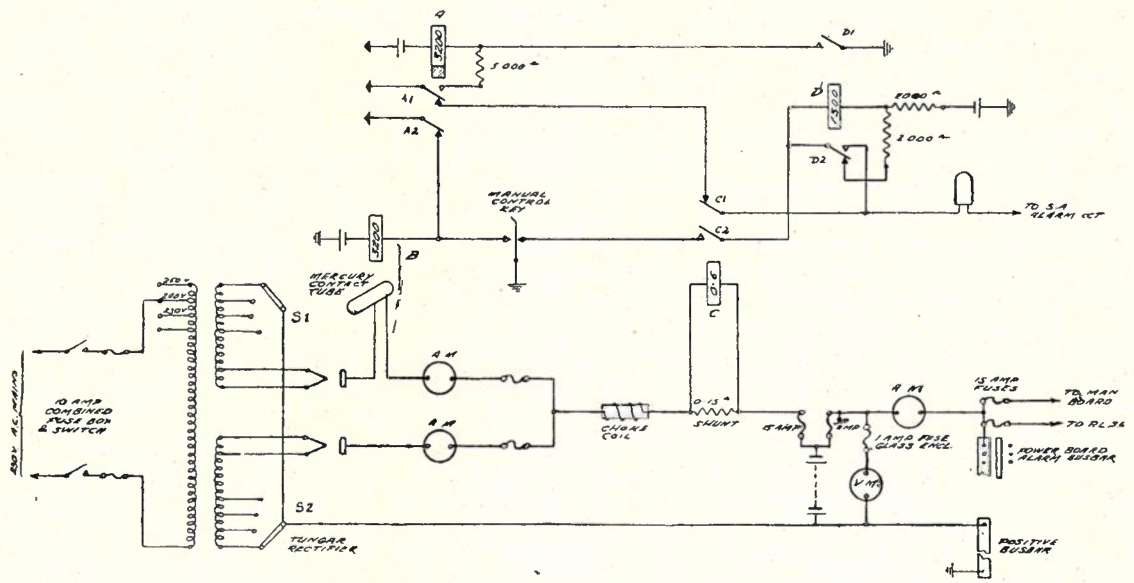


Fig. 3.—Typical power circuit showing Tungar rectifier.

Incorrect operation of the circuit is arranged to provide an alarm. If relay D operates and for any reason C relay does not release an alarm circuit is closed via contacts D2 and C2 to earth at the manual control key. This alarm signifies that the charge has not been disconnected. If relay A releases, but C does not operate (charge fail) the alarm circuit is completed via contacts A1 and C1 to earth.

THE C.B. AND AUTOMATIC HANDSET WALL TELEPHONE—

237CBW AND 237AW

T. T. Lowe

This article describes the Standard C.B. and Automatic Handset Wall Telephone which has just been adopted by the Department.

Reason for Introduction: Telephone 566, which was the standard type of handset telephone adopted when the Department introduced handset telephones (in 1932), is designed as a table instrument. Several manufacturers produced wall types of moulded instruments and a few of one type were purchased by subscribers and installed during the short period when subscribers were allowed to purchase their own handset telephones; but the Department did not adopt any of these types or purchase any stocks. It was arranged to meet the demand for wall type instruments by mounting the table model on a mild steel bracket which was affixed to the wall.

This method possesses an obvious advantage in connection with the purchasing and stocking of telephones, in that only one model is involved instead of two for each of the three types of service, i.e., Magneto, C.B. and Automatic. In practice this means only three models instead of six. On the other hand, there are obvious disadvantages in using the table model on a wall, the arrangement being at best an improvisation while the cost of supplying and fitting the bracket is additional, and there are some maintenance difficulties. For these reasons there has been a constant watch on developments of moulded wall sets and it is possible that eventually a suitable moulded type of wall instrument, when standardized, will be adopted by the Department.

In the meantime, after considerable effort and investigation, type 237 described in this article has been introduced as an instrument designed for wall mounting, having a case which is of the existing non-moulded standard type used in ordinary C.B. and Automatic instruments designed for wall mounting.

There have been two objectives: firstly, to find a satisfactory use for the existing stock of telephone cases and bellsets, and secondly, to provide an instrument which could be adopted as a wall type standard. The instrument standardised includes all the advantages of handset operation of the 566 wall type and, in addition, all the latest improvements in circuit operation.

Appearance of Renovated Instrument: There is obvious need for all concerned in the production, handling, fitting and canvassing of this instrument to recognise that it is to compete with the moulded table model and must be supplied in absolutely new condition to the subscriber so that there will be no cause for any suggestion that higher rental is being charged for a second-hand article. The approved models have been scrupulously cleaned down and completely stripped. The woodwork must have the entire exposed surface cleared of all indentations and the surface preferably machine sanded before it is stained and polished. Some very nice timbers have been used in these cases and when properly treated the appearance is attractive. Before deciding on staining and polishing as the treatment for the case, models in special black lacquers were examined, but rejected because the finished instrument was too dull and it was found better to brighten it by using the standard stainless

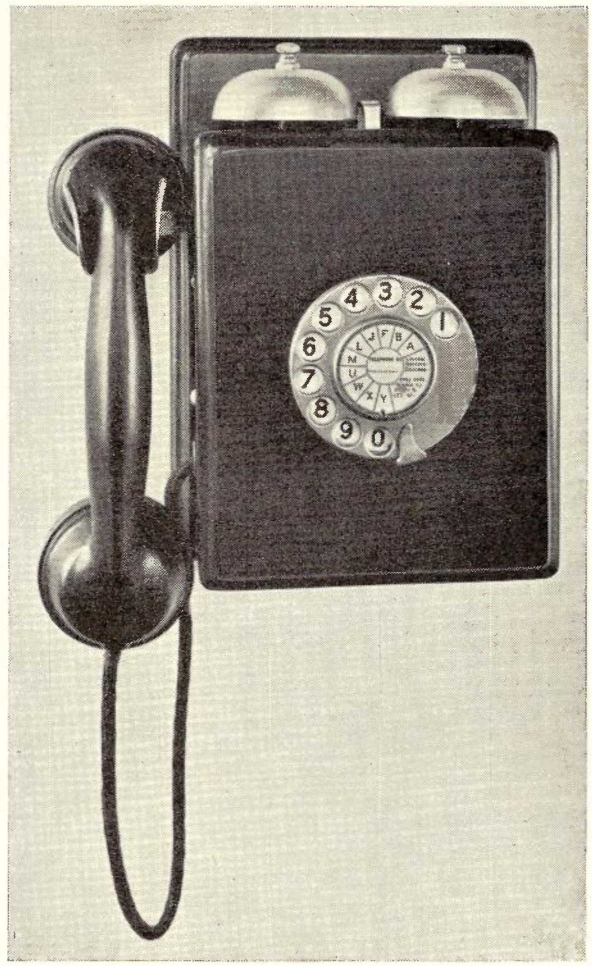


Fig. 1.—Handset Wall Telephone 237 A.W.

steel dial and having all exposed metal fittings finished to have appearance equal to or brighter than that of the dial, such as chromium plating over nickel.

The Stock Title Numbers Allotted to Telephones: The stock title numbers of telephones are allotted as follows:—

(1) Where practicable and convenient, the stock title numbers agree with the relevant B.P.O. numbers.
(2) Table telephones have even numbers and wall telephones odd numbers.
(3) Numbers between 300 and 399 will be reserved for Handset telephones of the new shape, i.e., the 300 type with an anti-sidetone induction coil. (Journal, Volume 2, No. 2, Oct., 1938.)
(4) Numbers between 200 and 299 will be reserved for all other Handset telephones fitted with an anti-sidetone induction coil. (Journal No. 6, Dec., 1937, and Volume 2, No. 3, Feb., 1939, and this issue.)
(5) Numbers below 199 will be reserved for all other types of telephones, i.e., the older type sidetone sets and Handset telephones fitted with an anti-sidetone transformer No. 35A.

Number of Handset Telephones in Service: There are at present approximately 275,000 handset telephones in service in the Commonwealth. Of these 215,000 are C.B. and Automatic, of which one-seventh are of the wall type. The net increase per month is about 950 C.B. and Automatic wall type or between 11,000 and 12,000 per annum, so that there is ample scope for the use of the new instrument, which is intended to be issued instead of the 566 and 232 types on wall brackets as soon as stocks are available.

General Description: The telephone is shown in Fig. 1. The C.B. wall instrument will be known as 237CBW and the automatic wall set as 237AW. The polished oak telephone case is 6 ins. wide x 7¾ ins. long x 3 ins. deep, and is provided with a polished oak back 6¾ ins. wide x 9½ ins. long. The magneto bell mechanism, switchhook spring set, anti-sidetone induction coil, and 2 mF condenser, are mounted inside the wooden case, the bell gongs being mounted on top of the case. The switchhook is fitted on the left-hand side of the instrument to provide the rest for the standard black moulded handset No. 164, which is fitted with a black Swedish Ericsson type instrument cord 3 ft. 6 ins. long. On the automatic instrument the calling dial is mounted in the centre of the front of the wooden case. In the C.B. set the dial is replaced by a wooden dial dummy polished to match the oak case. One advantage of the new instrument is that when an ordinary C.B. or Automatic wall telephone is to be replaced by a handset instrument, there will be no further markings on the wall, as the new instrument occupies the same space and the same fixing holes and plugs will serve.

Induction Coil: Anti-sidetone induction coil No. 22 or equivalent was used in the first models and may be used again, the circuit being in accordance with Fig. 6. In many cases, however, the sidetone induction coil No. 14 having 17 ohms + 26 ohms windings is already available, therefore it has been modified to the anti-sidetone type (A.S.T.I.C. No. 14A) by providing two additional non-inductive windings of 500 ohms and 50 ohms respectively. Additional terminals marked 5 and 6 are fitted on the wooden cheeks and the 500 ohm N.I. winding is connected between terminals 3 and 5 and the 50 ohm N.I. winding between terminals 5 and 6. The induction coil is connected as a hybrid transformer; the 550 ohm

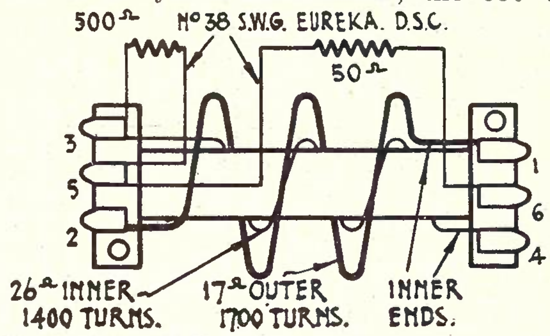


Fig. 2.—A.S.T.I.C. No. 14A connections and windings.

N.I. windings and the 2 mF. condenser forming the balance network. The operation of the induction coil in the circuit is explained later. Fig. 2 shows the connections and the windings.

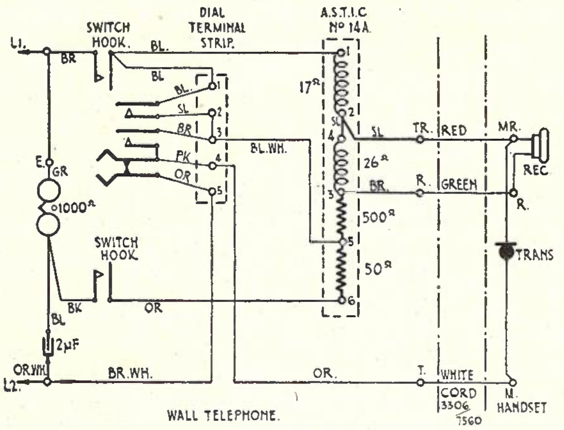
Switchhook: The switchhook, finished in chromium plate or equivalent, is designed specially for use on this instrument. It is shaped to prevent the handset when used reasonably, from being damaged by striking the wall, the blackboard, or the side of the wooden case of the telephone, if it is hurriedly replaced by the subscriber. The design has been altered slightly from that shown in Fig. 1 to suit manufacturing needs.

Transmitter Inset: Transmitter Inset No. 13 is used. It is generally known that this is now preferred to No. 10, as it incorporates certain improvements, which were explained in detail on page 268 of the December, 1937, issue of this Journal.

Instrument Cord: The use of the black rayon-covered instrument cord of Swedish Ericsson or equivalent design has been the practice for some time now and is being continued in this model. It gives freedom from kinking, twisting and excessive fraying, especially when it is treated reasonably. Much can be done by officers to effect improvement in the manner in which cords are treated by subscribers. On each occasion when attention is given to a telephone it is advisable to carefully untwist the cord and tactfully point out to the subscriber how easily this may be attended to constantly, so that the cord may be kept straight and the risk of faulty service, due to cord failure, thereby almost eliminated.

Circuit: The telephone is wired and connected in accordance with Drawing C.1514 (see Fig. 3), which shows also the connections between the telephone and the handset. A copy of the circuit is pasted inside the wooden case. If an extension bell is required it is connected between Line 1 and E and the strap removed. For C.B. working terminals 4 and 5 are strapped and the dial is replaced by a dial dummy.

Specification: Specification 777 deals with the conversion of C.B. bell sets to handset type wall telephones, as indicated in this article.



NOTES.

1. For C.B. working omit dial and strap terminals 4 and 5. Fit dial dummy.
2. Extension bell if required to be connected to terminals L1 and E and strap removed.

Fig. 3.—Handset Wall Telephone 237 A.W. and 237 C.B.W. (Drawing C.1514, Sheet No. 1).

Cardboard Cartons: The telephones are supplied packed in corrugated cardboard cartons and each instrument will be issued from the Stores Branch still in its carton. The instruments should be handled in the cartons at all points right up to the installation of the telephone in the subscriber's premises. Afterwards, the cartons will be used for returning recovered instruments from subscribers' premises to Stores. This practice is being followed as it has been found that, when telephones are wrapped in paper, metal parts frequently burst through the wrapping and damage the woodwork of other instruments. For this reason efforts are being made also to extend the use of cartons to all types of new, renovated or recovered instruments, and it should then be an easy matter for all instruments to be handled at all points without risk of damage. The cardboard cartons to be supplied are collapsible, and can therefore be carried readily from place to place. Also, being collapsible, a large number can be stored in a small space.

Circuit Description—Telephone 237AW, Drawing C.1514:

(i) **Incoming Calls (Fig. 3):** The incoming ringing circuit is from Line 1 to terminal E through the magneto bell and condenser to Line 2.

(ii) **Originating Calls:**

(a) **Dialling Circuit (Figs. 3 and 4):** The dialling circuit is from Line 1, through the switchhook springs, dial off-normal springs, dial impulse springs to Line 2. To reduce high voltage surges, a shunt circuit is provided across the dial impulse springs from Line 1 through the magneto bell and 50 ohm non-inductive winding of the induction coil in parallel through the 2 microfarad condenser to Line 2.

(b) **Transmitter Feed Current Circuits (Figs. 3 and 5):** The transmitter receives current from the exchange battery feeding bridge. The feed current circuit is from Line 1 through the switchhook springs, 17 ohm winding of the induction coil, transmitter, dial impulse springs to Line 2.

(c) **Sending Circuit and Sidetone Suppression (Figs. 3 and 5):** The operation of the set when transmitting is best understood by referring to the basic transmission circuit (Fig. 5) and considering the transmitter as an alternating current generator. If we assume that the impedance of the line equals that of the network and the number of turns and resistance of "a" equals the number of turns and resistance of "b," the current in "a" will equal that in "b," and each will tend to induce an equal but opposing current in "c," thus no current will flow through the receiver and no sidetone will be heard.

A.S.T.I.C. No. 14A has unequal turns on the line and network windings. This has the effect of bringing the transmission efficiency (sending and receiving) into line with that of telephone

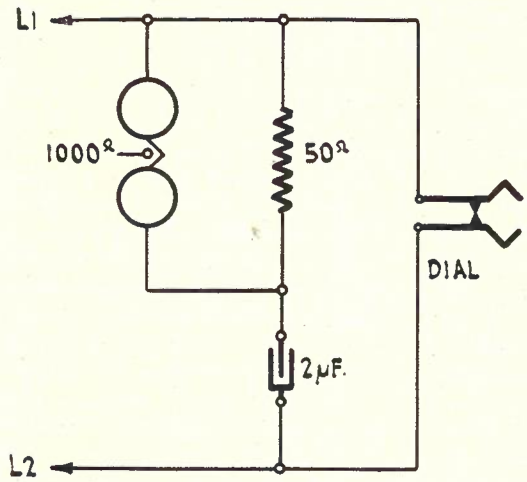


Fig. 4.—Dialling circuit.

566A. To obtain a sidetone balance with these unequal turns, it is necessary to use a balance network which has a different impedance to that which would be used with equal turns.

In practice, some sidetone is heard in all cases and the amount varies with the different connections, as the network can only be designed to suit average line conditions.

In the actual circuit of the telephone (Figs. 3 and 5) the auto-transformer principle is used and this in no way alters the operation of the set. It will be remembered that an auto-transformer has one winding only, portion of this winding being common to both coupled circuits. The receiver is connected directly across winding "b" (26 ohms winding, 4-3) and winding "c" is omitted. The passage of direct current through the receiver and the balance network is prevented by the 2 mF. condenser and satisfactory line and receiver impedance matching conditions are provided.

