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DEVELOPMENTS IN CARRIER TELEGRAPH TRANSMISSION IN AUSTRALIA

R. E. Page, A.M.I.E. (Aust.) and J. L. Skerrett

FOREWORD BY R. E. PAGE, A.M.I.E.(AUST.)

The introduction of the first carrier telegraph system into Australia in 1927 marked a considerable advance in the methods of providing and working the more important telegraph circuits between the capital cities of the Commonwealth. This first system, a Western Electric Type "B," of 10 channels, was installed between Melbourne and Sydney in 1927, some two years after the first three-channel carrier telephone system had been placed in service between the two capitals, and is still in operation, carrying important circuits between those two centres.

The success of the type "B" system in providing a number of comparatively high speed, but more particularly, stable and readily controlled, telegraph channels, superimposed over one physical line, led to the early installation of further similar systems between the other State capitals: Sydney-Brisbane, Melbourne-Adelaide, and Adelaide-Perth. These systems then became the principal media for the transmission of telegraph traffic between the mainland capitals of the Commonwealth. With the advent of the type "B" system, the traffic handling methods tended to develop into the extraction of the utmost carrying capacity from each channel, and large volumes of traffic were shifted over long distances by machine telegraph systems. The Murray Multiplex system was used, the quadruple multiplex between adjacent capitals and triple multiplex where two links were used in tandem.

The capabilities of these methods in disposing of heavy telegraph traffic loads are demonstrated by the fact that until as recently as June, 1942, the carrier telegraph channels (all of type "B") between the various capitals were still few in number, being from Perth to Adelaide, 5; Adelaide to Melbourne, 10; Melbourne to Sydney, 10; and Sydney to Brisbane, 4 only. Each of these telegraph systems required for its operation a "carrier line" over the long interstate routes, and this fact, from the point of view of the Lines Design Engineer, soon came to be regarded as a disadvantage since, with the growing demands for telephone channels between the capitals, the physical telephone lines in use for the type "B" telegraph systems could not be used for multichannel carrier telephone systems, nor could they be used for physical broadcast relay channels between the capitals.

In 1935 the first voice frequency carrier telegraph system was placed in service between Sydney and Tamworth. It provided 18 duplex channels which were operated over one channel only of a three-channel telephone carrier system. The proposal to install this system had been initiated by the writer (then located in New South Wales) and justified because of the large savings in operating costs to be achieved by the abolition of Tamworth as a large telegraph repeating centre, and on the line plant side by the savings in maintenance costs from the abolition of old iron wire telegraph lines, including the disposal of an entire pole line 160 miles in length then existing and carrying physical iron wire telegraph lines between Maitland and Tamworth. All these advantages were actually secured, but in addition valuable floor space was recovered at Tamworth to meet other requirements, while the grade of telegraph service was very greatly improved since the stability and improved maintenance practices of "carrier" working were also secured for the benefit of the telegraph channels.

Experience with this first system led to the installation of other 18-channel V.F. systems between Sydney and Wagga and Brisbane and Townsville to secure similar advantages on the operating side to those gained with the Tamworth system. A 12-channel V.F. system was also obtained for use between Sydney and Lismore, but at the outbreak of the European war in 1939 this was diverted and placed into service between Sydney and Canberra.

It will be seen that development between 1927 and 1939, regarded from the point of view of the number of systems installed and the number of telegraph channels provided, had been comparatively slow. The ability of the type "B" systems between the interstate capitals to handle heavy traffic loads had tended to restrict the introduction of additional systems, while the few

V.F. systems in use had been installed between intrastate centres to secure operating advantages. In the main, the great bulk of the intrastate telegraph circuits were still provided by physical lines, many of them of inferior quality, being of iron wire (numbers of them more than 50 years old) or provided over circuits secured as by-products of telephone lines, viz., composite telegraph circuits or caihlos over physical telephone channels.

The outbreak of war with Japan in December, 1941, and the subsequent building up of armed forces in Australia from early in 1942 onwards, gave rise to heavy demands upon the Department to provide additional telegraph communication facilities throughout Australia. For the reasons outlined in the foregoing, the Department was very badly placed to produce at short notice numbers of additional communication channels. The telegraph channels required by the forces were those capable of operating teleprinter or teletype services over long distances between headquarters located in capital cities and the forward areas, many hundreds of miles, and in some cases over 2,000 miles distant. The problem was rendered more difficult by the fact that each branch of the defence forces required to have available at all times one or more services for its own individual use. Thus, instead of the traffic being brought to one centre and passed to other States or centres over a few channels using machine systems, as under Departmental practice, the demand quickly grew for numbers of separate channels each capable of operating continuously teleprinter and teletype services over long distances.

The quickest and most economical way of providing groups of efficient telegraph channels capable of meeting the conditions required was by the use of multi-channel carrier telegraph systems. As the position stood in 1942, the means available of meeting the requirements of the defence forces were very limited, nor was the outlook in respect of securing additional equipment to provide additional facilities very bright. Prior to 1942, all carrier telegraph systems installed in the Commonwealth had been obtained from overseas. Only one firm in Australia, Standard Telephones & Cables Pty. Ltd., was proceeding with local manufacture, but production had not been finalised at that stage. Due to the war, overseas supplies had practically ceased. Indeed, with the single exception of one 18-channel system of B.G.E. manufacture, delivered from Great Britain late in 1941, no carrier telegraph equipment could be secured from any source outside Australia for 4½ years from the outbreak of the European war, i.e., from 1939 to 1944.

The Department had never attempted the manufacture of equipment of this type in its own workshops, but had during 1941 endeavoured to develop a four-channel carrier telegraph system, now known as the Type "R" system, in order to take advantage of the frequency spectrum between 3,000 and 5,200 cycles which is available with some telephone carrier systems, between the highest frequency of the V.F. telephone channel and the lowest frequency of the first carrier channel. This system was intended for operation over physical lines without intermediate repeaters, and, therefore, had application to special cases only.

A test of the capabilities of local manufactures by the invitation of short-dated tenders early in 1942 for carrier telegraph equipment showed that it was hopeless to expect any supply from this source other than from Standard Telephones & Cables Pty. Ltd. within 12 months. Standard Telephones & Cables Pty. Ltd. already held an order for one 18-channel V.F. system, but their supplies of raw materials were very limited. Arrangements were made with the company to vary the order to provide for two nine-channel systems in lieu of one 18 channel system in order to spread the available materials, and thus the benefits, and a little later a further two 9-channel systems were ordered. Steps were also taken to develop and improve the 4-channel Type "R" system with a view to producing several of them departmentally to meet immediate needs. Two 4-channel systems of this type were completed early in 1942, and carrier telegraph service on these systems was provided from Adelaide to Alice Springs by February, 1942, and to the Darwin area by April, 1942, the systems being operated in both cases over carrier telephone channels.

By this time it was becoming obvious that demands from the services were increasing so rapidly that even the use of a number of 4-channel systems would provide temporary relief only. The difficulties in attempting manufacture of further systems or systems providing a greater number of channels was the lack of high permeability core material for the manufacture of filters or any supplies of the special sensitive telegraph receiving relays used in these systems. Fortunately, a limited supply of core material, suitable for use with voice frequencies, had been located with a local firm in Melbourne. This core material was secured, and the difficulty of receiving relays was partly overcome by the development of a suitable relay, known departmentally as the P.R. 10. Manufacture of supplies of these relays, which has been described in a previous issue of this Journal (Vol. 4, No. 4, June, 1943), was commenced in the Melbourne workshops, and the design and development of voice-frequency carrier telegraph systems of nine channels as well as some of four channels was undertaken. To increase the rate of output, contracts were let for component parts and some complete panel units, and while the main manufacture and assembly was undertaken in the Melbourne workshops, manufacture of several systems was also undertaken by the Transmission Engineers, Sydney and Adelaide, filters and relays being supplied from Melbourne. This spreading of effort proved very successful in securing quick results, as it enabled the production of several systems in a short time, and played no small part in alleviating the heavy demands for long distance telegraph services which persisted during the second half of 1942.