Referring again to the basic transmission circuit (Fig. 5) in order to ensure maximum sending and receiving efficiency, it would be of advantage to interchange the positions of the receiver

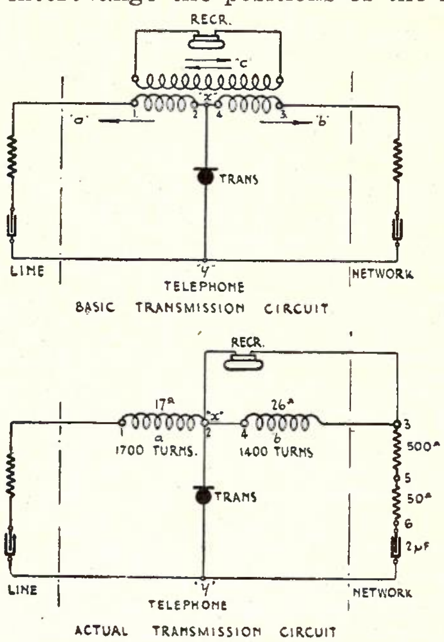


Fig. 5.—Transmission circuit, Handset Wall Telephone 237 A.W. and 237 C.B.W.

and transmitter, as is done in the local battery anti-sidetone circuit, since the impedance of the receiver approximately matches the impedance of the line and network in parallel, and the impedance of the winding "c" could be readily varied to match the transmitter. (See this Journal, Volume 2, No. 3, Feb., 1939.)

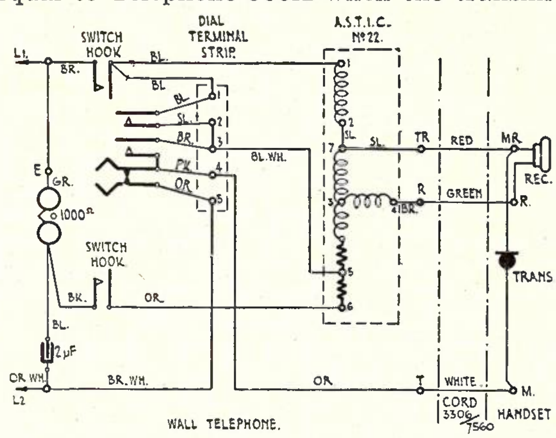
However, in the common battery case it is impracticable to interchange the positions of the transmitter and receiver in this circuit, as the transmitter must be connected between points "X" and "Y" in order to feed current to it from the line.

As the resistance of transmitter insets No. 13 used in common battery telephones varies between 50 and 80 ohms, in order to obtain correct impedance matching, it would be necessary to use a second transformer, but the extra cost is not warranted. As the circuit when measured from the transmitter terminals has a higher impedance than the average transmitter, maximum sending efficiency is obtained when the transmitter resistance is high—say, 75 ohms. This applies also to common battery circuits using anti-sidetone induction coils Nos. 20, 22, 24 and S.T. & C.'s No. 4C.

Impedance Matching: It will be remembered that any circuit will absorb maximum power from a source of supply such as a generator, a transmitter or a transformer if its impedance matches the impedance of the sources of supply. If both the magnitude and angle of the load can be adjusted, then the resistive component of the load should equal that of the source of supply, while the reactive components should be equal in magnitude but of opposite sign.

(d) **Receiving Circuit (Figs. 3 and 5):** In the receiving condition the voice frequency current passes from Line 1 through the switchhook springs, the 17 ohm winding of the induction coil 1-2, transmitter, dial impulse springs, back to Line 2. Due to the low impedance path offered by the transmitter, very little current from the line passes through the parallel circuit formed by the 26 ohm induction coil winding 4-3 in parallel with the receiver and induction coil windings 3-5 and 5-6. The flux due to the current through the 17 ohm induction coil winding 1-2 induces a potential in the 26 ohm winding 4-3 which drives current round the local receiver circuit. The small current from the line passing through winding 4-3 tends to assist the current passing through winding 1-2.

Transmission Efficiency: The transmission efficiency (sending and receiving) of the telephone is equal to Telephone 566A when the transmitter



NOTES.

1. For C.B. working omit dial and strap terminals 4 and 5. Fit dial dummy.
2. Extension bell if required to be connected to terminals L1 and E and strap removed.

Fig. 6.—Handset Wall Telephone 237 A.W. and 237 C.B.W. (Drawing C.1514, Sheet No. 2).

resistance is 75 ohms. The average sidetone reduction is about 5-6db greater than Telephone 566A and 10-15db greater than a sidetone telephone such as 461A using induction coil No. 14.

Development: The model was developed in the Chief Engineer's office of this Department and the work done in the Research Laboratories in connection with the method of converting induction coil No. 14 to 14A is referred to in Test Report 1038. The development is a continuation of work carried out in this office in connection with the introduction of Telephones 233MW and 235MW, as described on page 147 of the February, 1939, issue of this Journal, the former being the telephone in a Stromberg Carlson case, and the latter a similar article in the British Ericsson case.

The Characteristics and Applications of Protection Equipment for Telecommunication Services in Australia

J. H. T. Fisher, B.E.

Part I.: Characteristics and Construction of Protective Devices—Air-gap Arresters.

Introduction. During the last few years the rapid growth of Carrier Telephone and Telegraph systems on trunk line routes, and in particular the installation of Broadcast Programme Carrier systems on inter-capital trunk line routes in Australia, has focussed attention on protection equipment.

The development of satisfactory and reliable equipment to provide protection against the effects of lightning and faults in or contacts with electric power lines, is especially important on these trunk line routes, as failure of a line circuit due to inadequate protection means not only a physical channel out of traffic, but perhaps a large number of carrier frequency channels as well. Further, the installation of Carrier Systems on Trunk Lines has necessitated the provision of high and low pass line filters at both terminal and repeater stations, and as these are expensive items of equipment it is necessary to protect them against damage from lightning or power surges on the lines.

Protection against lightning is particularly necessary along the north-eastern coast of N.S.W. and the eastern coast of Queensland, where thunderstorms are frequent and severe. (Reference 1 at end of this article.) The coastal area, including Brisbane, Ipswich, Lismore and Glen Innes near the Queensland-N.S.W. border, experiences an average number of 30 to 60 thunderstorms per annum, the majority of which occur during the summer months from October to March. Protection against the effects of faults in and contacts with high tension power lines is particularly necessary in Tasmania, where telephone and power lines are closely paralleled on many routes for long distances. (Reference 2.)

Protection equipment for many years has been gradually developing and improving, but recently somewhat radical innovations have been made, and the object of this paper is to review past practice and to describe and explain the purpose of the latest developments in this country.

The three main items of protection equipment in use are the lightning arrester, the heat coil, and the fuse. Other secondary pieces of equipment will be mentioned in passing, but these three will be considered in detail in Parts I. and II. of this article.

Lightning Arresters

These are connected between either wire of a telephone circuit and earth at protected points, and their purpose is to provide a path to earth for lightning and for certain currents arising from electric power contacts or induction on the telephone lines, thus preventing damage to cable or equipment connected to the lines.

The requirements of lightning arresters are as follows:—

(a) At normal operating voltages on the line circuit they must present an "open circuit" to earth.

(b) They must have high insulation resistance under all atmospheric conditions, producing negligible leakage of circuit operating currents.

(c) They must "break down" and provide a low impedance path to earth at some voltage above the normal circuit operating voltages, so as to provide the necessary protection against lightning or electric power currents. This breakdown voltage must be as low as circuit operating voltages and manufacturing tolerances in the arrester permit. In this paper "breakdown voltage" will be understood to imply D.C. breakdown voltage, as with A.C., breakdown depends on peak-voltage and not on R.M.S. value.

(d) Their "breakdown" delay must be small enough to ensure that the arrester operates before a dangerous voltage on the line can cause damage to cable or equipment.

(e) They must operate in such a manner as to cause as little interruption or disturbance to the circuit as possible.

(f) Their breakdown voltage must remain reasonably constant throughout their life.

(g) After each operation or breakdown the arresters must return to their normal condition as soon as the dangerous voltage is removed, and must be able to re-operate immediately should a dangerous voltage reappear on the line, i.e., the arrester itself should not become damaged as a result of its "breakdown," and must therefore be capable of withstanding high energy surges or heavy discharge currents for an appreciable time.

The practical unit of electrical energy is the Joule or Watt-Second and the magnitude of lightning surges is conveniently expressed in terms of this unit. Induced lightning surges of over 54 joules have been experienced on telephone lines.

(h) They must be as compact in size as is possible, consistent with electrical efficiency, as large numbers have to be mounted in Protected Cable Boxes on Cable terminal poles and on main distributing frames in exchanges.

(i) They must be reasonably inexpensive as they have to be used in very large numbers inside exchanges, at subscribers' premises, and out-of-doors on open wire lines.

No lightning arrester so far produced fulfils all these requirements.

Lightning arresters used on High Tension Power Lines are designed to carry currents associated with direct lightning strokes, which may momentarily reach values up to 200,000 amps; but these arresters are very large and costly, and the lines which they protect are carried on high steel towers which makes them more susceptible to direct strokes than are telephone lines. The incidence of direct strokes on telephone lines, moreover, is very low compared with that of induced lightning surges, and consequently it is not generally considered economical to design arresters for telecommunication use to withstand direct strokes. Thus, while such arresters should provide adequate protection against induced lightning surges, they are expected only to minimise the damage in cases of direct strokes, and in such cases they may be severely damaged themselves.

There are three main types of lightning arrester for Telecommunication Systems: metallic electrode air-gap arresters, carbon arresters, and gas-filled arresters. Breakdown of the first two types occurs by spark or arc discharge between the electrodes, which are normally "open circuit," when the potential difference between them rises above a certain critical value which increases with the distance between them and depends also on the shape of the electrodes, atmospheric density, and relative humidity. Once breakdown occurs the potential difference between the electrodes immediately falls to a low value of about 20 to 40 V. until the arc extinguishes, and as the arc has a negative characteristic, i.e., an increase in current produces a decrease in voltage, the voltage tends to continue to fall until the line is discharged, or in the case of power contacts on the line until a condition of equilibrium is reached. Thus the first two types of arrester present a very low impedance path to earth once they have broken down and their "breakdown" delay is extremely small. When the arc ceases due to discharge of the line or removal of a power contact, the arrester will not again break down until the breakdown potential is again established between the electrodes, provided the arrester has not been damaged by the arc.

Fig. 1 shows a typical D.C. voltage-current discharge characteristic for an air-gap arrester, the specimen in this case being of the type shown in Fig. 3b.

Due to the dependence of breakdown voltage of these air-gap arresters on atmospheric conditions and on the shape of the electrodes, which may be modified at points where discharges have occurred due to the effect of the heat of discharge on the electrode material, the value of breakdown voltage for any specimen is somewhat erratic, and successive values may be considerably greater or less than the preceding one. Although some carbon arresters described below have insulating varnish between the electrodes, this becomes punctured by initial discharges, and

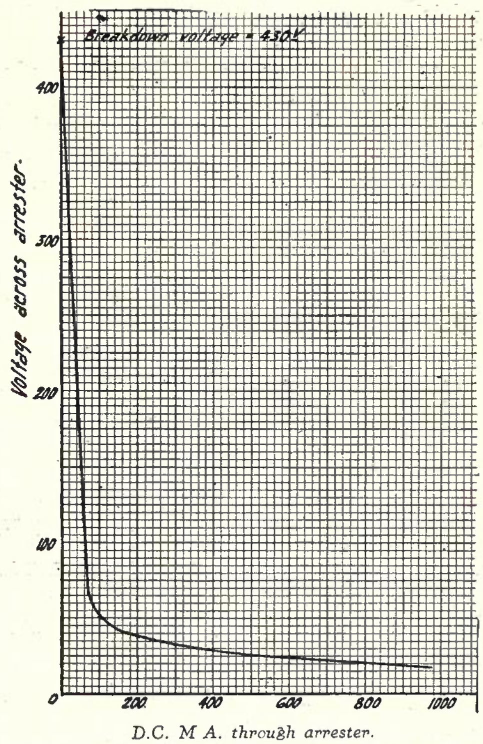


Fig. 1.—D.C. voltage-current discharge characteristic of an air-gap lightning arrester. (Specimen of type shown in Fig. 3b.)

thereafter an air-gap exists within these punctures and exhibits the same characteristics as other air-gap arresters.

The breakdown voltage of gas-filled arresters depends on certain other characteristics which will be considered later in Part II.

Metallic electrode air-gap arresters, carbon arresters, and gas-filled arresters are all in use in Australia and will be discussed in detail.

Metallic-electrode Air-gap Arresters. In their simplest form these were discarded years ago as a primary means of protection against lightning or power contacts, as the metal electrodes fuse too readily under the heat of an arc discharge, changing the air-gap spacing and hence the breakdown voltage. However, in some forms they are useful as a secondary or "overflow" protection in conjunction with other types of arrester and their use in this capacity will be referred to later.

One type known as the Protector Electrode No. 1 is at present being developed by Siemens Bros. in conjunction with the B.P.O. This consists of two metallic electrodes separated by an air gap and sealed within a transparent insulating moulding, and is designed to replace the conventional pair of carbon blocks in existing protector mountings. This type has been given field tests in Australia, but is not yet sufficiently developed to warrant its general adoption. Further improvements, however, when effected, may make it superior in performance to the carbon block types, which are at present standard in this country.

Other special types of metallic electrode air-gap arrester have been developed overseas, but as they have not been adopted in Australia they will not be described in this article. Interested readers will, however, find further information in references 3 to 6.

Carbon Arresters

(a) **Development.** These have been used by the Department for many years, and the development of the present standard type may be traced through the following types developed in the past. All these types have approximately the same dimensions, each block being approximately $1\frac{1}{4}$ ins. x 3/8th in. x 7/32nd in., and the same specified breakdown voltage of 500 to 750 V. In each case the A blocks were connected to line and the B blocks to earth, the blocks being mounted with their operating faces in a vertical plane.

(i) **Types 236 A and B (Fig. 2a)** was one of the earliest types used, and consisted of two carbon blocks separated by a U-shaped Mica sheet approximately 0.004 in. thick. Block A had a longitudinal groove on the side opposite the operating face. Block B was flat on both sides, but had a small depression in the centre of its operating face filled with an alloy having a melting point of about 200 to 210° F. A heavy discharge current produced by sustained contact of the telephone line with a high tension power line would cause this alloy plug to melt, thus permanently short-circuiting the blocks and so earthing the line. After such an operation the blocks were discarded.

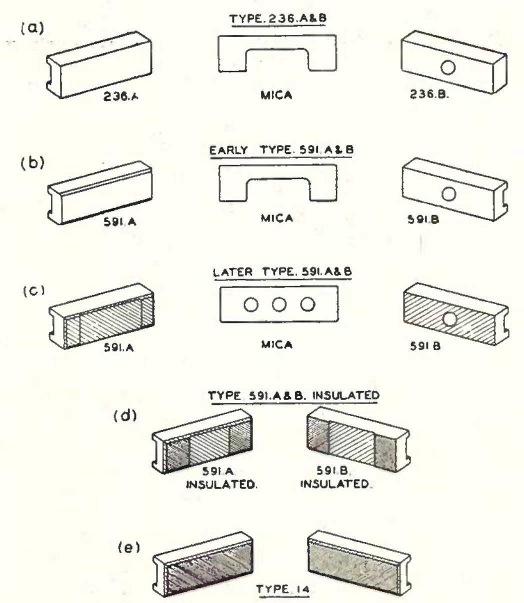


Fig. 2.—Carbon Arresters.

(ii) **Type 591 A and B (Fig. 2b),** first type, introduced later, consisted of two carbon blocks, separated by a mica sheet 0.004 in. thick. The long sides of the operating face of block A were chamfered, and block B had a fusible alloy plug. Both blocks had longitudinal grooves on the sides opposite the operating faces, so that they could be fitted into protector clips with security.

In the second type 591 A and B arrester (Fig. 2c), first used by the Department in 1927, the A block was chamfered on all sides of the operating face, and had a transverse recess 7/8ths in. wide and 0.002 in. to 0.003 in. deep ground across the centre of its operating face, leaving "steps" at each end, 3/16ths in. wide. Block B retained the fusible alloy plug. The mica separators used with these were of a different design, being rectangular sheets 0.003 in. to 0.005 in. thick, with three 1/8th in. holes drilled in them to allow the passage of sparks and the fused alloy. The operating faces of both blocks were treated with an "anti-dust" varnish of various colours.

(iii) **591 A and B Insulated (Fig. 2d).** This was first used by the Department in 1931, and consisted of two carbon blocks, the operating faces of both being treated with red "anti-dust" varnish, and, in addition, having a "step" of insulating varnish 5/16ths in. wide and 0.002 in. thick painted across each end. Block A was chamfered all round its operating face, and block B had no fusible alloy plug. Mica separators were not used.

(iv) **Type No. 14 (Fig. 2e),** introduced in 1937, is the present standard in Australia for use in Exchange M.D.F.'s and Sub-station Protectors and is generally replacing all other types. It consists of a pair of identical carbon blocks, having the usual longitudinal grooves on the back, and a chamfer all round their operating faces. The operating faces are ground perfectly flat, and treated with red "anti-dust" varnish, and then coated uniformly with a film of clear insulating varnish approximately 0.0015 in. thick. Mica separators are not used.

(b) **Characteristics of Carbon Arresters.** Carbon Arresters have certain inherent disadvantages. In the 236 A and B type, atmospheric dust tended to accumulate on the sides of the blocks, bridging over the edge of the mica, which produced low insulation resistance, especially with high atmospheric humidity. In the 591 A and B type, the long edges of the operating face of the A block were chamfered, which reduced this trouble, as it was then necessary for the dust to cover the whole of the mica edge exposed by the chamfer in order to produce leakage. The chamfered edges were retained in the insulated type of blocks, and in the No. 14 type both blocks are chamfered, as this reduces the likelihood of atmospheric dust bridging across the edges of the varnish coatings.

The requirement that Carbon Arresters should have a breakdown voltage of 500-750 V. necessitates that the air-gap between the blocks should be of the order of 0.003 in. to 0.004 in. Gaps smaller than this are too susceptible to short-circuit troubles due to the accumulation of dust on the operating faces, and the breakdown voltage becomes too high with larger gaps. In the earlier types, the carbon was comparatively soft, coarse grained, and very liable to disintegrate under the action of discharges, forming carbon dust. Carbon dust was also formed on the surfaces during manufacture. The U shape of the micas used with the earlier carbons was designed to allow loose carbon dust to fall clear from the air gap when used as in Fig. 2 (a) and (b), but if the micas were inserted upside down the low I.R. trouble due to carbon and atmospheric dust in the gap was increased. The low I.R. was unstable and produced noise in the telephone circuit. This condition could often be reduced by removing the carbons, wiping the operating surfaces, and replacing, but in time these surfaces became so pitted that the carbons had to be discarded. Later, the "anti-dust" varnish was applied to the operating surfaces to fill the pores of the carbon and seal in any carbon dust produced in manufacture and the perforated micas were introduced to endeavour to exclude atmospheric dust. Trouble was also experienced with the micas in the earlier types of arrester, as great difficulty was experienced in obtaining micas of uniform thickness, and hence breakdown voltages varied over a wide range. The introduction of the insulation "step" at either end of the operating surfaces made micas unnecessary, but atmospheric dust was still able to accumulate in the air gap between the "steps." The final development of the No. 14 Carbon Blocks having perfectly flat operating surfaces coated with a double film of "anti-dust" varnish and insulating varnish reduced the trouble from atmospheric dust, but the difficulty remained of obtaining uniform thicknesses of varnish film. Trouble has also been experienced in warm climates, where the varnish becomes tacky and sticks the blocks together so that they cannot be separated for examination without the varnish peeling off. The varnish film always tends to remain thinnest along the edges of the chamfers round the operating surfaces, and it is usually along these edges that breakdown of the block occurs. Possibly rounding of these edges before application of the varnish might prevent this and result in more uniform breakdown voltages.

When breakdown occurs with the No. 14 Carbon Block Arrester, the varnish film is of course punctured, and although the modern carbon is hard, fine grained and chemically pure, a small amount of very fine carbon dust is liable to form. In some cases this dust will bridge the sides of the hole punctured in the varnish film and cause a short circuit or low I.R.; carbonising of the varnish itself by the arc may also contribute to this trouble. This means that in many cases after breakdown even No. 14 carbons cause noise on the telephone circuit, if not a definite "earth," and noise, which may be arising from punctured carbons at several protected points along a line after a thunderstorm or induced power surge on the line, is very difficult to locate and very troublesome.

It has, therefore, become necessary in some exchanges on trunk line routes to examine all carbons on trunk lines after the occurrence of an induced power surge, power contact or direct lightning stroke on lines on the route, or after a particularly severe thunderstorm, and to discard all those which have holes punctured in the varnish film. It is more economical to do this than to spend time endeavouring to localise noise which may not be found on the lines until considerably later. The breakdown voltage of all the above types of carbons may be subject to considerable variation from operation to operation due to the changes produced in the operating surfaces of the carbon by the discharge arcs and due also to changes in atmospheric conditions. Because of these defects and weaknesses the maintenance cost of carbon arresters is high, for although their individual costs are low, many thousands are used in Australia every year; the cost of labour for replacing them, which often involves travelling to unattended stations, is also considerable.

In some districts where thunderstorms are frequent and severe, it is believed that in an attempt to reduce the cost incurred and time lost in this replacement of carbons, two micas instead of one have sometimes in the past been inserted between the uninsulated types of carbons, and micas used even with the 591 A and B insulated and No. 14 types. This may have appeared to reduce maintenance visits by decreasing the number of "earthed" carbons due to the formation of craters and lumps on the operating surfaces with excessive discharges, but such a practice is highly dangerous, for the use of additional micas will increase the breakdown voltage of arresters by 100 per cent. or more, thus subjecting equipment to voltages in excess of those for which it has been designed and perhaps cause danger to human life.

Some specimens of No. 14 Carbon Arresters tested in the Research Laboratories have been shattered after being subjected to five condenser discharges simulating lightning surges having energy of 10 joules each, when no previous tests had been applied. This was probably due to the sudden vaporisation by a discharge of a small amount of moisture in the carbon. Other specimens which had first been subjected to several breakdown tests of much lower energy have withstood discharges increasing up to 10 successive discharges of 50 joules each without shattering or formation of a short circuit, any moisture having been probably dried out by the initial discharges of low energy.

(c) **Carbon Arresters with Special Features.** Attempts have been made by manufacturers to produce a type of carbon block which will not have the above disadvantages. Two types of carbon block of design radically different from those listed above will be described, and also a device designed to safeguard Carbon Arresters and lengthen their useful life, the Short Circuiting Relay Protector.

(i) The first of these Carbon Blocks (Fig. 3a) (Refs. 3, 4 and 8) consists of a white or blue Ceramic frame approximately 1¼ in. x 3/8ths in. x ¼ in., having a slight recess on the operating face and a longitudinal groove on the opposite face. A rectangular slot passes right through the centre of this frame, and a small carbon insert approximately 3/8ths in. x 7/64ths in. x 13/64ths in. is secured in the slot by means of a fusible cement. The edges of the recess in the Ceramic frame are perfectly flat, and the operating surface of the

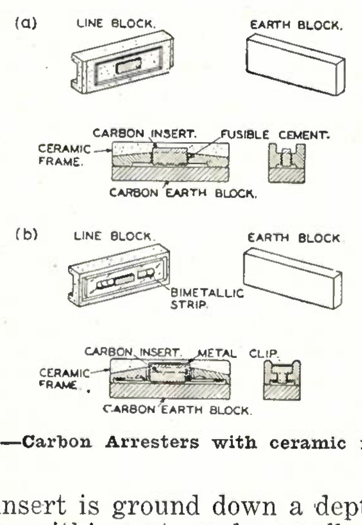


Fig. 3.—Carbon Arresters with ceramic frames.

carbon insert is ground down a depth of up to 0.006 in. within extremely small tolerances below these edges. The block is paired with a perfectly plain carbon block 1¼ in. x 3/8ths in. x 5/32nds in., with an operating face ground flat. When the two blocks are assembled together in the usual protector clips, the line side clip makes contact with the protruding back of the carbon insert, and an air gap of up to 0.006 in., depending on the breakdown voltage required, is left between the operating face of the insert and the carbon block. The ground face of the latter block makes close contact all round with the ground face of the Ceramic frame, so as to exclude atmospheric dust from the air gap. Should any carbon dust be formed by discharges, it will be free to fall clear of the air gap and lodge at the side of the recess in the Ceramic frame, where it will not give trouble. Heavy discharges produced by sustained contact of the telephone line with a high tension power line will cause the fusible cement to melt, when the pressure of the protector clip will force the carbon insert in to earth the line on the carbon block. After such an operation the Ceramic block would have to be discarded.

In the laboratory some specimens of these blocks have been shattered by condenser discharges simulating lightning surges of 90 joules, but they have been found to withstand damage, even when no previous tests have been applied to "dry them out."

The mounting of the carbon insert in the frame of insulating material means that any leakage which may occur will be along the comparatively long path over this material between the carbon insert and the earth carbon block forming the other electrode. Thus if the insulating material is non-hygroscopic, leakage trouble should be small, and if it is also non-carbonising under the heat developed by an arc discharge the arrester will not develop short circuits unless the carbon itself builds up a bridge across the air gap. Carbon Arresters of this type are being installed on protected poles at Terminal and Repeater Stations on the Sydney-Melbourne 12-Channel Type J Carrier System. They are obtainable in several ranges of breakdown voltage.

(ii) The second type of Carbon Block (Fig. 3b) (Refs. 7 and 8) is very similar in design and dimensions to the last, but in this case the frame is of unglazed white porcelain, and the carbon insert is of T-shaped section, being secured in position by a metal clip which holds the shoulders of the insert against cheeks on either side of the hole through the porcelain frame. A slotted bi-metallic strip rests in the recess in porcelain block round the operating face of the carbon insert, and is soldered near one end to the metal clip. Heavy discharges produced by sustained contact of the telephone line with a high tension power line will cause this bi-metallic strip to heat up and bend until it makes contact with the carbon block forming the other electrode, earthing the line. After the power contact has been cleared the bi-metallic strip will cool and straighten, leaving the arrester normal once more. Thus this arrester provides a short-circuiting feature for certain sustained power currents which does not render the arrester useless after operation.

The surface of the bi-metallic strip should be not easily corroded, and it is necessary that care be exercised in manufacture to avoid the contact of the metal with any corrosive substances, as corrosion on the metal in the recess round the operating face of the carbon insert would lead to low insulation resistance developing between the electrodes of the arrester. The air gap in this arrester is stated by the manufacturers to be 0.003 in. with a tolerance of $\pm$ 0.00025 in.

The breakdown voltages of the above two types of Carbon Arresters are of the same order and show about the same degree of variation as those of the various types of carbon blocks adopted by the Department in the past. Tests are being carried out in the Research Laboratories of the Department on specimen arresters of both types shown in Fig. 3 to determine their suitability or otherwise for replacement of the Standard No. 14 carbons. Their construction makes them necessarily more expensive than No. 14 carbons, but if their maintenance costs are lower they may prove to be more economical.

(d) **The Short-circuiting Relay Protector.** This has been developed in America by the Bell Laboratories for installation at remote or unattended protected points on lines which are subject to contact with or induction from high tension power lines. It is used in conjunction with Carbon Arresters (American types 26 and 27, similar to Fig. 3a, see c(i) above), which are considered by the designers of the relay to be "the simplest and most satisfactory from the standpoint of speed of operation and impedance following breakdown" (Ref. 10).

The Short-circuiting Relay Protector in its simplest form (Ref. 9) consists of a relay about 3 ins. long overall having two pairs of carbon arresters associated with a single pair of wires mounted at one end. The relay winding, which may be shunted by a non-inductive resistance, is in series with the common earth lead to these two arresters. The relay has two pairs of make contacts which are connected across the two carbon arresters respectively. When breakdown of either arrester occurs the current through the arrester energises the relay, and if this current is sufficiently heavy and persistent, as is likely to be the case with a power contact, the relay operates rapidly and its contacts short circuit both arresters, thus preventing damage to the latter by sustained discharge. The magnetic circuit of the relay is designed to saturate on small current values to prevent high voltages being developed across the winding with high discharge currents. A non-magnetic stop is placed between the relay armature and core to prevent holding-up on grounded telegraph currents on the line after operation. The relay contacts are designed to carry or break 150 amperes. Such relays have been in use in America for some time with satisfactory results.

There is also a multi-grounding Relay Protector (Ref. 10) for installation on pole routes carrying several pairs of wires. This has a somewhat more complicated circuit designed to short circuit the arresters on all the lines as soon as any one of them breaks down due to a power fault or contact; this circuit requires a local battery at the protected point.

Such Short-circuiting Relay systems are necessarily expensive and it would only be economical to instal them at remote or unattended protected points where the incidence of high tension power contacts or induced surges is very high.

(e) **General.** With carbon arresters, devices such as the fusible alloy plug in the early types of earth carbon blocks, the fusible cement setting of the carbon insert of the block in Fig. 3a, the bi-metallic strip in the porcelain frame block of Fig. 3b, and the Short-circuiting Relay Protector, are all designed to provide a positive earth connection to the line, of either a permanent or temporary nature, in the event of sustained contact of the line with electric power lines. It must be remembered, however, that these devices can function only after the breakdown of the arrester has occurred, and this is required to occur at D.C. potentials from 500 to 750 V., according to Carbon Arrester specifications. The most frequent contacts with power lines are those involving 230 V. distribution power lines, and such contacts will not operate carbon arresters and hence cannot cause any of the above earthing devices to function. Further, if contacts occur with 600 V. traction-power lines, in many cases the carbon arresters on the telephone line will not operate. Hence the operation of these earthing devices is practically limited to cases of sustained faults in or contacts with high tension power lines of more than 750 V. pressure, and such cases are comparatively rare in most parts of Australia. Thus the protection of telephone lines against contacts with power lines of 230 V. or other voltages below 750 V. peak must be provided by fuses, heat coils, or lightning arresters of low breakdown voltage, and the only arresters which have reliable breakdown voltages below 230 V. are the gas-filled type, which will be described in Part II.

[**Editor's Note:** This is the first of a series of three articles by Mr. Fisher on the problem of protection of telecommunication services in this country. Parts 2 and 3 will appear in subsequent issues.]

Bibliography

1. Commonwealth Meteorological Bureau, Bulletin 19, 1934—H. Barkley.
2. Interference to Telephone Lines from High Voltage Transmission Lines—H. A. Finlay. The Telecommunication Journal of Australia, December, 1936.
3. "Lightning and Lightning Protection"—W. G. Radley. The Post Office Electrical Engineers' Journal, October, 1937.
4. Protective Devices for Telecommunication Purposes—Captain B. S. Cohen. Journal of the I.E.E., February, 1939.
5. High Tension Protection of Telephone Instruments—E. Bergholm. Ericsson Review, No. 3, 1935.
6. A New Method of Protection for Communication Systems—E. R. Benda and W. Wild. Siemens Review, No. 3, 1938.
7. The Type 2105 Discharge Block—R. G. Sands. Automatic Electric Review, September, 1936.
8. The Sands Bi-metal Lightning Arrester—A. B. Smith. The Strowger Technical Journal, June, 1938.
9. Short-circuiting Relay Protectors—D. T. Osgood. Bell Laboratory Record, June, 1938.
10. Design Features of Short-circuiting Relay Protectors—J. D. Tebo. Bell Laboratory Record, June, 1938.

Trunking Schemes for Large Country Automatic Exchanges

H. K. Gregg

There is, fundamentally, little difference between the design of an automatic exchange for a country area and one for a metropolitan area. In metropolitan networks, generally, we are committed to a particular method of trunking and numbering because of existing exchanges, but in a proposed country exchange these restrictions are usually absent. The result is that greater scope is available in the choice of trunking

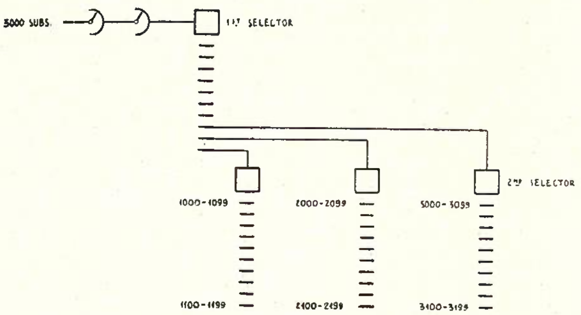


Fig. 1.—Geelong Trunking Scheme.

schemes and in the selection of switches to effect the trunking. This freedom of choice enables the designer to select the most economical system without in any way degrading the service to the telephone user. In this article various methods of trunking will be discussed and the functions of special switches associated with the system will be described.

Geelong Exchange. The first large country automatic exchange to be installed in Australia was Geelong, Victoria. This exchange was placed into service in 1912 with approximately 800 subscribers connected. The trunking diagram is shown in Fig. 1 and reference to this diagram will be made in subsequent paragraphs, and comparison made with more modern methods of trunking to show how economies in switching plant have been effected. It will be observed that the Geelong trunking scheme is similar to that employed in the first of the metropolitan exchanges except that no junction working is required. The equipment individual to the subscriber consists of plunger (Keith) type line switches and the outlets from these trunk through plunger type secondary switches to first selectors. A four-figure numbering scheme is employed and for each of the first two digits dialled there is a separate rank of group selectors. The last two digits operate the final selector, which is of the 100 outlet type.

After Geelong, at intervals, Cairns (Queensland) and Canberra (A.C.T.) exchanges were installed. Both of these exchanges followed orthodox trunking principles, but they differed from Geelong mainly in the fact that rotary 24-outlet subscribers' uniselectors are provided instead of plunger type preselectors.