Manufacture of this type of equipment proceeded during 1942 and 1943 as rapidly as all the difficulties of labour shortage and shortage of special components and raw materials permitted. By the end of 1943, 15 systems providing four, six, or nine channels each, had been produced and installed. Standard Telephones & Cables Pty. Ltd., Sydney, completed four 9-channel systems in the same period, and subsequently supplied further equipment to permit the extension of two of these 9-channel systems to 12 channels and two of them to 18 channels. (Incidentally, 14/4-channel terminals —equivalent to 7/4-channel systems—were also produced in the Department's Melbourne workshops during the same period for use by the Australian Army Signals Corps on mobile communication units in forward areas or for use in combat areas outside Australia proper.)

The establishment of this "production line" and the subsequent installation of the equipment transformed the position of the Department in respect to meeting telegraph channel requirements throughout Australia not only for the armed forces but to cope with the very heavy increase in telegraph traffic over the Department's own services, due to the widespread activities associated with the mobilisation of the national resources for the war effort and the extensive rearrangements of population brought about thereby.

The extent to which additional carrier telegraph facilities were provided in this period is indicated by the following figures:—

	Channels.	Mileage.
Channels and mileage of channels provided by carrier telegraph systems existing in Australia at 31/12/41	240	114,240
Channels and mileage of channels provided by carrier telegraph systems existing in Australia at 31/12/42	384	234,040
Channels and mileage of channels provided by carrier telegraph systems existing in Australia at 31/12/43	590	358,840

It will thus be seen that during the single year, 1942, the carrier telegraph mileage which had been built up over the previous 15 years throughout the Commonwealth was doubled, and by the end of 1943 it had been trebled.

The new installations had spread throughout every mainland State of the Commonwealth. Since so much of this new equipment is in use for military purposes, the locations of the various systems installed cannot be given at this stage, but an indication of the manner in which each State has shared in the building up of channels over the period mentioned is shown by Fig. A, which compares the carrier telegraph channels routing through each of the five mainland capital cities of the Commonwealth in January, 1944, with those existing two years previously in January, 1942.

In meeting various requests for numbers of additional telegraph channels at short notice over long distances with little or no spare equipment available it was necessary from time to time to adopt unusual expedients. A striking example is provided by the rearrangement and extension of carrier telegraph facilities between Brisbane, Sydney, Melbourne, and Canberra which took place during July, 1942. The importance of the results secured and the expedition with which they were carried through, despite the many difficulties to be overcome at that time, were such that a description of the various steps involved and the manner of carrying them into effect will be of general interest.

All channels provided by the carrier telegraph systems in use at June, 1942, between the capital cities concerned were fully occupied, there were no spares on any route, and the most serious bottle-neck was the link between Brisbane and Sydney, where four type "B" carrier channels only were available. (See Fig. B, Phase 1.) In anticipation that there would be need for some additional telegraph facilities between Brisbane and Sydney in the early future, the manufacture, departmentally, of equipment designed to extend this system to its full capacity of 10 channels had been commenced in Sydney a few months earlier, and completion of this additional equipment was expected early in July. The only carrier telegraph equipment on hand and not actually in use at this time was one four-channel type "R" system, the manufacture of which had just been completed by the Department in Melbourne. Delivery was, however, expected early in July of a 9-channel system from Standard Telephones & Cables Pty. Ltd., Sydney. This latter system was intended for installation between Melbourne and Adelaide.

An examination of the routing of the various existing circuits provided by the inter-capital systems showed that although ten channels were provided on the direct route between Melbourne and Sydney, a further nine channels were derived by extending nine of the channels in the 18-channel system between Melbourne and Canberra through to Sydney over nine of the channels in the Canberra-Sydney 12-channel system. Thus of the existing circuits in the Melbourne-Canberra and Canberra-Sydney systems, there were, at that time, only nine direct channels serving between Melbourne and Canberra and three direct channels between Canberra and Sydney.

Standard Telephones & Cables Pty. Ltd. met the Department's request for early completion of the 9-channel system, and it was delivered in Sydney on July 3, but without the all-important receiving relays, which were not available until and Sydney. The type "R" system was then brought into operation between those centres and the three existing channels transferred to it, thus throwing free all channels in the existing 12-channel system between Canberra and Sydney and providing one extra circuit.

The Sydney terminal of this 12-channel sys-

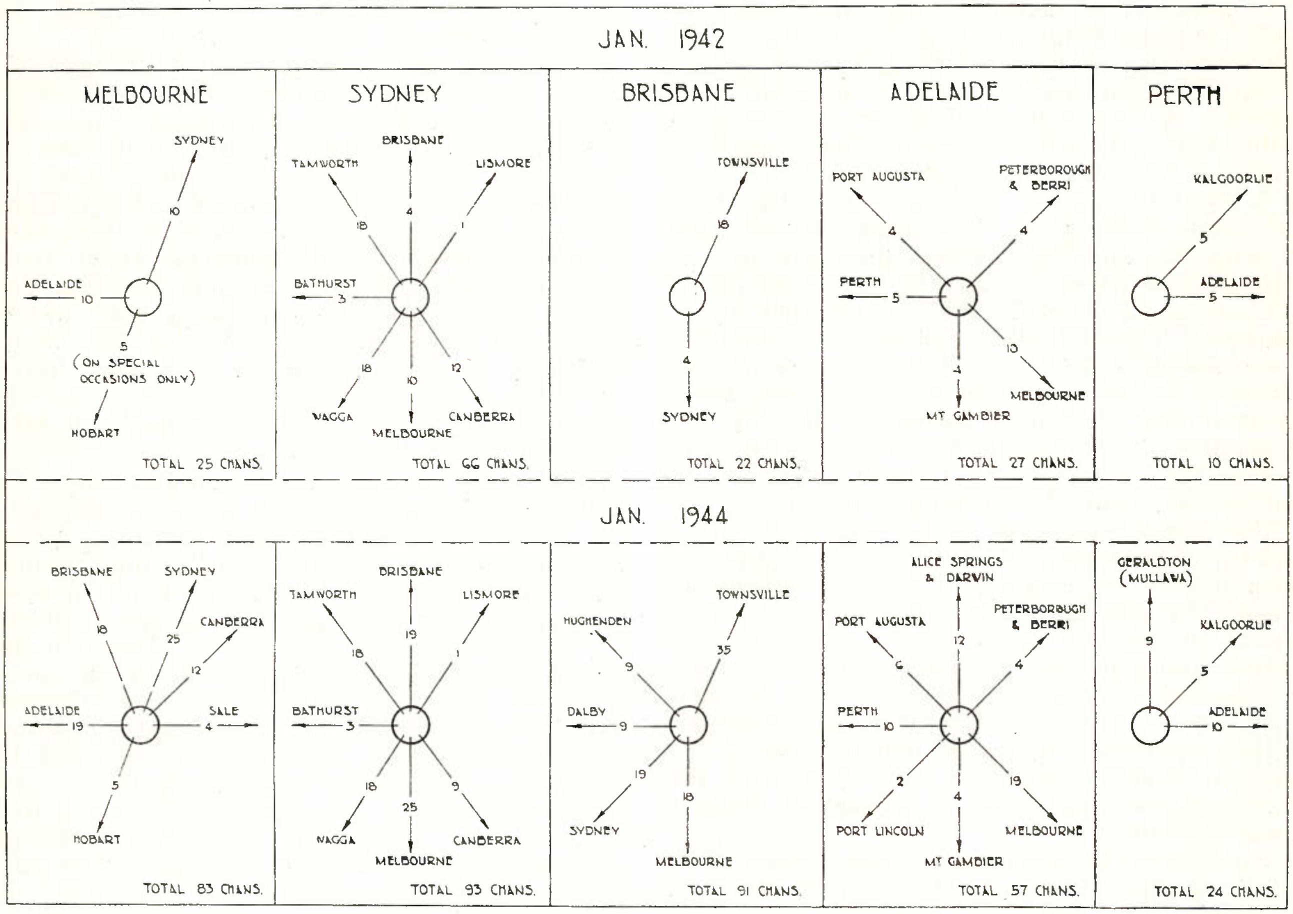


Fig. A.

a week later. As the first step in a complete plan it was decided to install this system on the direct route between Sydney and Melbourne. Since heavy transport congestion existed at the time over the railway system due to the break of gauge at Albury, the terminal for use at Melbourne was brought from Sydney by road by Departmental gas-producer truck. This truck, on its return journey, took back to Canberra and Sydney respectively the two terminals of the departmentally manufactured type "R" system. The new nine-channel system on the direct Melbourne-Sydney route was brought into service on or about the 12th July, after the receipt, by post, of the receiving relays. This installation permitted the diversion to the direct route of the nine Melbourne-Sydney channels previously routed via Canberra. This diversion left three channels only to be catered for between Canberra tem was then transported, again by departmental truck, from Sydney to Melbourne and set up to work into the terminal at Canberra over the Melbourne-Canberra route. The cut-over of this system permitted the transfer thereto of the nine direct Melbourne-Canberra circuits (leaving three spares), and permitted the complete recovery of the 18-channel system between Melbourne and Canberra. In the meantime, the additional equipment to extend the Sydney-Brisbane type "B" system by six channels had been completed in Sydney and the equipment for the Brisbane end transferred there. This equipment varied in many respects from the existing type "B" equipment, but, subject to some initial difficulties in arranging interconnection with the existing equipment, was brought into operation on the 15th July.

The final step to be undertaken was the placing into operation between Melbourne and Brisbane of the 18-channel system which had been freed between Melbourne and Canberra. This involved the transfer to Brisbane of the 18-channel terminal from Canberra. In the carrying out of the rearrangement to this stage, numerous minor difficulties had been met and overcome, but the time within which it had been intimated that the series of operations to provide all the channels required could be completed, viz., the end of July, was now running short, only eight days remained. It was decided, therefore, to attempt the transfer by air, and with the assistance of the U.S. Army Signals Corps, arrangements were made to transport by bomber plane the Canberra terminal with all its accessories, weighing, in all, some 18cwt., from Canberra to Brisbane. This was successfully accomplished, the plane picking up the terminal at Canberra and landing it without mishap the same day in Brisbane. Installation of the Brisbane terminal had been prepared for and was pushed forward with expedition. Suitable telephone channels had already been selected, over which the telegraph service was to operate direct between Brisbane and Melbourne without any intermediate telegraph equipment in Sydney. The successful cutting-over into service of this system on July 31 completed the operations.

weeks from the time that advice of requirements was first received by the Department and without the loss or closing down at any stage of any of the existing telegraph channels, which comprised some of the most important circuits in the Commonwealth. The time occupied between the actual receipt of the complete equipment for the 9-channel system used between Melbourne and Sydney which permitted the series of operations to commence until the final cut-over into service of the 18-channel system between Melbourne and Brisbane was 21 days only.

Apart from development in numbers of channels and channel mileage, a large number of technical improvements have been made in the period between the installation of the first carrier telegraph system in 1927 and the present day, particularly in relation to the generation of frequencies, the elimination of sending relays, the introduction of level compensating circuits, and numerous other specific electrical and physical aspects. An important development, however, is that experience has resulted in a clearer conception of the problems associated with carrier telegraph transmission, and considerable advancement has been made towards determining the possibilities and limitations of systems with respect to distortion and interference. This aspect will

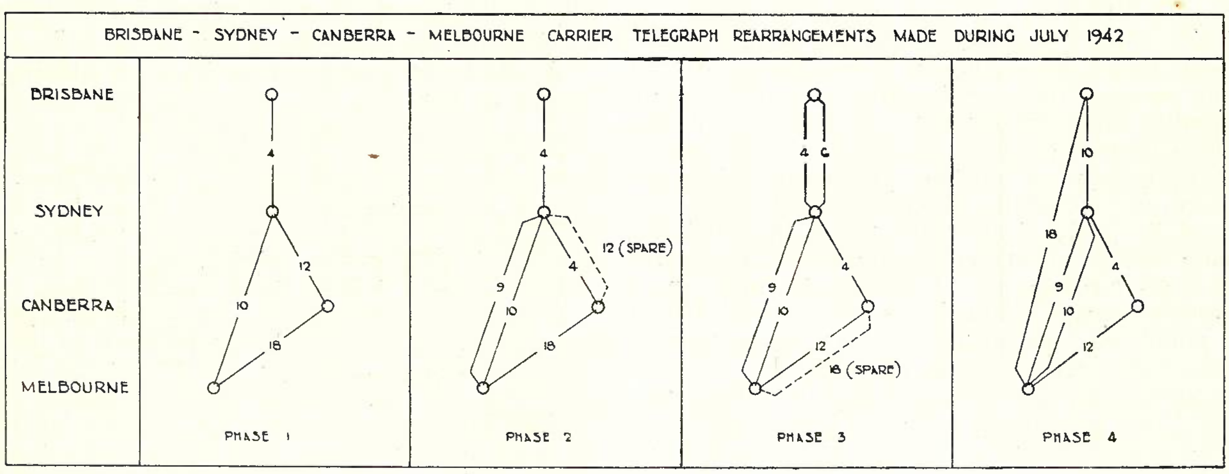


Fig. B.

The various stages of this operation will be followed by reference to phases 1 to 4 of Fig. B.

These changes enabled all the circuits which had been requested by the military authorities between the four capitals to be provided with a margin of two spares between Melbourne and Brisbane and a similar number between Melbourne and Canberra. For the introduction of a small quantity only of new equipment, the mileage of carrier telegraph channels was increased by over 100 per cent. from 18,700 to 40,600. The whole operation described was completed in five

be discussed in more detail in the technical articles describing the various systems which will appear in this and later issues of the Journal.

It is interesting to review the part played by carrier telegraphs in the evolution of telegraph practice over long distances. As the range of telegraph communication extended, the necessity to utilise expensive lines to the best advantage led to the development of two main systems of telegraphy—high speed systems and multiplex systems. High speed systems obtain increased output, speeding transmission beyond the ability of a single operator by using automatic transmitters which can be fed with perforated tape prepared in advance by a number of operators; multiplex systems, on the other hand, assign the line in turn to a number of operators, thus obtaining high channel carrying capacity by transmitting a number of messages simultaneously, each operator working at normal speed.

With the advent of carrier telegraph systems capable of subdividing a line or, alternatively, a speech channel into a large number of telegraph channels, at the same time offering greater flexibility and obviating the need to retain complicated mechanical apparatus, it became economical to assign one channel end per operator on the basis of machine operation using teleprinter or teletype machines. In this connection it should be mentioned here that the earlier carrier telegraph system, the Type "B," had sufficient channel band width to take a quadruple multiplex machine system and the narrower band widths suitable for teleprinter-teletype-transmission were first introduced with the voice frequency systems.

The success of the voice frequency carrier telegraph system is due, firstly, to its adaptability to economical operation over telephone circuits by making use of the whole frequency band usually allocated for speech purposes, and secondly to the fact that it requires transmission characteristics similar to those of the telephone speech channels. Since it is now regular practice to operate voice frequency telegraph systems over carrier telephone channels, it may be said that every advance directed towards an improvement in quality and performance of telephone circuits, such as improved band width, better equalisation, and regulation of circuits, reduction of interference and crosstalk, all contribute towards improved telegraph transmission. With voice frequency telegraph systems, wherever satisfactory telephone circuits are established, high speed reliable telegraph channels can be provided. Under the conditions operating in the Commonwealth, where both services are operated by the one administration, the telegraph and telephone services thus tend to become not so much competitors as services complementary to one another.

In order to describe the details of the various systems in use a series of articles has been prepared by Mr. J. L. Skerrett. These will also cover the technical developments which have taken place in carrier telegraph working and survey some of the problems associated with the establishment of a reliable long distance telegraph network. The first paper appears in the current issue of this Journal. The second article will have reference more particularly to the Australian Post-office Type "R" and Voice Frequency systems, while the third will discuss the telegraph transmission aspects of carrier telegraph systems and the associated telegraph apparatus.

Developments in Carrier Telegraph Transmission in Australia

PART 1.—J. L. SKERRETT

The Type B Carrier Telegraph System

The earliest development in carrier telegraph working commenced with the introduction of the Type B system. This system provides up to a maximum of 10 duplex (duo-directional simplex) channels on an open wire pair, and several such systems have been installed in the Commonwealth principally between capital cities. Experience over a number of years has proved them to be of simple yet robust design and, despite the absence of refinements included in later carrier telegraph systems, the Type B systems in use are rendering excellent service, although they require more maintenance and lack the flexibility of later systems.