Tamworth Exchange. The next country automatic exchange was Tamworth (N.S.W.) and, at about the same time, provision was made for exchanges at Wagga (N.S.W.) and Rockhampton (Queensland). The trunking schemes for the latter two exchanges are similar to that provided for Tamworth, so that a description of the Tamworth scheme can be taken as typical of the three exchanges.

Fig. 2 shows the Tamworth trunking diagram. This exchange was designed for an initial capacity of approximately 900 subscribers. It is provided with 2000 type equipment mounted on 10 ft. 6 in. racks. This method of mounting represents an economy over installations such as Geelong on account of the saving in floor space. The subscribers' equipment consists of 200 point line finders and, although this is a departure from the previous country automatic exchanges, it follows current practice for all but the busier metropolitan exchanges. However, so far as this article is concerned, the interesting feature is the use of digit absorbing selectors.

Digit Absorbing Selector. For the Tamworth installation, the digit absorbing selector combines the functions of a first and second selector. Employing a 4-figure numbering scheme, 1000

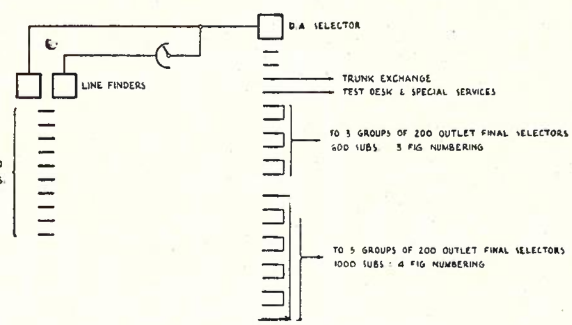


Fig. 2.—Tamworth Trunking Scheme.

subscribers can be served by the use of these D.A. selectors and final selectors only; or, if a mixed 3 and 4-figure numbering scheme is used, 1600 subscribers may be connected. If additional subscribers are to be catered for, a rank of regular second selectors can be installed, which would provide for a further 1000 subscribers.

Referring to the trunking diagram, Fig. 2, the functions of the digit absorbing selector will be understood more readily if a call is traced. The switch has a 600 contact bank providing for two sets of 100 outlets. In the first place, the numbers of the 1000 subscribers served from the lower bank of the D.A. switch must commence with the digit "2." Assume the required number is "2345." When "2" is dialled the switch does not step, but a wiper switching relay is operated which switches into circuit the wipers serving the lower set of banks. The next digit "3" steps the switch in the normal manner and a search is effected over the relevant level of the lower bank for a free outlet to a final selector. The remaining digits "4" and "5" operate the final selector in the normal manner. It will be seen that in this operation this switch combines the functions of a first and second selector, but uses only one mechanism, although the bank must necessarily have twice the capacity of the usual 100 outlet group selector.

If instead of "2" the first digit dialled is "3," stages. The D.A. selector, on the other hand, switches in the lower set of banks when "2" is dialled without engaging a level, and levels 1 to 8 inclusive of the upper set of banks are available for switching when digits greater than "2" are dialled. The result is that switching to subsequent stages can occur when any one of 9 digits is dialled, i.e., the same as for the orthodox first selector. In addition, the D.A. switch does not involve any movement, apart from relay operation, when effecting discrimination, so that there is a saving in wear and tear on the switch.

Fig. 3 shows the circuit of the D.A. selector, and the following brief circuit description will explain its functions:—

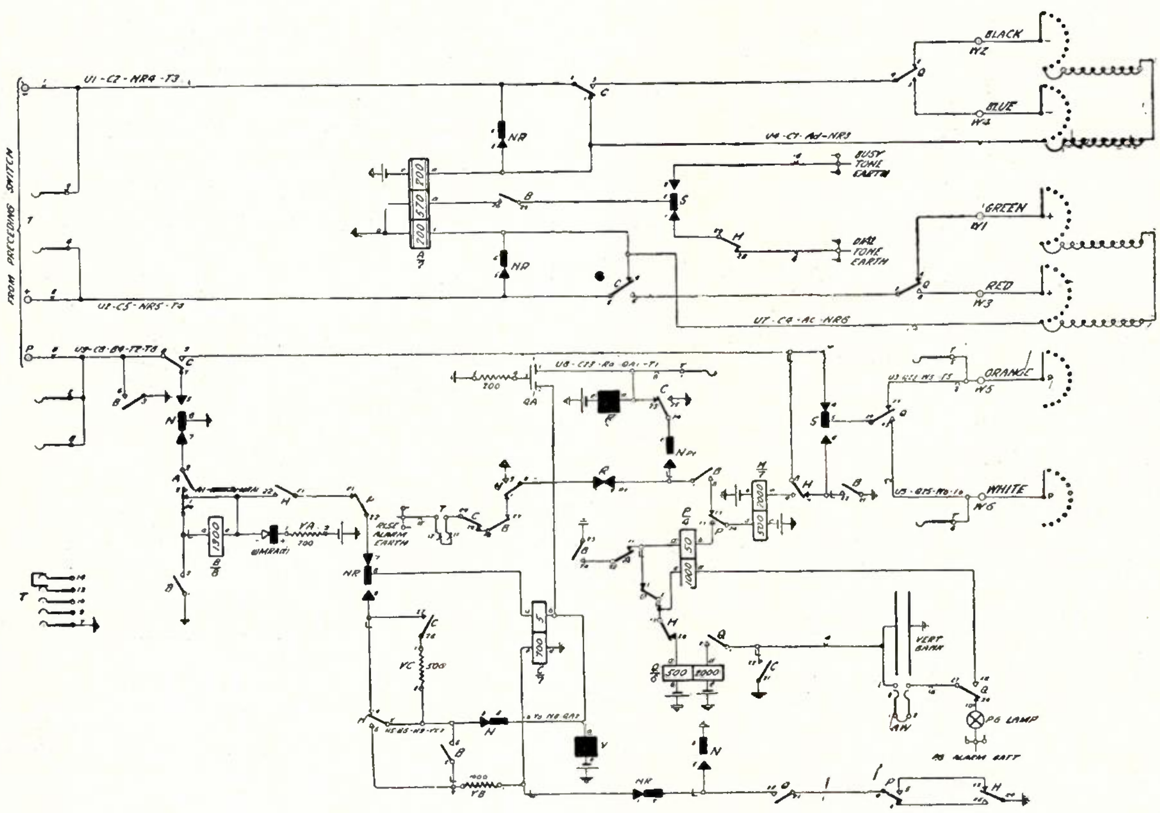


Fig. 3.—2000 type digit absorbing group selector.

the upper bank wipers will remain in circuit and the switch will step vertically to level 1—not level 3—that is, the first two impulses will be absorbed. Similarly, if "4" is dialled the switch will step to level 2, and so on, two impulses being absorbed from whatever number is dialled. When "0" is dialled the wipers are stepped to level 8, and consequently, under normal circumstances, levels 9 and 10 cannot be used. It may seem that the use of two levels is being lost, but actually the number of available levels is the same as when orthodox first selectors are used. With the latter, level 1 cannot be used because of the false impulse hazard, so that 9 levels are available for trunking to subsequent

If the first digit is 2, it is absorbed by relays and the switch does not step vertically. The second train steps the switch to the level corresponding to the digit dialled, and outlets are tested by wipers 1, 2 and 5. If the first digit dialled is greater than 2, the switch commences to step vertically after the first two impulses, and therefore reaches a level corresponding to the digit dialled, minus 2. The outlets are tested over wipers 3, 4 and 6. If the first digit dialled is 1, corresponding to a false impulse, it is absorbed by relay operations and the circuit returns to its initial condition.

Switch seized.—The loop is extended to operate A which operates B. Relay B earths the private to guard the connection, connects dial tone and operates C by its 700 ohm winding, 1000 ohm resistance spool YB, operated B contact, N springs and V magnet. Relay C gives a PG alarm via the vertical wiper and bank.

Assume 2 is dialled. When A releases on the first impulse break, a circuit is completed to operate Q via B, A, P and H contacts. Q, in operating, locks to C and prepares a circuit for P to operate. When A again operates, the short-circuit across the 1000 ohm winding of P is removed and P operates in series with Q. Relay P breaks the V magnet circuit and prepares a circuit for H. When A releases on the second impulse H operates in series with the 50 ohm winding of P; H locks and when A operates again, P releases. Since H and Q are operated and P released, C will be short-circuited, and when it releases Q also will release, since its holding circuit is broken. When Q releases C will again operate and the switch is ready to receive its second train of impulses, with A, B, C and H operated.

If the first digit is greater than 2, the third impulse break is directed to the vertical magnet via operated contacts H21 and normal contact P22. Q remains operated throughout the rest of the call over the off-normal position of the vertical bank, and causes the selector to hunt over the second hundred group of contacts.

Rotary hunting.—The rotary magnet now operates and steps the wipers into the bank, the circuit being R magnet C, N, R and H contacts to earth. If the first outlet is engaged, earth on the P wire prevents the release of H, and the rotary magnet, by self-interrupted drive steps the wipers forward until a P contact free from earth is reached. Relay H now releases, cuts the rotary magnet drive and operates C via V magnet, 5 ohm winding of C, NR, H and B springs 1000 ohm spool, 700 ohm winding of C to earth. Relay C switches the negative, positive and P wires through to the next switch and operates H via C, N, B and P springs, 500 ohm winding of H to battery. Relay H operates and locks to the earthed private. Relays A and B release and dialling to the next switch proceeds.

All outlets busy.—The switch rotates to the 11th step. The cam springs S operate to connect busy tone to the caller and earth to the P wiper to operate the overflow meter.

Release of switch.—During conversation relay H is held to the earthed P wiper and H retains C as already described. When earth is removed from the private, H releases and, after a short interval C releases. The incoming P wire is now earthed from N operated to guard the switch until it reaches normal, and the self-interrupted circuit for the rotary magnet is closed as follows: magnet, C, N, R, H, B and C contacts to release alarm earth. The switch now automatically steps to the end of the level and then restores to normal by spring tension. When the N springs open, earth is removed from the private and the switch is free to deal with the next call. Should some mechanical defect prevent the switch restoring to normal, an alarm is given.

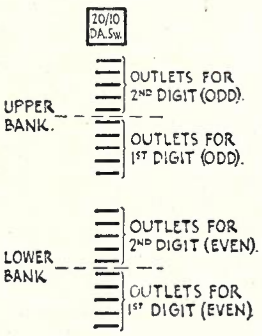
If the first digit dialled had been 1, Q and P operate as before, but H does not operate. C is short-circuited and releases, causing P and Q to release, so that the selector relays are again in the dial tone position. It will be seen, therefore, that false impulses are absorbed automatically.

The D.A. switch is referred to as a 20/10 switch, i.e., it has 20 levels each having 10 outlets. (It will be recollected that in the 2000 type exchanges in metropolitan areas the group selectors are generally 10/20 switches, i.e., 10 levels each having 20 outlets.) When comparing the economic features of this switch with those of regular type switches, it is found that it has a mechanism only very slightly more complicated than an ordinary group selector, and also it employs a 660 point bank, i.e., a bank of twice the capacity of its orthodox counterpart—the 10/10 group selector, but as the mechanism combines the work of a first and second group selector for 1000 subscribers a big saving is made, so far as mechanisms are concerned. On the other hand, if regular first and second selectors were used for 1000 subscribers, banks would be necessary for the first and second selectors, and as the bank of the D.A. switch is twice the usual capacity for a 10 outlet switch there is no saving in banks. Nevertheless, the D.A. switch is attractive economically, but only within certain limits. Maintenance difficulties are increased if the size of the bank is increased to 1200 points to permit the use of 20 outlets per level. This is an obvious disadvantage because a greater number of subsequent switches are required if 10 outlet switches are used than when 20 outlet levels are used. Moreover, if the exchange is to grow to, say, 5000 lines, second selectors must be provided for the second, third, fourth and fifth thousand groups. These second selectors are served by the upper bank of the D.A. switch, but to provide access to the second selectors D.A. switches for the full 5000 lines must be provided, although only half the bank is required so far as 4000 of the 5000 lines are concerned. This aspect detracts from the economical advantage of the switch for large exchanges. However, up to approximately 4000 to 5000 lines, it is economical to use the switch, and fortunately not many country exchanges will exceed 4000 lines within 20 years, which is the usual planning period for exchange equipment.

In single exchange networks, i.e., networks comprised of one exchange only, the fact that when using D.A. selectors the numbering scheme must commence with the digit 2, is generally of little importance. There are occasions when it is necessary to consider a numbering scheme commencing with a digit other than 2, and the D.A. switch described would not be suitable for such a scheme. However, another type of D.A. switch has been developed recently which permits absorption on any level. No switches of this type are yet in service in Australia, but its functions and switching scheme are novel, and because of the flexibility of numbering that it will permit a brief description will be given.

As with the D.A. switch already described, the new switch is a 20/10 outlet type, i.e., it has 2 sets of 10 levels each with 10 outlets, but this latest development uses a new arrangement of groups. The first digit allows access to the lower 5 levels of both upper and lower sets of banks—odd digits use the upper set, and even digits the lower. This is made possible by a pulse halving circuit arrangement. If, say, 10 is dialled the wipers lift only 5 steps, and the wipers associated with the lower bank are connected into circuit. The odd and even digits are distinguished by the condition of the wiper switching relay which is operated for odd digits and unoperated for even digits.

When the absorption is required on a particular level, relevant normal post spring strappings



DIGIT DIALLED	SWITCH STEPS TO LEVEL.
1.	1 UPPER BANK
2.	1. LOWER "
3	2. UPPER "
4.	2. LOWER "
5	3 UPPER "
6	3 LOWER "
7	4 UPPER "
8.	4 LOWER "
9.	5 UPPER "
0.	5 LOWER "

Fig. 4.—Switching arrangement for 20/10 digit absorbing selector (local absorption digit 7).

are effected. If absorption is required when, say, the digit 7 is dialled the wipers are stepped to level 4, where the circuit conditions are tested and the wipers, instead of cutting in, automatically step vertically to level 5. They remain opposite level 5 until the next digit is dialled. When this is received the switch again steps vertically and again pulse halving circuit arrangements are utilised, i.e., if the second digit is 3 the wipers are stepped another two levels to level 7 and cut in on the upper bank. Fig. 4 illustrates the trunking arrangement for this switch. For digits other than the one on which absorption is required, the wipers cut in on the relevant level and trunk to subsequent switches.

Although this switch is not in service it offers, by the use of novel methods, full flexibility for trunking. Because of this flexibility it is capable of more general application than the type of D.A. switch provided for Tamworth.

Reverting again to the Tamworth trunking scheme, it will be seen that 200 outlet final selectors are used, i.e., the final selector multiple has a capacity for 200 subscribers' lines. With this scheme each group of final selectors is served from two levels on the bank of the D.A. selector, or of the second selector. This arrangement is similar to the final selector trunking in 2000 type metropolitan exchanges, but is mentioned at this point because it represents a saving in the number of final selectors when compared with the 100 outlet switches such as are installed at Geelong. This saving is due, of course, to the effect of the larger group.

Three Digit Final Selector. From the discussion of the D.A. switch it is concluded that the maximum economy from the use of this switch results when up to 1600 subscribers are to be served, and that the economy diminishes with an increase in the number of subscribers until, at about 5000 subscribers, it would be better to use regular first and second selectors. There is another type of switch which alters this economic comparison. This switch is the 3 digit final selector, or it may be termed a "digit absorbing final

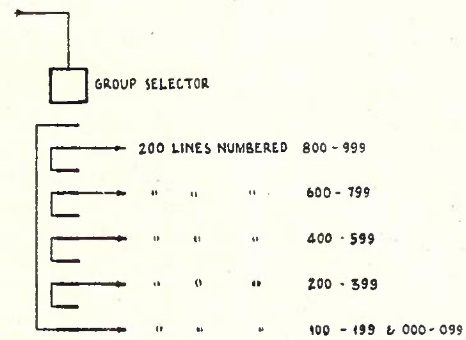


Fig. 5a.—Trunking arrangement for 1000 lines using 5 groups of 200 outlet, 2 digit final selectors.

selector." The usual type of 200 outlet final selector is now fairly generally known. The latter has 200 subscribers' lines connected to its bank and is accessible from 2 levels of the preceding switch, i.e., depending on the level to which the preceding switch is stepped the wipers of the relevant bank of the final selector are connected into circuit. The final selectors are in 5 groups of 200 subscribers and are served by the 10 levels of the preceding rank of switches. This arrangement is shown schematically in Fig. 5 (a).