In the Type B system 20 separate carrier frequencies are employed, 10 in each direction of transmission, the low frequency group (3.33-5.50 kC/sec.) being transmitted in the B-A direction and the high frequency group (6.50-10.00 kC/sec.) in the A-B direction. The separation between adjacent carrier frequencies ranges from 240 cycles per second at the lower end of the frequency band and in the A-B direction progressively widens until it is 500 cycles per second wide between the two highest frequencies.

A block schematic of a Type B channel is shown in Fig. 1.

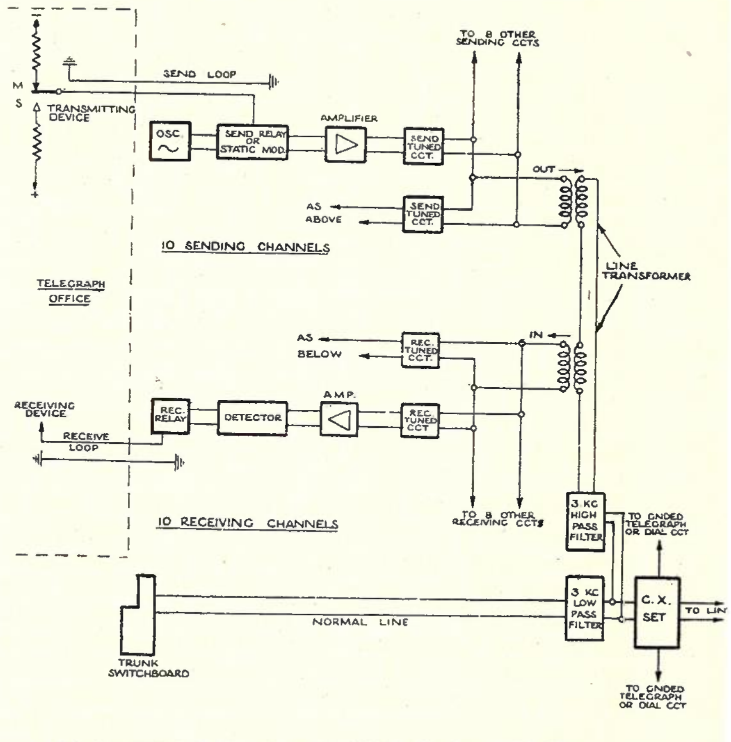


Fig. 1.—Type B Carrier Telegraph System (10 Duo-Directional Simplex Channels).

Carrier telegraph, as well as carrier telephone, systems employ alternating currents of different frequencies to provide for the transmission of several messages simultaneously over the same pair of wires without interfering with each other or with the normal telephone and telegraph circuits on these wires. In the telegraph systems the alternating current or carrier current of a channel is interrupted to form the signalling characters just as a direct current is interrupted in a simple telegraph circuit. The various messages can be separated from each other at the receiving end because, in the Type B system, each frequency is capable of being selected from all of the others by means of an electrical selecting circuit commonly known as a "tuned circuit." To permit interconnection in the plant, relays or their equivalent (viz., static modulators) are employed at the transmitting end, connected by means of direct current circuits to the sending operators' keys, machines, or transmitters. At the receiving end the carrier currents after rectification are caused to operate polarised telegraph relays which subsequently control the receiving sounders or printers.

As the frequencies used in the Type B system are above the commercial voice frequency range it will be seen from Fig. 1 that, with the aid of normal High and Low Pass Line Filters having a 3,000 cycles cut-off, the Type B system can be superimposed on a telephone circuit without interfering with the normal use of the line for voice frequency telephone and composite telegraph working.

The channel equipment at the sending end consists of an oscillator generating the required frequency, a send relay or static modulator, a single stage amplifier, and a sending tuned circuit. For receiving incoming signals a receiving tuned circuit, a two-stage amplifier, a detector, and a receive telegraph relay are provided. In setting up the channels the sending oscillator and tuned circuit are set to the correct frequency, and at the far end the corresponding receiving circuit is tuned accurately to that frequency from the received carrier current itself.

Circuit Operation (See Fig. 1): The carrier current, which is an alternating current generated by the oscillator, is connected to the amplifier and until interrupted to form the telegraph signals is continuously transmitted to line via the sending tuned circuit and line transformer. The oscillator output is intermittently blocked by the operation of the sending relay or static modulator which is controlled by direct current telegraph signals from the send telegraph loop.

Incoming pulses of carrier frequency, after being selected by the proper receiving tuned circuit, are amplified and detected, and the pulses of rectified current in the anode circuit of the detector valve operate the carrier receive relay, which, from its tongue, delivers double current signals to the local telegraph receive loop.

If it is desired to extend the range of a Type B system repeaters are inserted at intervals of approximately 150 miles. These repeaters are similar to the conventional carrier telephone repeater, and a block schematic diagram, which is self-explanatory, is shown in Fig. 2.

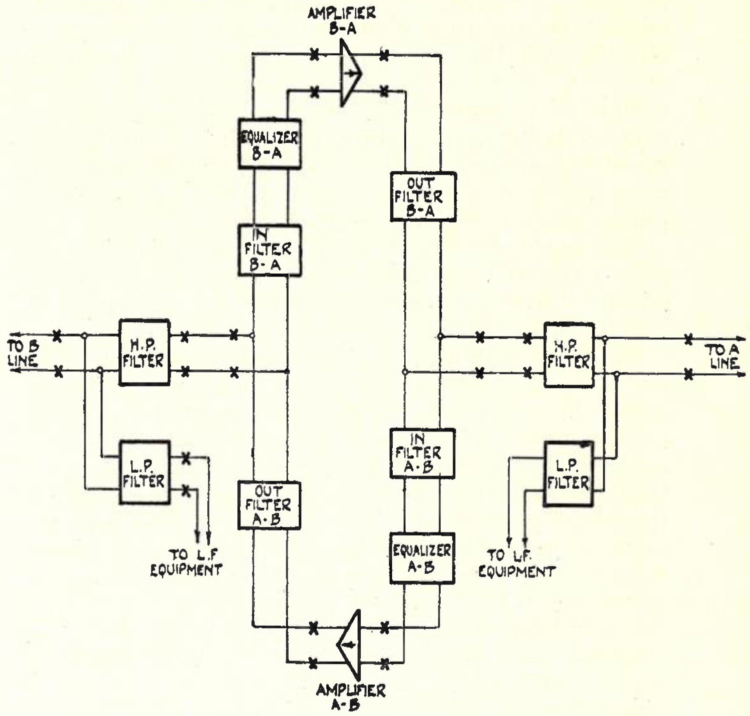


Fig. 2.—Type B Carrier Telegraph Repeater.

It will be noted that separation between the grouped frequency bands in each direction of transmission is obtained at repeaters by means of directional filters.

As the Type B system completely absorbs the frequency spectrum between 3.3 and 10.0 kC/sec., its application to an open wire line precludes the use of single and three-channel carrier telephone systems on the same pair. This extravagant use of the frequency spectrum is one of the main present-day disadvantages. The system can, however, be applied to one channel of a carrier telephone system by retuning the A-B direction frequency group down to the same part of the spectrum occupied by the B-A frequency group, and then injecting the system into a carrier telephone channel whose modulator and demodulator oscillators have also been retuned to permit the wanted sidebands to fall within the range of the requisite band pass filters. (Note: This method is explained in greater detail in an article appearing in the June, 1942, issue of this Journal, Page 27.) This process is greatly assisted by the fact that all Type B oscillators and tuned circuits can be readily tuned to any other Type B frequency. An alternative method after retuning would be to apply the system to a four-wire physical circuit in the range 3.3-5.5 kC/sec., thus setting free the frequency spectrum above 6 kC/sec. for the application of three-channel carrier telephone systems.

The above methods are only justified as expedients to employ existing equipment to the best advantage and thus clear valuable high-frequency circuits for the application of carrier telephone systems. They offer no advantage over the application of a nine or 18 channel voice frequency carrier telegraph system over the same transmission medium, and, in fact, the latter method does not involve any retuning of the carrier telephone system channel oscillators.

The earliest Type B systems were mounted on floor pattern units and require considerable floor space. Later systems were mounted on standard carrier type racks.

Static Modulators Versus Sending Relays: The use of a non-linear conductor (e.g., metal rectifiers) as a variable impedance under the control of the polarity of the applied voltage has been extensively employed in recent years for many telecommunication circuit purposes, and one of the main applications has resulted in the replacement of sending relays by the now familiar static modulators. The static modulator was first introduced with V.F. carrier telegraph systems, and its advantages over the sending relay were so marked that steps were taken during 1938 to replace all 215A type sending relays in Type B systems with static modulator circuits.

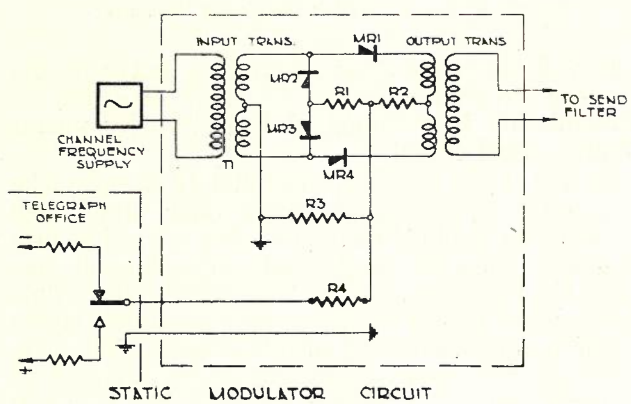


Fig. 3.

Figs. 3 and 4 illustrate two types of static modulator circuit used in carrier telegraph working. Referring to Fig. 3, the static modulator unit consists of an input transformer T1, modulator unit comprising copper oxide rectifier units MR1-4, resistors R1, 2, and output transformer T2. Resistor R4 is the current limiting resistor in the send telegraph loop, and its value is chosen to limit the current in the loop to the standard value of 25 milliamps. The shunt resistor R3 ensures that the current applied to the rectifier network is limited to the correct value.

When the transmitting telegraph apparatus at the telegraph office is in the "marking" condition negative potential is applied to the static modulator and rectifiers MR1 and MR4 become conducting. At the same time rectifiers MR2 and MR3 become non-conducting, and thus offer a high impedance shunt across the secondary winding of T1. Thus, carrier frequency from the oscillator is permitted to pass freely to the send filter unit, the attenuation in the static modulator being that due to the transformers alone.

When the potential applied to the static modulator is reversed due to the application of a "spacing" signal, the rectifier impedances are reversed (i.e., MR2 and MR3 become conducting and MR1 and MR4 non-conducting), resulting in a low resistance shunt across the secondary of transformer T1, together with a high resistance series path to the passage of carrier frequency from the channel oscillator.

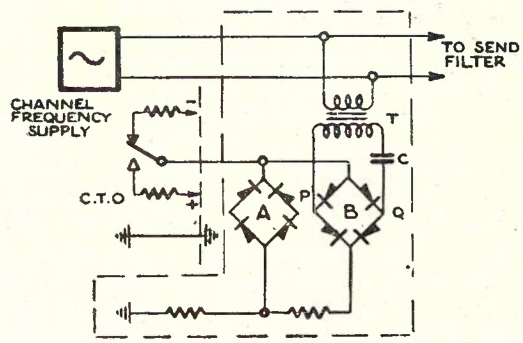


Fig. 4.—Static Modulator Circuit.

Referring now to Fig. 4, the two bridges A and B, which are identical, are made up of copper oxide metal rectifier elements. Transformer T has a 10 to 1 ratio step up and the primary is connected across the output of the channel frequency source whilst bridge B is connected across the secondary. The impedance of bridge B between the points P, Q, is therefore effectively in shunt across the carrier frequency source, and modulation is effected by varying the value of this reflected impedance from a low value during "spacing" signals to a high value during "marking" signals, the variation being controlled by the magnitude and direction of current in the send telegraph loop. When a "marking" signal is applied bridge A presents a low forward resistance and the send loop current flowing through it and the series resistance R biases the rectifier elements in bridge B in the backward direction so that they present a high impedance and carrier frequency is transmitted to line. When the polarity of the applied D.C. is reversed on a "spacing" signal bridge A becomes high resistance and bridge B low resistance so that the shunting loss is high and practically no carrier passes to line.

Typical values of the A.C. impedance across points P and Q are 300,000 ohms and 100 ohms during "marking" and "spacing" elements respectively, the corresponding reflected impedances through transformer T being 3,000 ohms and 1 ohm.

Bridge A and its series resistance serve to produce the correct value of negative bias across bridge B in the "marking" condition and tend to equalise the D.C. loop current in the marking and spacing intervals. The condenser C prevents the flow of D.C. through the secondary winding of transformer T.

A static modulator may, therefore, be said to modulate the carrier frequency of the channel with which it is associated in accordance with the polarity of the telegraph signals applied from the telegraph office resulting in pulses of carrier to line corresponding to a "marking" signal and cessation of carrier during a "spacing" signal.

Looked at in another light the static modulator may be regarded as an attenuator switching device such that with an applied D.C. polarity of negative potential the attenuation offered to the A.C. channel frequency is of the order of 4 db., whereas upon reversal of the D.C. polarity to a positive potential the attenuation increases to 40 decibel. In other words the "discrimination" of the static modulator is, on the above quoted values, 36 decibel. Thus, whilst in the blocking condition carrier is still passed to line, the level is so low that it is below the threshold of operation of the receiving equipment. In early static modulators "discrimination" values of the order of 30 decibel were obtained, but in circuits employed in the last two or three years the "discrimination" has been increased to values of 40 and 50 decibel due mainly to steeper voltage-resistance characteristics of the rectifier elements employed.

The elimination of apparatus which contains moving parts and requires regular maintenance attention to ensure operation free from contact and bias troubles is attractive, and the discrimination of the latest static modulator circuits is such as to definitely establish their superiority over mechanical send relays.

It is interesting to note that, whilst various static modulator circuits have been tried in American practice, their use has not been extended because they imposed certain operating limitations on the associated telegraph apparatus in use. Such limitations have not been experienced with the telegraph apparatus and arrangements in use in Australian practice.

In order to eliminate the difficulties caused by high resistance contacts of sending relays, one American company evolved the interesting circuit arrangement shown in Fig. 5. The auto transformer is connected so as to provide a high impedance looking towards the generator, while Rs, which is the order of 50,000 ohms, provides a corresponding high resistance towards the output, the sending filter being suitably padded to ensure a satisfactory termination. With this arrangement the contact resistances in both the "marking" and "spacing" positions may vary considerably without seriously affecting the transmitting efficiency.

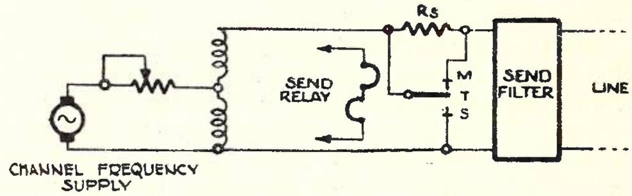


Fig. 5.—Send-Relay Circuit.

VOICE FREQUENCY CARRIER TELEGRAPH SYSTEMS

The major developments in long-distance telegraph transmission have taken place since the introduction of multi-channel voice frequency telegraph (M.C.V.F.) working.

The frequencies used are the odd multiples of a base frequency of 60 cycles per second in the range 420-2,460 cycles per second. Reasons for the adoption of this frequency grouping are as follow:—

(1) The average telephone channel has an approximate linear frequency response between 300 and 2,600 cycles per second, and this consideration sets the lower and upper limit to the choice of telegraph carrier frequencies for M.C.V.F. systems which must be capable of operating over a normal telephone circuit.

(Carrier telephone channels complying with the revised C.C.I.F. specification for increased band width 300-3,400 cycles per second are now being introduced in the plant in Type J open wire 12-channel systems and in cable carrier systems. It will be appreciated that M.C.V.F. systems operated over channels of this band width can be extended to an upper limit of 3,180 cycles per second, thus permitting the derivation of 24 to 26 telegraph channels from one telephone circuit.)

(2) The required telegraph transmission speed decides the band width required for each channel. Although normally used for machine teleprinter working (50 bauds), M.C.V.F. systems are designed to cater for a transmission speed of 66 bauds. This provides a margin over the required speed of 50 bauds, and permits the connection of two or three channels in tandem.