Now consider the position if 200 subscribers could be served from each level of the preceding switch, i.e., a total of 10 groups each of 200 lines and thus achieve the economy of the large group, but still maintain individual trunking from each level of the preceding switch. This is shown schematically in Fig. 5 (b). By these means 2000 lines can be served from the one rank of penultimate switches. This method of trunking can be arranged by the use of what is termed a "3 digit final selector." The last 2 digits which

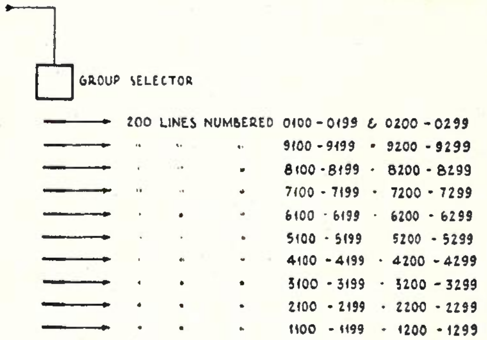


Fig. 5b.—Trunking arrangement for 2000 lines using 10 groups of 200 outlet, 3 digit final selectors.

normally operate the final selector are preceded by an extra digit which effects the wiper switching operation, but does not involve any mechanical movement of the final selector.

Fig. 6 shows schematically the wiper switching arrangement for the 3 digit final selector. If the third last digit is 1 the wiper switching relay does not operate and the wipers serving the first 100 group are connected into circuit. If, however, the third last digit were 2 the relay operates and the wipers associated with the second group are now switched into circuit. An example will illustrate the numbering scheme.

Referring to Fig. 5 (b), if the called line is "4200" the first digit dialled, "4," operates the first selector to the 4th level. This selects a trunk to an idle final selector. The next digit dialled, "2," operates the switching relay in the final selector and connects the wipers to the second hundred line group. The two final digits dialled, "00," select line "00" in the 4200 group. If the desired number had been "4100" instead of "4200," the operation would have been the same except that the first digit dialled on the final selector would have been "1" instead of "2," the switching relay would not have operated and the wipers would have been connected to the first hundred line group.

Let us now see how the use of this type of final selector would have affected the Tamworth installation. Fig. 7 shows the Tamworth trunking diagram using:—

(a) D.A. switches plus 2 digit final selectors.
(b) 10/10 group selectors plus 3 digit final selectors.

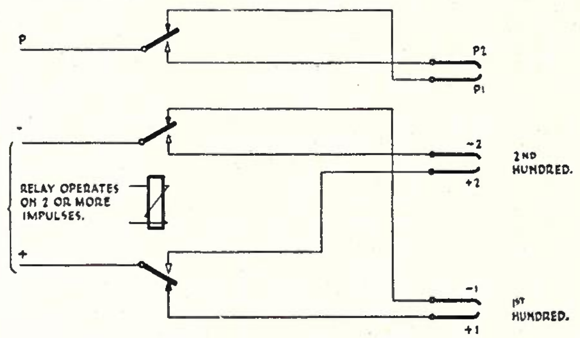


Fig. 6.—Wiper switching arrangement of 3 digit, 200 outlet final selector.

(c) D.A. switches plus 3 digit final selectors.

Using only D.A. switches and the usual type of 2 digit final selectors, we find that it is possible to cater for a total of 1600 subscribers and, to do this, a mixture of 3 and 4-figure numbering must be employed. On the other hand, if a 3 digit final selector had been used 1400 subscribers could be accommodated by using orthodox 10/10 first group selectors. Further, by retaining the D.A. selector and using it in conjunction with the 3 digit final selector the capacity could be increased to 3200 subscribers. With the latter scheme, if it is necessary to increase the exchange beyond 3200 subscribers, the addition of a rank of regular second selectors adds 2000 to the capacity. It will be appreciated, of course, that, whereas with the D.A. original

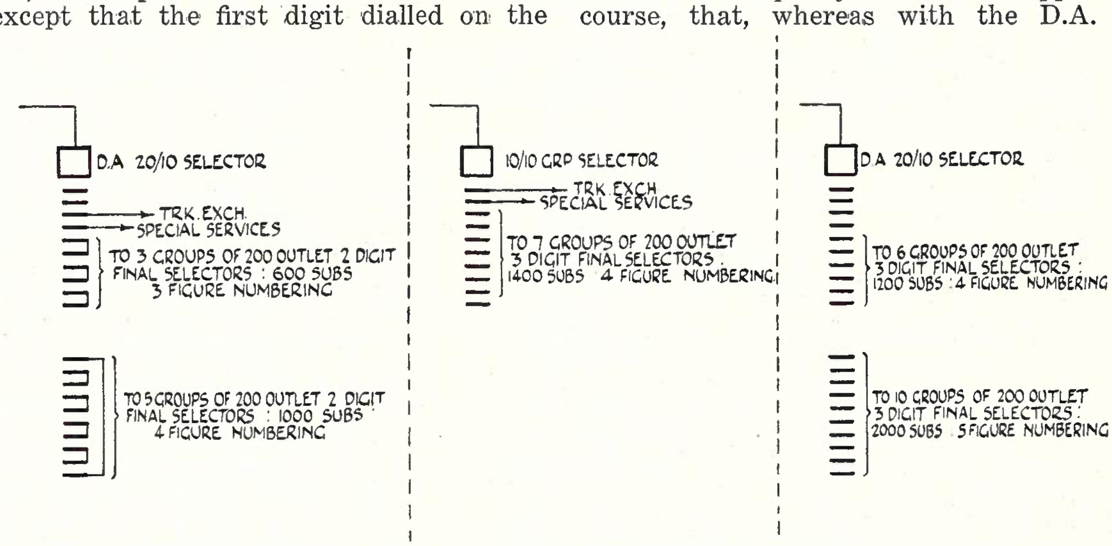


Fig. 7.—Modifications to Tamworth Trunking Scheme.

scheme we had a mixed 3 and 4 digit numbering, we will have, when using the D.A. selector in conjunction with the 3 digit final selector, a mixture of 4 and 5-figure numbering.

Having in mind that it is necessary to reduce the cost of automatic installations to a minimum, consideration might be given to reducing the size of the P.B.X. final selector banks. It will be appreciated that a 300 point bank costs less than a 400 point bank, and a 400 point bank less than an 800 point bank. Roughly, for banks of similar size of multiple the cost is proportional to the number of contacts. Now a 200 outlet P.B.X. final selector bank has 800 contacts, but in a country exchange with, say, 1600 lines, it is not often that more than approximately 40 P.B.X. lines are required, so that by providing a multiple of 800 points for 200 lines provision is considerably in excess of actual requirements. It would be of advantage to restrict the P.B.X. feature to only 100 of the 200 lines and provide only for straight line service on the other 100 lines. By these means the size of the bank could be reduced from 800 point to 700 point, i.e., 300 point for the straight line services and 400 point for the P.B.X. services.

The objection to this is that another type of bank is introduced and also a minor modification to the usual final selector is required, and it may be argued that the saving obtained is not warranted when interchangeability of equipment is considered. This objection is valid if there is only a little difference in cost between the 700 and 800 point banks.

The 3 digit final selector also has another interesting feature, and that is the provision of party line service. Party line services are fairly common in country centres and constitute rather a difficult economical problem when automatic working is being considered. Fig. 8 shows schematically how selection is effected on a 3 digit 200 line final selector which also caters for party lines of up to 5 stations. This final selector is provided with a minor type rotary switch which serves a dual purpose, in that it selects either of the 200 groups and also selects the ringing frequency or code required to ring a particular station wanted. Contacts 1 to 5 of the minor switch select the first of the 200 groups as well as the ringing frequency or code. Five ringing frequencies or 5 different ringing codes can be provided. Contacts 6 to 10 of the minor switch select the 2nd of the 200 groups as well as the ringing frequency or code. This selection is effected by the last digit of the subscriber's number, i.e., any number having 1, 2, 3, 4 or 5 as the last digit is in the first hundred group, or any number having 6, 7, 8, 9 or 0 as the last digit is in the 2nd hundred group. This arrangement is somewhat different from the discrimination when serving regular subscribers. It will be remembered that the selection of a particular hundred was effected by the 3rd last digit of the subscriber's number, whereas in the party line arrangement discrimination is effected by the last digit of the subscriber's number.

An example will illustrate the numbering for the party line scheme. Referring to Fig. 9, when calling, say, "6002," the first digit dialled, "6," operates the first selector to level 6 and selects a trunk to the final selector. The next two digits, "00," step the final selector to level "0" and on to the 10th contact in that level, but no

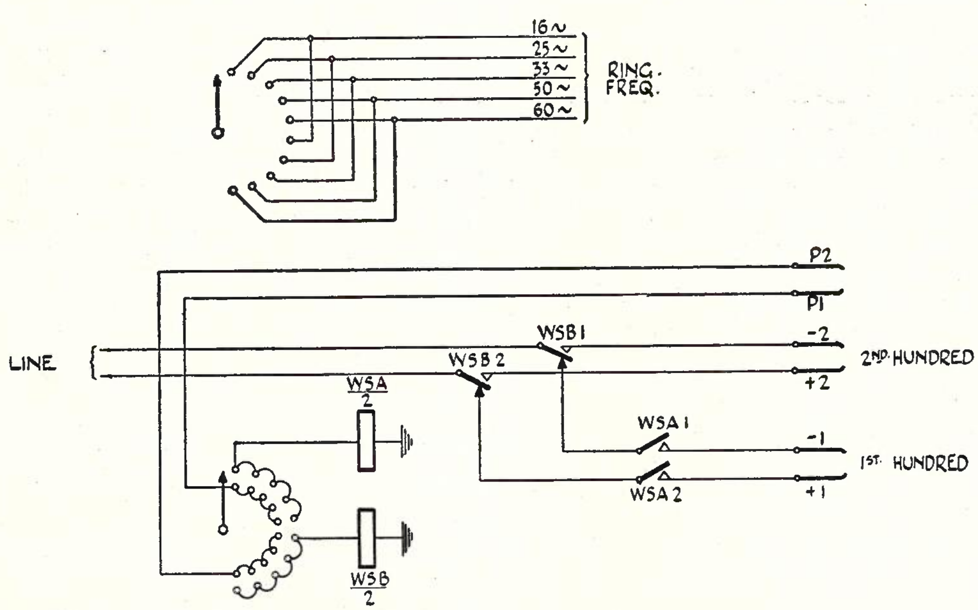


Fig. 8.—Schematic of wiper switching arrangement of 200 outlet, 3 digit party line final selector.

connection with the line is made since the wiper circuits are open at the wiper switching relays. The final digit dialled, "2," operates the minor switch to contact No. 2 and causes the wipers to

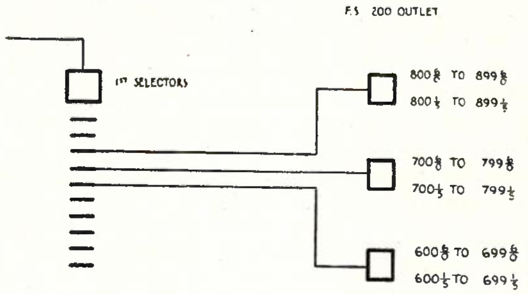


Fig. 9.—Numbering scheme for 200 outlet, 3 digit party line final selectors.

be switched to the first hundred group. Since the minor switch simultaneously also selects the ringing frequency of the called party, the final selector will send out the relevant frequency or code. If the last digit dialled had been 7 instead of 2, the operation would have been the same except that the second hundred group would have been switched into circuit.

Another interesting application of the 3 digit final selectors is in R.A.X. working. This is rather outside the scope of this article, but it is important to note that a capacity of 200 lines is possible by using only final selectors, that is, without any group selection.

From the foregoing it will be appreciated that since the installation of the earlier country automatic exchanges considerable development in switch design has taken place, and by taking advantage of these developments the cost of installing automatic equipment in country exchanges can be substantially reduced.

In conclusion, it should be mentioned that, as a result of enquiries from the Department, the digit absorbing selector first described was submitted by Standard Telephones and Cables, from whom the equipment for Tamworth was purchased. The later type of digit absorbing selector has been developed by A.T.E., Liverpool, and acknowledgment is made to this firm's local Company, A.E.C. (Aust.), for the circuits and description which they have made available. The three digit final selector is a development of A.E.C., Chicago, and to their local Company, Automatic Electric Telephones, acknowledgment is made for circuits and information which have been quoted in this article.

ANSWERS TO EXAMINATION PAPERS

The answers to examination papers are not claimed to be thoroughly exhaustive and complete, They are, however, accurate so far as they go and as such might be given by any student capable of securing high marks.

EXAMINATION NO. 2132.—MECHANIC, GRADE 1—TELEPHONE INSTALLATION AND MAINTENANCE

H. AITCHISON

Q. 1.—Define the terms:—

(a) Mutual Induction.

(b) Farad.

(c) Cycle as applied to Alternating current.

(d) Ohm.

(e) Watt.

A.—(a) The inductive effect created in a conductor due to a variation of current in another conductor in its vicinity is known as mutual induction.

(b) The Farad is the unit of capacity and is equal to 10^{-9} absolute units. It is the capacity of a conductor such that 1 coulomb of electricity will raise its potential by 1 volt. The usual unit used is the micro-farad, which is 10^{-6} Farads.

(c) Alternating currents vary between a maximum in a positive direction and a maximum in a negative direction alternately. One cycle is the complete alternation, i.e., the building up of the current to the maximum positive value, the dying away to zero, the building up in the maximum negative value and the dying away to zero. The usual method of expressing the frequency with which the above action takes place is in cycles per second.

(d) The ohm is the practical unit of resistance. The standard ohm is the resistance offered at the temperature of melting ice to an unvarying electric current by a column of mercury 14.4521 grammes in mass, 106.3 cms. in length and having a uniform cross sectional area.

(e) The watt is the practical unit of power. It is the amount of energy expended per second by a steady current of one ampere under a pressure of one volt. With alternating current, the product of the instantaneous value of the amperes and the instantaneous value of the volts gives the instantaneous value of the power in watts and the algebraic mean value over a whole period is the power in watts. A watt is equal to 10^7 ergs per second or one joule per second.

Q. 2.—What material is used as a depolarizer in a dry cell, and what is the action of the depolarizer? What precautions are taken to keep the contents of the cell moist? Why must the vent holes in the sealing compound at the top of the cell be kept clear?

A.—Manganese dioxide is used as a depolarizer in a dry cell and is contained in a sac of loosely woven material round the carbon electrode. During the action of the cell while it is connected to a circuit, hydrogen gas forms on the surface of the carbon rod. If no steps are taken to remove it, this will result in the internal resistance of the cell gradually rising as the hydrogen gas bubbles form a high resistance film over the carbon rod. The inclusion of the manganese dioxide results in the combining of this hydrogen and the oxygen in the depolarizer to form water (H_2O) which then permeates through the ammonium chloride or electrolyte and assists in keeping it moist. The active parts of the cell are effectively sealed in the container and the initial water in the paste forming the electrolyte is thus prevented from evaporating. The formation of the water described above assists in this respect. Certain gases may be generated during the action of the cell and, if no escape for these is provided, they may reach a sufficiently high pressure to destroy the sealing. To enable them to escape easily the vent hole must be kept clear.

Q. 3.—Draw diagrams showing the construction of a receiver used in a magneto telephone. Explain the function of each component and how the receiver operates.

A.—The sketch below shows a typical receiver of the handset type. The function of a receiver is to convert the electrical impulses of speech current in the telephone circuit into sound waves which convey the received speech to the ear of the listener.

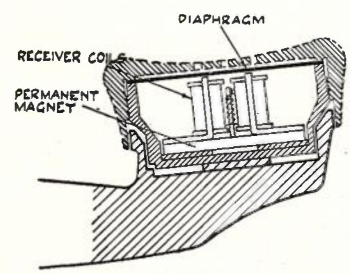


Fig. 1.

The main components are: —

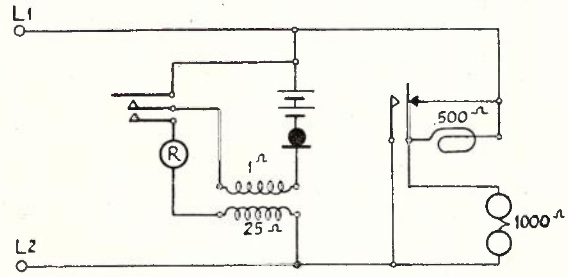
A permanent magnet fitted with soft iron pole pieces on which the coils are wound.

A case and earpiece which when screwed together clamp a diaphragm at a predetermined distance from the ends of the pole pieces. This distance is the minimum to allow the diaphragm to clear the pole-pieces when it is vibrating under the action of the speech currents.

Q. 4.—The circuit of a magneto local battery telephone is shown in the sketch below. Describe the operation of the circuit:—

(a) When a call is being received;

(b) When a call is being originated.



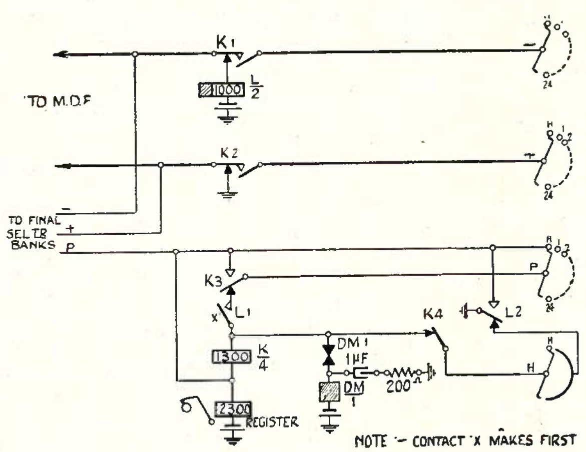
A.—(a) When a call is being received, the telephone is in the normal position and the incoming ringing current has a path from L_1 to L_2 through the bell.