In M.C.V.F. systems the channel carrier frequency is modulated with a low frequency (up to 25 cycles per second) for teleprinter transmission. It is usual to transmit the carrier and both sidebands, as it would be exceedingly difficult in the small band width available to design channel band pass filters with sufficiently sharp cut-off to eliminate the carrier and one side band. Moreover in telegraph transmission wave front distortion is of primary importance, and correct phase relationship between carrier and sideband is essential. With the carrier in the centre of the transmission band the phase compensation is automatic. If the carrier were suppressed it would involve reintroduction at correct frequency and phase at the distant terminal with consequent synchronisation and phase correction adjustments.

As the channel carrier frequency and both side-bands are transmitted an effective band width of 33 cycles per second each side of the carrier frequency is required. In practice the channel width must be approximately twice this value to give a margin for filter design and allow the filter pass band to be approximately linear over the required frequency band.

(3) The actual frequencies adopted were chosen with a view to preventing interchannel interference which may occur due to non-linearity of loading coils, amplifiers, etc. With regard to interference frequencies, those of greatest magnitude are the second harmonics and simple sum and difference products of any pair of carrier frequencies.

By choosing a basic frequency and using the odd multiples the sum and difference products will always be even multiples, and these then lie midway between the carrier frequencies, that is, at a point where the stop band characteristic of the channel band pass filters has maximum attenuation.

Two main types of M.C.V.F. system are employed in the network, viz., the 18-channel M.C.V.F. system (120 cycle spacing) and the 9-channel M.C.V.F. system (240 cycle spacing). Each channel can be operated on a duo-directional simplex basis. The channel frequency allocations are as shown in Table 1.

Channel Number		Channel Frequency c.p.s.	Channel Number		Channel Frequency c.p.s.
18-Channel System (120 c.p.s.)	9-Channel System (240 c.p.s.)		18-Channel System (120 c.p.s.)	9-Channel System (240 c.p.s.)	
1		420	10	5	1500
2	1	540	11		1620
3		660	12	6	1740
4	2	780	13		1860
5		900	14	7	1980
6	3	1020	15		2100
7		1140	16	8	2220
8	4	1260	17		2340
9		1380	18	9	2460

Table 1.

Frequency Allocation—18- and 9-Channel V.F. Systems

Both systems can, of course, be initially installed, partially equipped and later extended to their full capacity. The 9-channel 240 cycle spaced system is of advantage between centres where development beyond a maximum of nine channels is not anticipated.

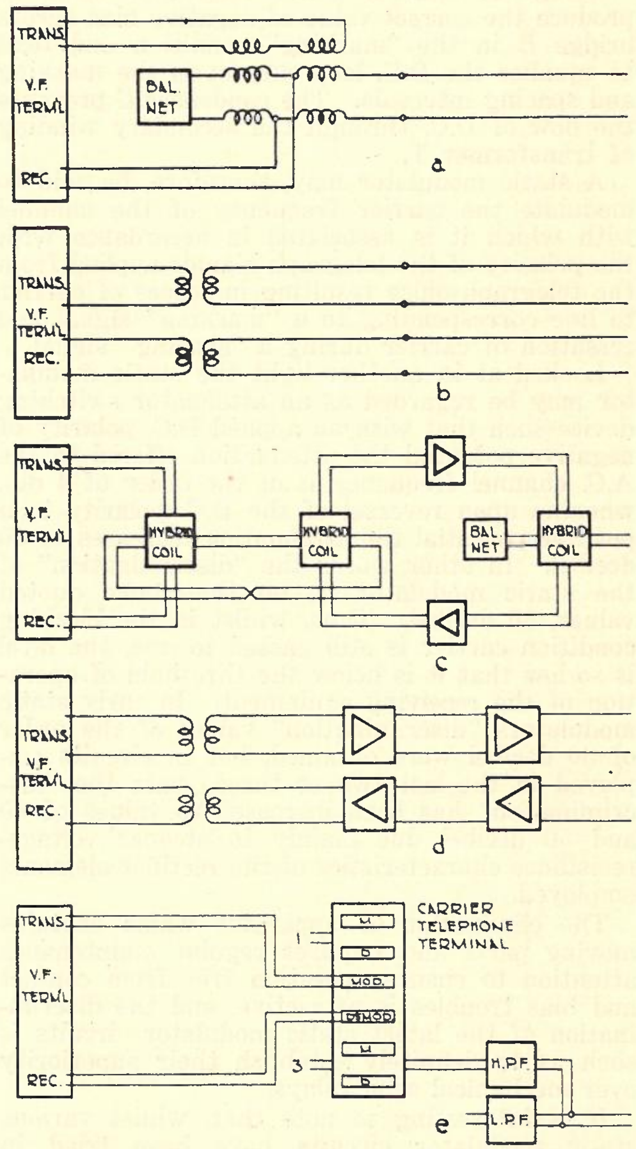


Fig. 6.—Circuit Applications—M.C.V.F. Systems.

(1) Two-wire voice frequency physical circuits operating over aerial or cable wires, providing a maximum of nine duo-directional simplex telegraph channels as shown in Fig. 6a.

(2) Four-wire voice frequency physical circuits, operating over aerial or cable wires, providing a maximum of 18 duo-directional simplex telegraph channels as shown in Fig. 6b.

(3) Two-wire voice frequency physical circuits operating over aerial or cable wires and equipped with intermediate or terminal amplifiers, providing a maximum of nine duo-directional simplex telegraph channels as shown in Fig. 6c.

(4) Four-wire voice frequency physical circuits operating over aerial or cable wires, and equipped with intermediate or terminal amplifiers, providing a maximum of 18 duo-directional simplex telegraph channels as shown in Fig. 6d.

(5) The transmit and receive paths of a carrier telephone channel, providing a maximum of 18 duo-directional simplex telegraph channels as shown in Fig. 6e.

Circuit Application: Whilst the frequency range of M.C.V.F. systems permits their application to normal two-wire or four-wire voice frequency circuits derived from open wires or cable pairs, they are generally operated over and absorb a carrier telephone channel. This is largely due to the fact that carrier telephone circuits exist between the centres where telegraph facilities are required, and, in addition, are more stable and have a lower overall equivalent than the corresponding physical circuit. It is likely that future extension of four-wire voice frequency circuits in cables will be followed by the derivation of M.C.V.F. circuits therefrom. In this connection it is of interest to note that the M.C.V.F. systems in use can, in general, be operated over a circuit having a maximum transmission equivalent of 24 decibel at 3,000 cycles per second. (This is equivalent to a distance of 400 miles on a 200lb. copper circuit not equipped with amplifiers.)

Except in special circumstances M.C.V.F. systems are operated over four-wire circuits because they employ the same frequencies for each direction of transmission. If they are applied to a two-wire circuit the number of derived channels is halved, thus, in a 18-channel system nine different frequencies have to be employed in each direction. Moreover, it is usual to delete the mid-channel for hybrid or directional filter discrimination purposes so that only eight duo-directional simplex channels are obtained.

The various circuit applications are shown in Fig. 6.

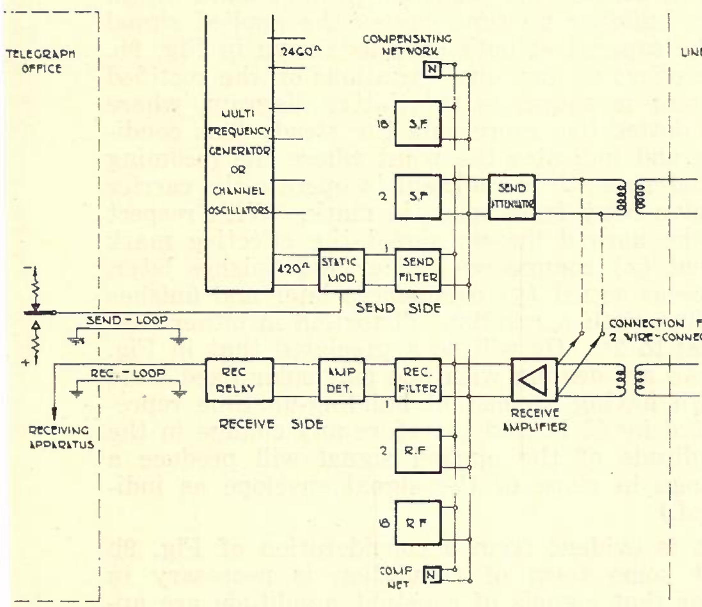


Fig. 7.—M.C.V.F. Systems—Block Schematic.

Fig. 7 shows in block schematic form the equipment provided for one channel of a M.C.V.F. system. Signals from the telegraph office consisting of positive and negative impulses are applied to the static relay which is also supplied with the appropriate channel frequency furnished from the channel oscillator.

In the static modulator the polarity of the applied telegraph signals controls the flow of channel frequency in such a way as to produce impulses of the frequency in a code corresponding to the transmitted telegraph intelligence. Thus, when a marking signal is applied to the static modulator the carrier current generated by the channel oscillator is passed to the send filter where the unwanted products generated in

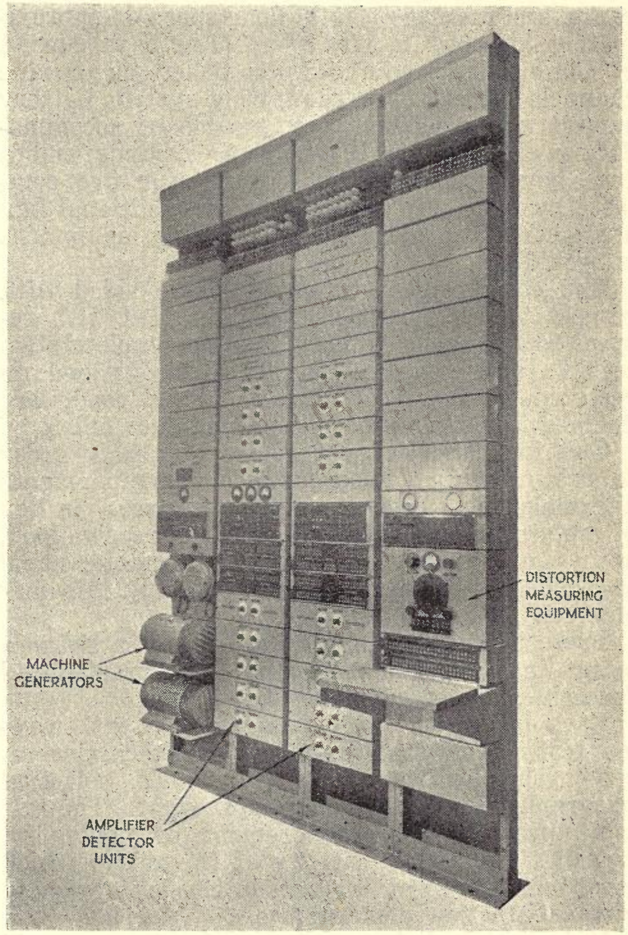


Fig. 8.—Typical 18-Channel V.F. Carrier Terminal.

the static modulator are rejected. Each channel frequency is then applied to line via the two-wire/four-wire line equipment panel.

At the receiving end the incoming A.C. signals applied to the two-wire/four-wire line equipment panel are passed to the receive amplifier where the level is restored to a suitable value and then applied to the channel receive filters. Each receive filter selects its allotted channel frequency and in each channel the signals are then applied to an amplifier detector where they are converted to D.C. impulses which operate the carrier receive relay, whose line winding forms part of the plate circuit of the detector valve.

The contacts of the receiving relay are connected to the positive and negative telegraph battery supplies, and the tongue of the relay supplies positive and negative signals to the receive telegraph loop, corresponding to the signals originated at the transmitting end.

A typical 18-channel system is shown in Fig. 8.

The 18-channel systems are accommodated on standard 10ft. 6in. high carrier racks. A first installation for a main centre complete with duplicate machine generators usually requires five racks, and occupies a total floor space of approximately 8ft. 6in. x 1ft. 3½in. The bays consist of channel bays equipped for either six or nine channels depending on the type of system, battery supply, and generator bay capable of accommodating circuits for 10 complete systems and a fuse bay accommodating circuits for five complete systems. In some cases an additional bay accommodating distortion measuring equipment is provided.

The equipment is mounted single sided with respect to the panels and double sided with respect to the racks. The wiring is completely accessible and complete circuits are contained on each side of the rack. The racks and panels are finished in the now familiar aluminium finish.

The jack and bay panels are hinged in order to retain double sided mounting arrangements and make most economical use of space. In lieu of meters in each separate send and receive loop, as in the Type B system, a separate meter panel is provided with facilities for patching into any channel.

Protection is provided by the use of resistance lamps in plate and telegraph loop circuits and fuses in filament circuits.

Each initial installation is complete with a relay test table for adjustment of the carrier receive relays which are of the 209FA polarised telegraph relay type or their equivalent. The test table provides for measurement of neutrality, transit time, and sensitivity of the relays which must be routined at frequent intervals in order to give satisfactory performance.

It is anticipated that future development will result in the replacement of the mechanical receive relay by a combination of valves termed a valve relay. Whilst suitable valve relays for particular purposes have been developed and give complete satisfaction for those purposes, a satisfactory generally applicable alternative to the electro magnetic relay is not yet available.

Effects of Telephone Circuit Level Variations on the Operation of M.C.V.F. Systems: In carrier telegraph transmission, where carrier is transmitted to line during a marking element and suppressed during a spacing element, we have the equivalent of single current transmission, and the receive relay requires a bias (either mechanical or electrical) in order to restore its tongue to the spacing contact on cessation of a marking signal. As the restoring force is fixed when the channel is "lined up" for operation by reversals transmitted from the distant terminal any subsequent variations in received signal level will result in bias distortion.

In M.C.V.F. working the necessity for maintaining constant amplitude of the received signal is dependent on the shape of the signal envelope. If the signal envelope were "square topped" in form, as shown in Fig. 9a, the bias distortion introduced by small changes in amplitude would be zero, whereas when the signal envelope is of sinusoidal shape small changes in amplitude are sufficient to cause considerable distortion. The signal applied to the channel band pass filters takes a definite time to build up to a steady state value. The extent of the building-up time is

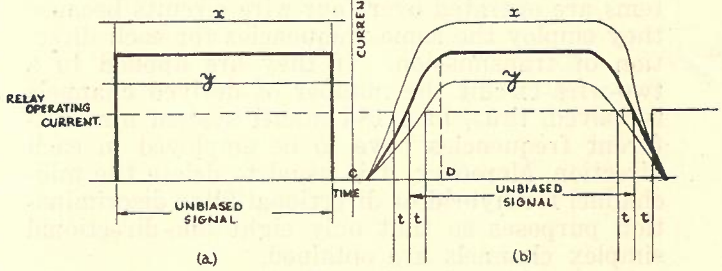


Fig. 9.

largely a function of the filter characteristics and increases with reduction in filter band width. This building up time causes the applied signal to be tapered at both ends as shown in Fig. 9b. The effect of line level variations on the rectified current is shown in this latter diagram, where the dotted line represents the steady bias condition and indicates the point where the incoming signal strength is sufficient to operate the carrier receive relay from space to mark. With respect to the normal line-up signal the effective mark signal (x) commences earlier and finishes later, whereas signal (y) commences later and finishes earlier, with a resultant distortion in either case equal to 2t. (It will be appreciated that in Fig. 9b we are dealing with one particular fixed band width having a constant building-up time represented by C, D, and therefore any change in the amplitude of the applied signal will produce a change in slope of the signal envelope as indicated.)

It is evident from a consideration of Fig. 9b that some form of regulation is necessary in order that signals of constant amplitude are applied to the carrier receive relay. This can be achieved either by ensuring that the telephone bearer circuit is held regulated to very close limits or by incorporating a level control feature in the carrier telegraph equipment. The former method is the most desirable in that all the equipment on any one circuit is thereby catered for, and a telephone channel on which the level variations are held to within ± 0.5 db. is satisfactory as a bearer channel for carrier telegraph systems. At present, however, the percentage of closely regulated telephone circuits in service is very small, and, whilst the proportion will steadily increase, this method cannot be completely adopted for some considerable time. It is, therefore, necessary to apply the level control feature to the M.C.V.F. system. This control is incorporated in the individual channel equipment because it cannot be satisfactorily applied to any common amplifier equipment in the carrier telegraph system (unless a pilot control frequency was utilized), due to the fact that the input to such equipment is continuously varying in a fortuitous manner, dependent on the number of channels which may be marking or spacing at any one instant. All M.C.V.F. systems in use, therefore, include an automatic level control circuit in the channel amplifier detector units. The inclusion of a limiter circuit in the amplifier detector results in a slight increase in distortion as compared with an amplifier detector unit without limiting features. The increase in distortion, however, is negligible, particularly when the large improvement in distortion during input level variations of the order of ± 5 db. is taken into account. Table No. 2, indicating average distortion measurements of various types of telegraph signals with and without a limiter circuit in the amplifier detector unit, best illustrates this point. This may also be taken as a comparison of distortion on Type B and M.C.V.F. systems, as the former system does not include any automatic level control, and as a result close attention by the maintenance attendant is necessary to secure uninterrupted service.