When the subscriber lifts the receiver to answer, the switchhook contacts close the primary circuit which includes the battery, transmitter and 1 ohm winding of the induction coil. The switchhook contacts also place the receiver across the circuit. When the transmitter is spoken into, the current flowing in the primary circuit is varied by reason of the variation of resistance in the transmitter. These variations induce a current in the 25 ohm winding of the induction coil (secondary) which pass out to line and thence to the other party on the connection.

(b) When a call is made from the telephone, the generator handle is turned. By a spring loaded cutout arrangement, the driving spindle of the generator moves laterally before the armature commences to turn. This lateral movement operates the generator springs, removing the short circuit from the armature winding and placing a short circuit across the 1000 ohm telephone bell.

The alternating current generated by the hand generator passes out to the exchange via L_1 and L_2. When the exchange has been rung, the receiver is removed from the switchhook and the conversation takes place as described above.

Q. 5.—The figure below shows the schematic diagram of the circuit of a subscriber's homing type preselector. Describe the operation of the circuit.



A.—The object of this switch is to connect the calling subscriber's telephone to a vacant group selector. In its normal position the wipers are resting on the first bank contact to which the switch returns on release. When the subscriber removes the receiver on his telephone preparatory to dialling, relay L operates from battery, relay L, K1, subscriber's loop, K2 to earth. L1, which is an "x" contact, makes before L2 and places a short round relay K to prevent this relay from operating until a free outlet is found. L2 puts earth on the P wire of the subscriber's multiple to make the line test engaged to incoming calls and also operates the driving magnet DM via the P wiper, K3, L1, DM1, coil of DM to battery. DM steps the wipers on to the 2nd contact in the bank and in so doing opens its own circuit at DM1. If the first selector to which this contact is wired is engaged, there is an earth on the P contact and the preselector steps on to the next contact as DM again operates to earth. When the P wiper rests on a free contact, the short circuit is removed from relay K which operates from earth, L2, relay K, DM1, coil of DM to battery. Relay K operates in series with DM which does not operate as the inclusion of the 1300 ohm winding of relay K reduces the current to below the operating value of DM. K1 and K2 extend the subscriber's loop to the positive and negative wipers which extend the loop to the selected first selector. K3 prepares a locking circuit to earth which is fed back from the seized switch over the P wiper. This earth also maintains the engaged condition on the calling subscriber's line in the final selector multiple. The circuit for relay L is opened at K1 and K2, but as L is slow to release, it ensures that the earth to hold K operated is maintained at L2 until replaced by that fed back from the group selector. L2 prepares the homing circuit. K4 disconnects the driving magnet DM from the homing arc.

When the called subscriber answers, the final selector in the switch train ahead sends back a metering condition to register a call to the calling subscriber. This metering condition is an impulse of an increased voltage which is fed back over the P wire and which is sufficient to operate the meter in parallel with relay K and the driving magnet. When the meter is operated and the increased voltage pulse is removed, it remains operated as it is so adjusted that it will hold on the normal current in the circuit. This safeguards the subscriber's interests by preventing more than one call being metered.

On completion of the conversation, the subscriber hangs up and the switch train is released. When earth is removed from the P bank contact, relay K releases, and at K4 closes the homing circuit. Earth through L2, homing arc and wiper, K4, DM1, coil of DM to battery operates DM which steps the wipers until they are again resting on the first bank contact. This breaks the homing circuit and the switch is again ready for the next call.

When the subscriber is called it is necessary to prevent the preselector operating. When the final selector wipers rest on the subscriber's line, earth is connected to the P wire and operates relay K to battery through DM, which does not operate. K1 and K2 prevent relay L from operating and the switch does not move. Although the subscriber's line is extended to the positive and negative wipers, this does not matter as they are resting on the home contacts, which are not wired.

Q. 6.—Describe in detail how speaking battery is supplied to two C.B. manual subscribers when they are speaking to each other.

A.—

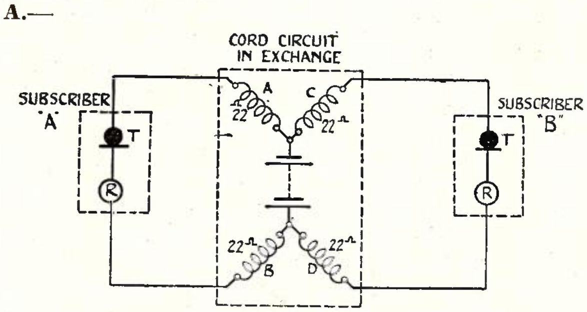


Fig. 1.

This circuit shows the repeating coil or Hayes system of central battery supply to two subscribers A and B connected together. The 22 ohm coils are wound on the one core of a coil known as a repeating coil, which forms part of the cord circuit in the exchange.

A steady current from the central battery flows in each telephone circuit through these coils and this current supplies the requisite voltage across the terminals of the transmitter at each sub-station. Suppose subscriber A is speaking.

The transmitter at A varies in resistance due to the action of the speech waves and causes a variation in the steady D.C. flowing in that particular part of the circuit. These variations of current in coils A and B of the repeating coil induce corresponding variations in coils C and D, and these variations are superposed on the steady DC already flowing in the telephone at B. These variations actuate the receiver at B and this conveys to the listening subscriber the speech from the subscriber at A.

Although one battery is used in an exchange for all connections which are bridged in parallel across it, there is no interaction between different circuits. This is ensured by keeping the resistance of the battery and leads down to a very low figure, thus obviating a voltage drop over them. Therefore any variation of current in a certain circuit has no effect on any other circuit except the one connected to it by virtue of the other half of the repeating coil windings of the particular cord circuit concerned.

Q. 7.—Describe the construction and action of any type of condenser with which you are familiar.

A.—The most common type of condenser used in telephony is the Mansbridge type. This condenser is constructed with thin tinfoil of special manufacture so as to ensure uniformity and good conductivity. Condensers are made from two continuous rolls of this foil interleaved with strips of very thin paper, the length of the roll depending on the required capacity. The roll is then thoroughly dried, impregnated with paraffin wax and compressed into a flat shape, the block thus obtained being next hermetically sealed in a tin case. Leads from the foil sheets are brought out to two insulated terminals mounted in one end of the case.

A condenser consists of two conductors separated by an insulator. When a condenser is inserted in a direct current circuit a current flows into the condenser until it becomes charged, the two plates being of opposite polarity.

When a condenser is inserted in an alternating current circuit during one half cycle the condenser becomes charged as previously described. On the next half cycle the condenser discharges and becomes charged in the opposite direction. Thus, although no current actually passes through the condenser, in the alternating current case the effect of the alternating current which flows to charge the condenser is apparent throughout the circuit.

Q. 8.—What are the functions of a group selector used in automatic telephony?

A.—The functions of a group selector are:—

To return dialling tone to the calling party when seized.

To step the shaft and wipers vertically under the control of the calling party's dial.

At the end of the impulse train to step the wipers into the level reached and hunt for and seize the first free outlet in the level.

To prevent interference with circuits over which the wipers are passing during hunting.

To guard the seized circuit from intrusion.

To extend the calling party's lines for the next stage of operation.

To connect "busy" signal to the calling party should all outlets in the level dialled be engaged.

To release, when release conditions are connected to the circuit.

Q. 9.—Describe the construction and operation of any type of ring off indicator used in a magneto exchange.

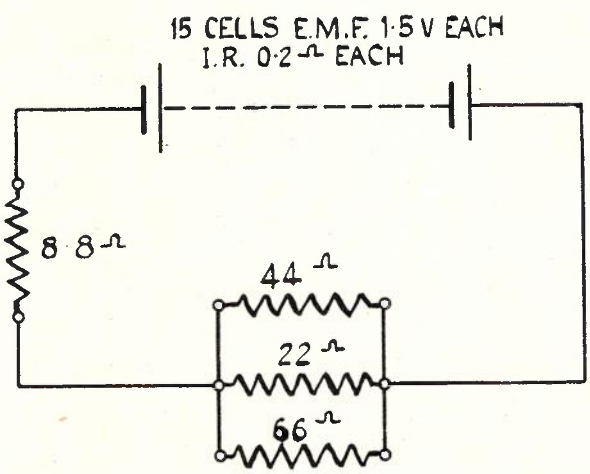
A.—The indicator has a single coil wound to a resistance of 1000 ohms. This coil is enclosed in a soft iron case. The soft iron core goes through the centre of the coil and screws into the case. The armature is a round disc which forms, in effect, the lid of the case. The shutter is hinged to the front of the indicator and the releasing latch is an extension of the armature.

As the magnetic circuit is of very small reluctance, the indicator is very sensitive and has great impedance. It can be therefore always connected in shunt across the circuit. It offers great impedance to speech currents but little more than its ohmic resistance to the 16 cycle ringing current.

The iron case also serves to confine the magnetic circuit to the indicator and thus prevents inductive effects on adjacent indicators.

The coil connections are brought out on tags which project through two clearance holes in the armature.

Q. 10.—Calculate the current flowing in each resistance of the following circuit:—



A.—Total voltage = 15 × 1.5 = 22.5 volts.
Resistance of battery = 15 × 0.2 = 3 ohms.
Joint resistance of the 3 parallel resistances—
= 1/(1/44 + 1/22 + 1/66) = 1/(11/132)
= 12 ohms.
Total resistance of circuit—
= 8.8 + 12 + 3 = 23.8 ohms.
C = E/R = 22.5/23.8 = 0.945 amps.
Current through battery and 8.8 ohm resistance—
= 0.945 amps.
Current divides in the three parallel resistances in the proportion of 6 : 3 : 2—
Current through 44 ohms = 3/11 of 0.945 = 0.258 amps.
,, ,, 22 ohms = 6/11 of 0.945 = 0.516 amps.
,, ,, 66 ohms = 2/11 of 0.945 = 0.172 amps.

EXAMINATION NO. 2194.—ENGINEER—LINE CONSTRUCTION (Cont.)

A. N. HOGGART, B.Sc.

Q. 5A.—(a) What are the principal requirements of the Departmental Specification for four-way earthenware conduits? Make a sketch and insert the dimen-

sions of any type of four-way conduits with which you are familiar.

(b) Describe in proper order the process of laying and jointing one type of four-way conduit. Include in your answer details of bedding required, depth and width of excavation, method of jointing and material used, method of ensuring correct alignment, tests during and after laying.

A.—(a) The following are the principal requirements of the specification for four-way earthenware conduits:—

(1) The whole of interior and exterior surfaces that will be exposed after jointing to be glazed.

(2) The inside surface to be free from all excrescences. The conduits shall be substantially free from roughness. The ends of the conduits shall be square on their longitudinal axis. The inside ends of the ducts shall be smoothly rounded off.

(3) The bores of the ducts shall be uniform throughout, truly centred and straight. Conduits shall be tested for smoothness and straightness by means of a mandril.

(4) The surfaces of the conduits shall be free from acids and soluble alkalies as shown by testing with litmus paper.

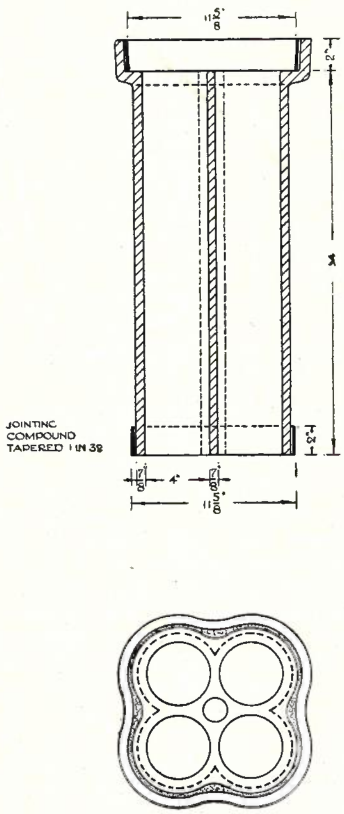


Fig. 1.—Self-Aligning 4-Way Conduit.

(5) A perfectly dry piece broken from the body of the conduit shall not absorb more than 7 per cent. of its weight after standing one hour in boiling water.

(6) Conduits shall withstand an internal hydraulic pressure test equal to a head of 30 feet of water.

(7) Conduits shall withstand a crushing test of 900 lbs. per lineal foot applied between two wooden blocks placed along the length of the conduit.

Figure 1 is a sketch of a four-way self-aligning conduit.

(b) Procedure for laying four-way self-aligning conduits:—

(1) Open trench which should be 1 ft. 3 ins. wide by 2 ft. deep (allowing approximately 15 ins. of cover) under footway. Under roadways, etc., the trench should be 6 ins. deeper.

(2) Level off and grade bottom of trench from manhole to manhole, so that there will be no tendency for water to collect in hollows in the ducts.

(3) Special bedding is not necessary unless the soil is of a gravelly or rocky nature in which case a bed of 2 ins. of sand or loose soil free from stones should be provided.

(4) Conduits are laid in bottom of trench, a small hollow being scooped out to accommodate the socket of each conduit. The first conduit to be laid is set in position, and the lining of the interior of the socket coated with bituminous jointing compound which is first heated to a suitable consistency. The lining of the spigot end of the next pipe should be similarly treated and then pressed fully home into the socket of pipe previously laid. If necessary, the duct should be levered into position by means of a crowbar applied to a large wooden block placed inside the duct socket. The remainder of the conduits are treated similarly. After the ducts are in position the seam of the joint is further treated with compound and special care is taken to ensure that the joints are waterproof. Care is also necessary to ensure that joints are free from dirt.

(6) When conduits are laid the trench should be back filled. Before the tops of the conduits are covered the earth along the side should be well tamped to prevent movement of the conduits.

(7) Self-aligning conduits do not require the use of mandrils when laying as the design of the joint ensures correct alignment. On completion of each section each duct should be tested by drawing through a mandril 3 ft. long and of diameter 3/16 in. less than that of the ducts.

Q. 5B.—(a) Describe the process of making a straight joint in a 400 pair 10 lb. subscribers' cable. Your answer should include a description of plumbing the joint, assuming sheet lead is used. The composition of the solder or wiping metal and the nature of the flux should be stated.

(b) Under what circumstances are:—

(i) Local type;

(ii) Trunk type star quad cables used?

State the essential differences between these types and explain the effect of the differences on the use of the cable.

A.—(a) Process of making straight joint in 400 pair cable:—

(1) The two cable ends should be set up in approximate position of joint with overlap of approximately 2 ft. 6 ins.

(2) Carefully strip the lead sheathing back off each end so that a space of approximately 2 ft. 3 ins. is left between the ends of sheathing. The conductors are then bound together with tape close to the sheathing and some of the tape is worked under the sheathing.

(3) The conductors are fanned out taking each layer in turn; half of each layer being bent upwards and remainder downwards, and each group is held together by twisting the ends. Each layer is bound with tape

close to the end of the sheathing, and any helical wrapping removed before fanning out.

(4) Starting from the centre of the cable the wires or quads should be jointed in turn, taking care not to split the pairs. With star quad cable, and unless the cable is a long one and limited within quad capacity balancing is being carried out, the wires with similar markings should be joined together. When jointing, a paper sleeve is first slipped over one conductor, and the ends of the wires to be joined twisted together for two complete but comparatively loose turns. The paper is then removed and the bare wires twisted for $\frac{3}{4}$ in., the twists getting shorter towards the tip. The rest of the wire should be snipped off and the joint bent over towards the paper sleeve, which should then be slipped over it.

(5) The joints in a pair or a quad should be made opposite each other, but those in different pairs or quads should be staggered to avoid bulkiness of the joint.

(6) On completion of jointing, the joint should be dried out by circulating hot air from a lamp or a blower.

(7) The joint is laced with a double thickness of thread, then wrapped firmly with overlapped helical turns of brown paper. The jointer's name and date is written on the wrapping, which is dried with warm air.

(8) The lead sleeve is prepared from a piece of 7 lb. sheet lead, size approximately 2 ft. 6 ins. x 10 ins., shaped to fit round joint, the ends being beaten down to fit neatly round cable sheathing. In preparing the sleeve, a border about 4 ins. wide is scraped clean round sides and ends of the piece, the ends of cable sheathing being similarly treated. The whole of the area cleaned is rubbed with stearine, which acts as a flux for the solder.

(9) The solder used consists of tin 34 per cent., lead 66 per cent, and is applied by means of a blow-lamp or air acetylene flame. The solder is worked into position by means of a moleskin pad, and should be worked as quickly as possible. The seam along the sleeve is sealed first and then the ends in turn. Care is necessary to ensure an air-tight joint free from pin holes, etc. Excessive heat also is to be avoided owing to danger of "burning" the lead and later leading to inter-crystalline fracture.

(10) After completion of the joint it is allowed to cool, and then carefully set into position on rests.

(11) Gas pressure test of the joints are made on every three or four lengths.

(b) (i) Local type star quad cable is used principally for subscribers' distribution, junction circuits, and minor trunk circuits.

(ii) Trunk type star quad cable is used for main trunk, or trunk entrance cables or where phantom circuits are to be used.

Trunk type cable compares with local type star quad cable in the following respects:—

(1) The insulation resistance is higher.

(2) The mean mutual capacity of each pair is lower.

(3) The variation in mean mutual capacity is lower.

(4) The capacity unbalance limits between pairs and to earth is lower.

(1) and (2) provide better transmission; (3) reduces impedance irregularities; (4) reduces cross-talk between various circuits, and noise interference.

Q. 6.—(a) Explain why cross-talk occurs between two untransposed aerial circuits. Include in your answer reference to electrostatic and electromagnetic effects and show why and to what extent cross-talk increases with frequency.

(b) What is meant by:—

(1) Far end cross talk?

(2) Near end cross-talk?

Explain with diagrams how each is measured.

(c) In four consecutive 8 mile transposition sections the measured far end cross-talk between two pairs is 60 decibels over each individual section. What would you expect the value of far end cross-talk over the same pairs to be when measured over the four sections, that is, a distance of 32 miles? Assume the sections to be joined together in the normal manner.

(d) A section 2 miles long over which the far end cross-talk between the same pairs is 30 decibels is added at one end, what would you expect the measured cross-talk to be over the 34 miles?

A.—(a) Cross-talk between two aerial circuits is due to the external magnetic and electrostatic fields of the disturbing circuits. Leakance is also a factor but this can be neglected in a well maintained line.

Fig. 1 shows the magnetic field resulting from currents in wires A and B, i.e., equal and opposite currents in A and B.

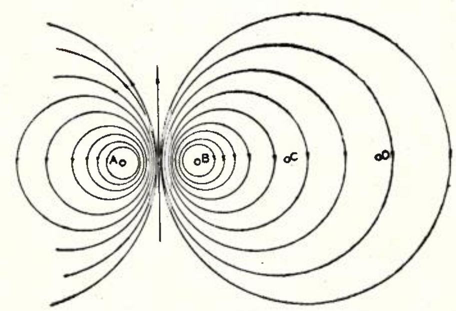


Fig. 1.—Magnetic Field of Telephone Line.

C and D represent wires through which the magnetic field of AB threads. Varying currents in AB will induce voltages in C and D but owing to the differences in the magnetic field at these points, these will not be equal; hence a current will tend to flow in the circuit of which CD forms part. The closer C is to AB and the wider the separation between C and D, the greater will be the induced potential difference.

Similarly the lines in Fig. 1 can be said to represent equipotential lines in the electrostatic field and the cross-talk in CD is due to the difference in the electrostatic potential at these points.

Electromagnetic cross-talk is due to currents in AB and electrostatic cross-talk is due to voltages in AB.

As the potential in CD due to electromagnetic induction is dependent on the rate of variation of the current in AB it is apparent that as the frequency rises the rate of variation of the current will rise and therefore the induced electromagnetic potential in CD will also rise.

(b) (1) Far end cross-talk is that heard on a circuit by a listener at the end distant from which the disturbing signal is sent.

(2) Near end crosstalk is that heard on a circuit by a listener at the end adjacent to that from which the disturbing signal is sent.

Far end crosstalk is measured by means of the circuit arrangements indicated in Fig. 2. The switch is placed in the two positions alternatively, and the crosstalk meter, which is a variable attenuator of high range, is adjusted until tone heard in receiver is the

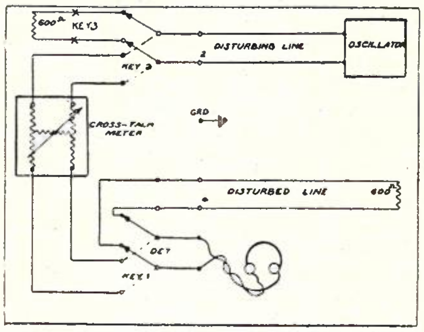


Fig. 2.—Measurement of "Far-End" Cross-Talk.

same in both positions of switch. The reading of the crosstalk meter gives the value of the crosstalk in decibels or crosstalk units.

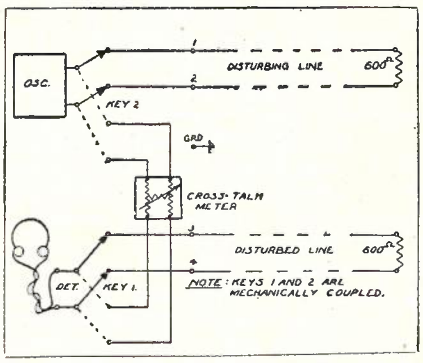


Fig. 3.—Measurement of "Near-End" Cross-Talk.

Near end crosstalk is measured by means of the circuit arrangements in Fig. 3. As before, the crosstalk meter is adjusted to give same tone in both positions of switch.

An amplifier may be necessary in the receiver circuit, or in the case of carrier frequency measurements a detector-amplifier.

(c) The crosstalk over the four sections depends on the transposition types and junction transpositions. For purposes of normal calculations, the square root of the sum of the squares of crosstalk in each section is used and will give a result which will probably be close to the actual figure, i.e.,

$$C = \sqrt{C_1^2 + C_2^2 + C_3^2 + C_4^2}$$

where C_1, C_2, etc., are crosstalk in each section in crosstalk units.

C = cross over whole section.

$$\therefore C = \sqrt{4 \times 1000^2} \text{ C.T.U. (60 db.} = 1000 \text{ C.T.U.)}$$
$$= 2000 \text{ C.T.U.}$$
$$= 54 \text{ db.}$$

The actual value can be expected to be in the vicinity of this figure.

If a section on which the crosstalk is 30 db. is added to the above, the overall crosstalk can be taken as 30 db. as the crosstalk of 54 db. is negligible compared with that of 30 db., since—

$$C = \sqrt{31{,}620^2 + 2000^2} \text{ (30 db.} = 31{,}620 \text{ C.T.U.}$$
$$= \sqrt{10^9 + 4 \times 10^6} \text{ C.T.U.}$$

as second term is negligible compared with first—

$$C = 31{,}620 \text{ C.T.U. approx.}$$
$$= 30 \text{ db. approx.}$$

Q. 7.—(a) Explain why unbalanced capacities in underground cable cause crosstalk between the side circuits. Show clearly in a diagram the capacities referred to. Describe the methods of reducing unbalanced capacities by:—

(i) Selection of the pairs to be jointed;
(ii) The use of condensers.

In the latter case, state what special properties the condensers should possess.

(b) What would be reasonable values for the mean and maximum capacity unbalance—considering side circuits only—in a trunk type star quad cable:—

(i) Over a manufacturing length of 176 yards;
(ii) Over a balanced loading coil section of 2000 yards?

Specify by reference to your diagram for (a) the capacity unbalances you are dealing with.

(c) What crosstalk values measured at 800 cycles would you expect to find between pairs in the same quad over a loading coil section 2000 yards long:—

(i) In a straight jointed local type star quad cable not capacity balanced;
(ii) In a capacity balanced trunk type star quad cable?

What would be the corresponding values between pairs from non-adjacent quads?

A.—Fig. 1 indicates in diagrammatic form the various capacities existing between the wires of a quad in an underground cable where AB is one side circuit, CD the other. It will be apparent between the wires there are direct capacitances w, x, y, z, and indirect capacitances involving a, b, c, d, etc. When considering crosstalk between the side circuits we can replace Fig. 1 with Fig. 2 where W, X, Y and Z are the resultant capacitances between the wires.

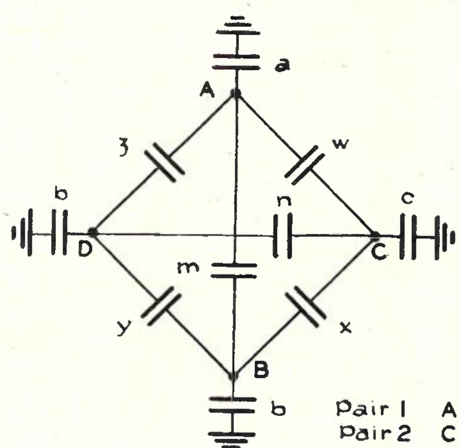


Fig. 1.—Direct Capacitances of Cable Quad.

Consider now that circuit AB is energized, and the effect of this on wire C. If W is not equal to X, then a potential will be induced in C proportional to W — X. Similarly if Z is not equal to Y a potential will be induced in D proportional to Y — Z. We therefore have for a condition of no interference from AB to CD that—

$$W - X + Y - Z = 0.$$

The same expression gives the condition also for no interference from CD to AB. It is therefore apparent that, unless the above relation is complied with, i.e., the capacities are unbalanced, then crosstalk between side circuits will take place, due to the resultant induced potential in the disturbed circuit.

In using the method of selecting pairs to reduce capacity unbalances, it is usual to balance out the capacities over a suitable length, preferably one loading

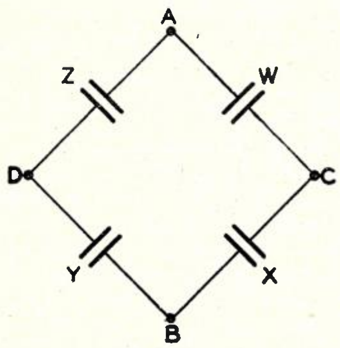


Fig. 1.—Resultant Capacitances of Cable Quad.

section. Balancing is carried out by means of 1, 3, 7 or 15 selected joints per section, the number depending on the length of the section, the limits to which the cable is to be balanced and the extent of unbalance in the cable. The lengths between selected joints should be as uniform as possible. All straight jointing apart from the selected joints is carried out and then the capacity unbalances are measured by means of a capacity unbalance bridge which is an AC bridge which reads unbalances directly. As the closest coupling occurs in the within quad condition, the majority of measurements are restricted to unbalances within the quad. The results are tabulated and from these, pairs are selected for jointing so that the unbalances tend to cancel out; where necessary crosses are inserted to achieve this. Alternate joints are balanced first, e.g., in an eight length section involving seven joints, numbers 1, 3, 5 and 7 are first treated, then numbers 2 and 6 and finally 4. As the work progresses the lengths over which balancing is carried out increase while at the same time the unbalances decrease.

As an alternative to selecting pairs, condensers may be connected in with the wires to cancel out the unbalances. The values of condensers required is determined by means of tests as before, except that tests over completed sections only are necessary. These condensers are usually included in the cable joint at the centre of the section.

The special properties required for these condensers are:—

(a) Small size so as not to make joint too bulky.

(b) High insulation resistance so as not to impair insulation of circuits.

(c) The temperature coefficient should be close to that of the cable.

(d) The phase difference must be low.

(e) They should have stability of characteristics over long period.

(b) The following figures for capacity unbalances in star quad trunk cables are maximum allowed by the specification; actual values will be considerably lower:—

(1) Over 176 yard length:—

Between pairs in same quad 125 mmF. (Max.)
W — X + Y — Z 33 mmF. (Mean)
Between pairs in adjacent quads 100 mmF. (Max.)
W — X + Y — Z 25 mmF. (Mean)
Between pairs and earth 420 mmF. (Max.)
a — b, or c — d 165 mmF. (Mean)

(2) Over loading section of 2000 yards:—

Between pairs in same quad 50 mmF.
Between pairs and earth 150 mmF.

(c) Crosstalk values in 2000 yard section of star quad cable:—

	Between pairs in Same Quad	Between pairs in Adjacent Quads
(i) Straight jointed local type	45-70 db.	80 db.upwards
(ii) Capacity balanced trunk cable	85 db.	90 db.

Q. 8.—(a) What do you understand by:—
(i) Anodic corrosion,
(ii) Cathodic corrosion

of underground cables? Describe briefly the conditions that give rise to each, and show how each affects an underground cable, stating the difference between the effects on cable in earthenware pipe and black iron pipe.

(b) Explain what is meant by "Boosted Drainage" stating under what circumstances it is used and why it is effective.

In some cases cables are connected to a zinc earthplate. Why is zinc used?

A.—(a) Anodic corrosion applied to underground cable refers to electrolytic corrosion which occurs when the cable is anodic to its surroundings, i.e., the cable is positive and discharging current. The currents setting up the conditions may be stray traction currents, return telegraph currents, etc., or galvanic, e.g., due to varying soil conditions, or to the cable being in contact with a metal such as copper which is electropositive to lead. Corrosion will take place if the current leaves the cable at a point where it is in contact with an electrolyte, i.e., if the cable is buried direct in the ground with the soil itself, or if in a conduit with moisture in the ducts. The natural salts in the ground provide the necessary conditions for the presence of the electrolyte which reacts with the lead forming a corrosion product. The corrosion is generally characterized by pitting of the sheath. Anodic corrosion will occur in earthen ware conduits, if the conduits are not perfectly dry, but if they can be maintained in a dry condition the conduits insulate the cable from the soil and tend to reduce the trouble. Anodic corrosion seldom occurs in black iron pipe as iron is electro-negative to lead and acts as a protection against this type of corrosion.

Cathodic corrosion refers to electrolytic corrosion which occurs when the cable is cathodic to its surroundings, i.e., the cable is negative and picking up current. The stray currents may be of the same nature as for anodic corrosion except that corrosion due to galvanic currents is very seldom experienced. Cathodic corrosion usually occurs in areas in which traction systems operate and stray currents are of considerable magnitude. With stray currents picking up on the pipe and cable, and the latter in contact with a film of moisture, hydroxides are formed (the composition of which depends on the constituents of the ground waters). The hydroxides react with the lead to form a corrosion product which consists of several modifications of lead monoxide and is always alkaline in reaction, and is characteristically yellow to red in colour. Cathodic corrosion is frequently experienced in iron pipe, particularly black iron, but seldom in other conduits. For this reason it is thought that the presence of ferric hydroxide has an accelerating effect on the corrosion.

(b) In areas where electrolytic corrosion of the anodic type is prevalent, it is the practice to provide "drainage" bonds from the underground cable sheath to the rail, negative feeder or negative busbar of the traction system, i.e., a metallic connection is made with the object of draining the current from the cable sheath on to the traction rail and preventing it escaping to earth. In order that this be effective, it is necessary for the potential of cable sheath to be lowered until it is negative to earth. Frequently this is not achieved with an ordinary bond, the cable sheath still remaining positive, and in order to overcome this difficulty an electromotive force is introduced into the drainage bond, the direction of the electromotive force being such as to increase the flow of current in the bond and thereby lower the potential of the cable until it is negative to earth and so overcoming the tendency to anodic corrosion.

Zinc earth plates are frequently connected to lead cables in anodic areas to combat electrolytic corrosion. Zinc is electro-negative relative to lead so that in such an area, stray currents will tend to discharge from the zinc rather than from the lead and consequently the potential of the lead cable will be lowered. The effect is similar to that of "boosted drainage."

ERRATUM.—An error has occurred in the answer to Question 3 of the Lines Construction Paper of Examination No. 2194—Engineer. The last sentence of Section (a) of the answer should read:—

"Also if the value of the inductance of the coils is increased, the cut off frequency is decreased."

EXAMINATION NO. 2194.—ENGINEER—TELEGRAPH EQUIPMENT

V. St. G. MAGNUSSON

Q. 1.—If the sending segment on the plateau of a quadruple multiplex system is covered with an insulating material, discuss fully the effects that would result under each of the following conditions:—

(a) Working duplex over a physical line using Gulstad vibrating relays; and

(b) Working over a carrier channel.

A.—If one of the sending segments on the plateau of a quadruple multiplex distributor is covered with an insulating material, it would mean that the polarity of the corresponding transmitter contacts would not be passed to the line. Depending on the particular combination, some letters would be transmitted correctly, whilst others would be mutilated. If the correcting segment is the one covered with an insulating material the corrected station would soon be out of synchronism. For the purpose of this answer, it is assumed that the one code element segment is insulated.

The result, when working duplex over a physical line and using Gulstad vibrating relays, would be such that when the sending brush passed over the insulated segment, the reception at the distant end would be under the control of the Gulstad winding of the relay at the receiving station. As the Gulstad windings control the tongue of the relay when the line current ceases to flow, the relay tongue would pass over to the opposite contact. Therefore, if the preceding signal was "marking" at the sending end and the signal to be transmitted over the insulated segment "spacing" the intended letter would be transmitted correctly. Under the same circumstance if the signal intended to be transmitted on the insulated segment was "marking" the letter would be mutilated.

Simply stated, it may be said that if the 5th sending segment of an arm is insulated, the opposite polarity to that transmitted on the 4th segment of the same arm will, in effect, be transmitted to the 5th receiving segment at the receiving station.

Taking the second condition, i.e., working over a carrier channel, assume the send loop to be connected to a polarized relay, type 215A. With this relay, the armature returns to the centre position when the coils are unenergized. If any one sending segment is insulated, "marking" current would be transmitted over the carrier channel during the period when the brush is passing over it.

Where static modulators are installed a similar condition would apply.

Q. 2.—What is the actual unit length of each signal impulse on a 7C direct keyboard type of Teleprinter? Discuss fully, with the aid of a sketch, the reasons for your answer, and indicate briefly any suggested alteration or additional equipment for bringing the actual output from a Teleprinter installation up to its approximate theoretical speed.

A.—The actual unit length of each signal impulse transmitted by a 7C direct keyboard teleprinter is one-seventh of the cycle necessary to transmit each character, or 20 milliseconds. The sender of the teleprinter is cut for a seven unit code and the transmitter cam drum completes its revolution in 140 milliseconds. Each signal element is of equal length. Five elements are required to form the character and in the sender the remaining two elements are for the start and stop

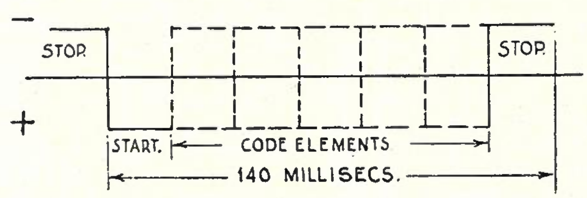


FIG. 1.

signals. Figure 1 shows graphically the complete cycle over the time period of 0-140 milliseconds. The receiver comes to rest $6\frac{1}{2}$ elements from the receipt of the start signal; this is half-way through the stop signal.

The Murray five unit code is utilized and any desired character represents a particular permutation of the five units. The start signal is sent to line prior to the character units and this sets the receptive mechanism in motion at the receiving end so that the acceptance period of the receiver will coincide with the transmission of the five code elements. At the end of the code elements, a stop signal is transmitted. The start and stop signals are necessary to re-establish synchronism between the transmitter and receiver at the completion of each revolution.

The receiving cam is cut for a six and one-half unit code and the sleeve completes its revolution in 130 milliseconds, and rests for a minimum period of 10 milliseconds. This rest period is necessary to nullify the otherwise cumulative effect of speed discrepancies between transmitter and receiver.

Due to locks and restraints on the transmitter keyboard, it is impossible to operate a key whilst transmission is in progress, and although the speed of the driving motor is adjusted to 71 w.p.m., this figure is the maximum theoretical speed of the teleprinter, and can never be attained in practice. This speed is subject to limitations, so far as the physical strain on the operator is concerned. The usual speed on teleprinters is 45 to 50 w.p.m. and this is considered reasonable.

The theoretical speed could be approached in practice by the use of a tape system for the transmission of the impulses. The Creed Auto-transmitter No. 6S will operate from ordinary Murray five unit code tape. The tape, after perforation, could be fed to the line at a speed of 66 w.p.m.

Q. 3.—Discuss fully the relative advantages and disadvantages of disposing of a traffic load of 12,000 M.U., maximum hour, in either direction between two centres 300 miles apart by means of:—

(a) A multiplex installation; and

(b) Asynchronous (i.e., start-stop) equipment.

Assume a message of twenty words equals 6 M.U.

A.—The first aspect to consider is the type of channels that can be made available between the two centres and their availability. It is possible that a voice frequency carrier system is in operation and if so this would have some effect upon the proposal. For the purpose of this proposal the question of disposing of the traffic concerned will be dealt with assuming that physical channels only are available. The effect on the proposal if voice frequency carrier channels are provided will be discussed.

The first figure to determine is the number of words per minute that must be disposed of during the busy or peak hour. Converting the 12,000 M.U. per hour to words per minute we have:—12,000 M.U. per hour $= 12{,}000/60 \times 20/6 = 666$ words per minute approx. Under normal circumstances, delay time is to be kept at a minimum.

Considering first asynchronous (stop-start) equipment. Teleprinters using tape transmission would be suitable. Whilst the maximum speed possible from a tape transmitter is 66 words per minute, a speed of 45 words per minute is used in this comparison. Using this output per set, the number of both send and receive units required at each centre would be $666/45 = 15$.

Dealing with the problem of traffic disposal by multiplex installations, as the centres are 300 miles apart it is probable that the line characteristics would limit the terminals to triple multiplex sets. Assuming that triple multiplex sets are installed and that each arm disposes of 45 words per minute, the number of sets to be installed at each centre would be $666/45 \times 3 = 5$.

Having determined the number of channel ends required under each system, the total cost per channel ends can be compared as follows:—

Item	Multiplex Systems No. required, 5			Asynchonous Systems No. required, 15		
	No. reqd.	Cost each	Total	No. reqd.	Cost each	Total
Perforators	15	£45	£675	15	£45	£675
Transmitters ..	15	36	540	15	36	540
Printers	15	110	1650	15	120	1800
Distributors	3	36	108			
Plateau	3	40	120			
Distr. Box	3	23	69			
Vibrator	3	36	108			
Total			£3270			£3015

Therefore the cost of providing the required channel end equipment would be lower if teleprinters are installed. Furthermore, the annual maintenance charges per channel end would be less. If either system is installed the following factors would be approximately equal:—

(a) Output per operator;

(b) Operating staff required;

(c) Flexibility.

Whilst providing and maintenance costs would be in favour of teleprinter installations, the rental costs of channels would be extremely high, 15 duo-directional physical circuits being necessary. Ten extra physicals would be required as compared with a triple multiplex installation and the annual rental charges on these lines would be considerable. These charges would definitely outweigh the lower providing and maintenance charges.

If a voice frequency system is in operation between the two centres it is possible that triple multiplex sets would not operate satisfactorily and double multiplex sets would need to be installed. This would mean that eight carrier channels would be required if multiplex systems are installed. Again, the rental charges for channels would be in favour of installing the multiplex terminals.

SECTION B

Q. 1.—In a Chief Telgraph Office there are twenty lightly loaded omnibus Morse simplex channels. Some are long circuits and subject to leakage. Explain, with the aid of a sketch, the circuit arrangements you would make to permit of the most economical staffing arrangements for traffic disposal.

A.—As all lines carry lightly loaded circuits, concentration would allow the most economical staffing arrangement for traffic disposal. Concentration satisfies the two main factors governing efficient and economical working; that is, speedy traffic disposal and a full traffic load for each operator. Concentration can be likened in many ways to grouping or trunking in automatic exchanges. Broadly, the same principles apply.

Of course, a possible alternative to concentrating the lines would be to increase, where practicable, the number of stations on some circuits by, for example, joining conveniently loaded lines end to end, but there are objections and limits to this method. In the first instance, the total resistance of the joined lines, with extra stations, would be high and the voltage required to provide working current may be excessive. Secondly, increasing the number of stations per circuit means that faults at any one station may affect all stations, and the average delay per station would, as a result, increase. Considering all factors, concentration of the existing lines at the C.T.O. is thought to be the most suitable method.

When concentrators are installed, only sufficient operators to handle the collective traffic from the whole twenty channels are required at any time. Each operator has before him a board containing line jacks and calling and busy lamps. His relay, sounder and key are terminated on a cord and plug with a changeover key in case of cord failure. All lines would be multipled to each concentrator position.

Telephone relays are now normally used in concentrator circuits. Relay A is an automatic switch type relay which can be readily adjusted so far as the tension of the restore spring is concerned. This is done by turning a thumb screw. A tension indicator passes over a graduated scale and shows comparative tensions. Previously, a telegraph line relay was used for the calling in relay (Relay A), but the telephone type relays have proved in service more convenient and satisfactory, particularly on leaky lines.

The circuit of a concentrator, together with the operator's cord circuit, is shown in Journal, Volume 1, No. 4, page 170 (December, 1936, issue). Briefly the circuit functions as follows:—When any distant station operator opens his key the primary line relay releases closing the energizing circuit of the secondary relay which locks over its own contact, and the release contact of the sleeve relay. The other contacts of the secondary relay operate the line calling lamps and pilot lamp relay.

The operator's Morse set, which is terminated on the tip and ring of a cord and plug, also has an earthed sleeve connection which, when plugged into the jack associated with a calling lamp, completes the sleeve relay circuit. The sleeve relay carries a changeover contact which releases the locking circuit on the secondary line relay to extinguish the line lamps and operates a number of ancillaried busy lamps, which in each case like the line lamps are mounted in strips associated with the line lamps.

Another function of the sleeve relay is to open the line relay circuit enabling current to flow directly through the operator's jack. When the traffic is completed the line circuit is closed and on withdrawal of the plug the primary line relay energises, thus restoring conditions to normal.

(To be continued.)

EXAMINATION NO. 2194.—ENGINEER—TRANSMISSION: LINE AND RADIO

J. W. READ, B.Sc., A.M.I.E E, A.M.I.E.(Aust.)

Section 1.—General Theory and Measurements

Q. 1.—The expression for the sending end impedance of a finite uniform line closed by any terminal impedance is—

$$Z = Z_0 \frac{(Z_0 \sinh Pl + Z_T \cosh Pl)}{(Z_0 \cosh Pl + Z_T \sinh Pl)}$$

How can this expression be used to determine the characteristic impedance and the propagation constant of the line?

A.—The expression—

$$Z = Z_0 \frac{(Z_0 \sinh Pl + Z_T \cosh Pl)}{(Z_0 \cosh Pl + Z_T \sinh Pl)}$$

gives for $Z_T = 0$ (short circuit condition)

$$Z = Z_c = Z_0 \tanh Pl \quad \ldots\ldots \text{I.}$$

and for $Z_T = \infty$ (open circuit condition)

$$Z = Z_f = Z_0 \cosh Pl \quad \ldots\ldots \text{II.}$$

multiplying I. by II.

$$Z_f Z_c = Z_0^2$$

$$\text{or } Z_0 = \sqrt{Z_f Z_c}$$

dividing II. into I.

$$\frac{Z_c}{Z_f} = \tanh^2 Pl$$

$$\sqrt{\frac{Z_c}{Z_f}} = \tanh Pl$$

$$= \frac{e^{Pl} - e^{-Pl}}{e^{Pl} + e^{-Pl}}$$

$$= \frac{e^{2Pl} - 1}{e^{2Pl} + 1}$$

from which—

$$(e^{2Pl} + 1)\sqrt{\frac{Z_c}{Z_f}} = e^{2Pl} - 1$$

$$e^{2Pl} = \frac{1 + \sqrt{Z_c/Z_f}}{1 - \sqrt{Z_c/Z_f}}$$

$$e^{2Pl} = \frac{\sqrt{Z_f} + \sqrt{Z_c}}{\sqrt{Z_f} - \sqrt{Z_c}}$$

$$= \frac{Z_f + Z_c + 2Z_0}{Z_f - Z_c}$$

$$= M \angle\theta$$

$$e^{2(\alpha + j\beta)l} = M e^{j\theta}$$

$$\text{so that } \alpha = \frac{1}{2l} \log_e M$$

$$\beta = \frac{n\pi + \theta}{2l}$$

$$P = \alpha + j\beta.$$

Q. 2.—A 40-lb. per mile cable circuit has the following constants per loop mile at 50 kC:—

R (effective) = 60 ohms.
L = 1.0 millihenry.
C = 0.066 microfarad.
G = 200 × 10⁻⁶ mhos.

It is desired to load this circuit to transmit up to 50 kC.

State:—

(a) What factors must be given consideration in determining the loading to be used in respect of:—

(i) Attenuation;
(ii) Characteristic Impedance;
(iii) Cut off?

(b) What would the attenuation per mile and the characteristic impedance be (approximately) if ideal coils having an inductance of 3 millihenries are used at intervals of one-seventh of a mile?

A.—(a) In determining the loading to work up to 50 kC the Attenuation is given approximately by—

$$= \tfrac{1}{2}R\sqrt{C/L} + \tfrac{1}{2}G\sqrt{L/C}$$

where R = resistance per mile
L = inductance per mile
C = capacity per mile; and
G = leakance per mile.

The characteristic impedance is given approximately by—

$$Z = \sqrt{L/C}$$

$$\text{The cut off frequency} = f_c = \frac{1}{\pi\sqrt{LS^2C}}$$

S = coil spacing in miles.

In an unloaded cable $\tfrac{1}{2}R\sqrt{C/L}$ is generally larger than $\tfrac{1}{2}G\sqrt{L/C}$ and a reduction in attenuation can be obtained by increasing L.

The above expression for attenuation is only applicable when the frequency is appreciably below the cut off frequency. It is not possible to work above about ⅔ of the cut off frequency. The loading should therefore be designed with $f_c = 50 \times 3/2 = 75$ kC.

Where special terminal units are used, the operating range may be up to .75 f_c. Such loading is very frequently applied to relatively short cables directly connected to aerial lines. In this case the loading is designed to avoid reflection and the Impedance should equal that of the aerial line (approx. 600 ohms).

If then Z and f_c are fixed, R, C and G are determined by the cable used, L^1 and S the inductance and spacing of the coils can be found from the equations quoted above.

The equations quoted above do not take into account the fact that the inductance is "lumped," and to allow for this more complicated formulæ are necessary.

(b) If $L^1 = 3$ mh

$$L = 22 \text{ mh/mile}$$

$$Z = \sqrt{\frac{22 \times 10^{-3}}{.066 \times 10^{-6}}} = 578 \text{ ohms.}$$

$$\alpha = \frac{30}{578} + \frac{200 \times 10^{-6} \times 578}{2}$$

$$= .052 + .058$$

$$= .11 \text{ nepers/mile}$$

$$= .95 \text{ db/mile.}$$

Q. 3.—An impedance irregularity at some point along a telephone line is to be located by alternating current bridge measurements. Give the details of the measurements you would make under the following headings:—

(a) The instruments to be used;

(b) The precautions to be taken;

(c) The measurements that should be made;

(d) The form in which the results should be recorded;

(e) The method of determining the location of the irregularity.

A.—To locate an impedance irregularity by AC methods the impedance should be measured by an impedance bridge.

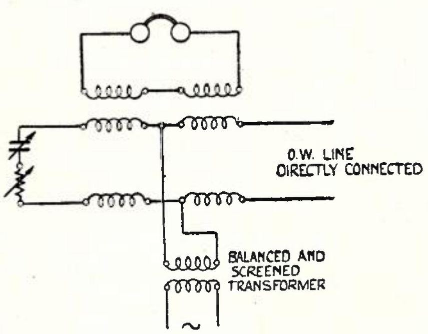


Fig. 1.—Hybrid Coil Type of Impedance Bridge.
(For Positive angle Impedances the capacity is connected in series with the Line to be measured.)

(a) The equipment required consists of:—

(i) A bridge, a suitable form of which is the hybrid coil of 3 winding transformer (type 4A impedance bridge).

(ii) A suitable source of variable frequency, such as an 8A oscillator.

(iii) A detector—a pair of receivers will be adequate in some cases, but more generally some form of detector amplifier is required. A battery supply is also required, such that the detector is not directly affected by the oscillator. Where small batteries are used it may be necessary to use a battery filter for the Detector.

(b) **Precautions.**—The source of alternating current must be balanced to ground. If there is no balanced transformer in the bridge input or oscillator output, one should be included. The earth connection of the bridge should be earthed to shield the bridge. The detector should also be isolated from the bridge. As shown in the above figure, the hybrid performs this function. The far end of the line should be terminated in as nearly as possible the characteristic impedance of the line. For open wire lines a 600 ohm termination is generally adequate.

(c) The bridge is balanced to give the value of R and C, which are equivalent to Z at a series of frequencies. These measurements should be made at not less than 6 frequencies per maximum value of impedance, and preferably more. They should also be continued along the frequency scale until a number of such maxima have been covered. The number so covered will depend on circumstances, but a wide frequency range will enhance the accuracy.

(d) The results should be recorded thus:—

Freq. cycles/sec. f	Res. R ohms	Capacity C μF	Angle	Cap. Reac. $\frac{1}{2\pi fC} = X$	$Z = \sqrt{R^2 + X^2}$

The angle indicates whether the condenser in the bridge is in series with R (negative angle) or in series with the unknown impedance, which will sometimes occur (positive angle). Z need not be calculated as R and X can be used for the subsequent steps.

(e) The values of R and X should then be graphed against frequency on a straight scale (not logarithmic). These will then be found to have a regular wave if a single impedance irregularity exists. The frequency interval f_i between two corresponding points on either graph should now be evaluated from the graph. Increased accuracy can be obtained by finding the difference in frequency between two maxima as far apart as possible and dividing by the number of intervals.

The distance to the irregularity is then given by—

$$\frac{\text{Velocity of propagation}}{2 f_i}$$

f_i will be actually an average value and if found from the R graph can be checked from the X graph. For open wire lines the velocity is approximately 180,000 miles/sec.

(To be continued.)

POLICY:

THE object of the Postal Electrical Society of Victoria is to promote diffusion of knowledge in the communication services of the Post Office.

In advancing this object by the publication of this Journal the Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

Editors are welcome to use not more than one-third of any article provided credit is given at the beginning or end, thus:—From "The Telecommunication Journal of Australia."

DISTRIBUTION:

This Journal is available to members of the Postal Electrical Society of Victoria without charge. Other officers of the Postmaster General's Department may obtain copies of all publications of the Society on the payment in advance of 4/- p.a. Single copies of this Journal are available at 2/- each.

COMMUNICATIONS:

All communications should be addressed to:—

A. R. GOURLEY,
Hon. Secretary, Postal Electrical Society of Victoria,
G.P.O. Box 4050, Melbourne.

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

Ruskin Press Pty. Ltd.
123 Latrobe Street
Melbourne