The most common method of compensation for the effects of slow changes in amplitude of the applied signal depends for its operation on the change of grid-cathode impedance of a valve when the potential on the grid reaches a point where grid current commences to flow, and also on the rectifying property of the grid cathode circuit. The elements of a limiter of this type are shown in Fig. 10, the value of grid bias depending on whether the valve is being used as an amplifier or rectifier.

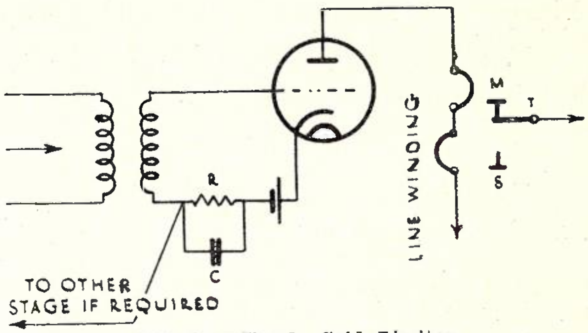


Fig. 10.—Simple Grid Limiter.

Considering a signal of large amplitude applied between grid and cathode, the carrier receive relay will operate just after the commencement of the building up period of the signal envelope, and when the peak amplitude exceeds the normal grid bias, grid current flows and charges condenser C. As a result, a voltage is developed across the C, R, combination, with resultant additional negative bias applied to the grid. As the time constant of the C, R, combination is large in comparison with the time between successive half waves, and is actually chosen to be greater than the longest interval between marking elements in the telegraph 5-unit code, the new bias value will be maintained on the grid, providing the amplitude of the input signal remains constant. Any variation in amplitude of the input signal will cause a variation of grid current, with a resultant change of bias on the grid. By a suitable choice of circuit constants,

Table 2.

Detector Plate Current (mA)		10.2	10.25	10.5	4.5	6	7.9	10.25	12	13.5	14.8	16
Signal Input Level		—5db	Ref. —20db	+5db	—3db	—2db	—1db	Ref. —25db	+1db	+2db	+3db	+4db
Test Signal	Distn.				Complete Failure							
1 : 1	%	3	3	4		20	10	3	7	14	21	24
2 : 2	%	1	1	2		19	7	1	9	15	22	25
5 : 1	%	4	4	4		21	8	2	9	15	20	25
1 : 5	%	4	3	3		21	9	2	9	15	20	25
Paris	%	4	3	4		22	9	3	9	14	20	25
Paris Rev.	%	4	3	4		22	9	3	9	14	20	25
		← Limiting Circuit Connected →			← Limiting Circuit Disconnected →							

the plate current is held substantially independent of input level variations over a range of ± 7.5 decibel. The additional bias developed across the limiting circuit may be applied to other stages to give greater control, and is usually applied to the amplifier stage preceding the detector in amplifier detector units. A typical amplifier detector circuit will be described in detail in the next article in this series.

Filters: The functions of the send filter associated with each channel of a M.C.V.F. system are, firstly, restriction of the frequency band width transmitted to line for each channel. This restriction of band width is necessary because the modulation of the carrier frequency of each channel with the applied D.C. telegraph signals in the static modulator results in the generation of a wide spectrum of side band frequencies on either side of the carrier. Suppression of the unwanted harmonics reduces the power to line and decreases the possibility of interchannel interference. The restricted band width also prevents harmonics of the channel carrier frequencies from passing to line and perhaps causing interchannel interference in a similar manner. The send filters also serve to present a high reactive impedance to the carrier frequencies of other channels at the commoning point of the filters, thus ensuring that the carrier output of any one channel is not dissipated in, or modulated by, the sending equipment of other channels which are connected in parallel with it.

The function of the receive filters is to divide the multi-frequency signals received over the line into the separate channel frequency bands, and direct these to the appropriate amplifier detectors.

In the eighteen channel M.C.V.F. systems, the send and receive filters are band-pass filters, having a band width of 120 cycles per second symmetrical about the mid-band frequency. In order to fulfil the functions outlined above, a single section suffices for each send filter and two sections for each receive filter.

The filter design is of particular interest in that internal impedance transformations are necessary in order to permit the use of components which are commercially realisable at reasonable cost. The transmission requirements which have to be satisfied are as follows:

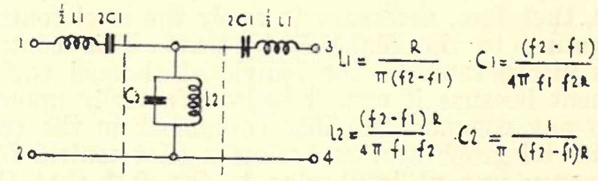
(a) "The attenuation characteristic shall be approximately symmetrical about the mid-band frequency."

(b) "The phase characteristic shall be approximately linear and of equal and opposite symmetry about the mid-band frequency."

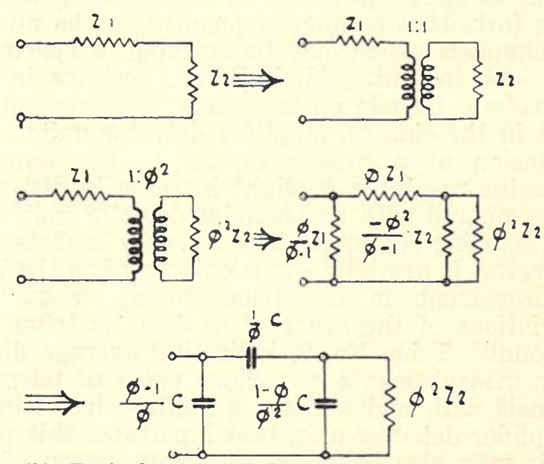
(c) "It is desirable that the attenuation of each receive filter ± 35 cycles per second from its mid-band frequency should not be more than 2.5 decibel above the attenuation at the mid-band frequency."

(d) "The attenuation of each receive filter ± 120 cycles per second from its mid-band frequency (that is, at the mid-band frequencies of the directly adjacent filters) should not be less than 30 decibel above the attenuation at the mid-band frequency."

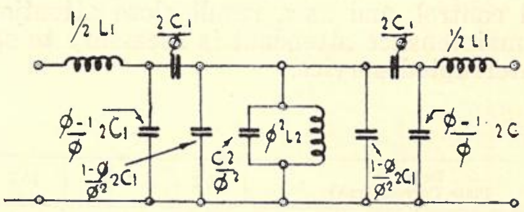
The confluent band pass filter section of the constant K type was employed as the basis of design since it satisfies the above requirements and they can be produced at less cost than M derived sections.



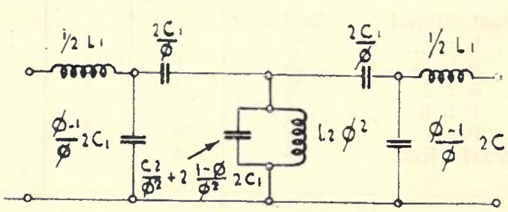
(a) Prototype Band Pass Filter Section.



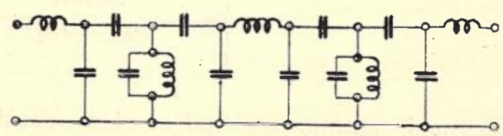
(b) Equivalence Used in Designing Impedance Transformation Filter Sections.



(c) Band Pass Filter Section with Internal Impedance Transformations. Electrically Equivalent to (a).



(d) Send Filter (Schematic).



(e) Receive Filter (Schematic).

Fig. 11.—Filter Design.

Fig. 11a is a representation of a full section with mid-series termination, together with the formulae for calculating the impedance elements. In these formulæ f_1 and f_2 are the lower and upper cut-off frequencies respectively, and R the impedances between which the filter is to be inserted, R for the filters concerned being a pure resistance of 600 ohms. The band width (f_2-f_1) is 120 cycles per second.

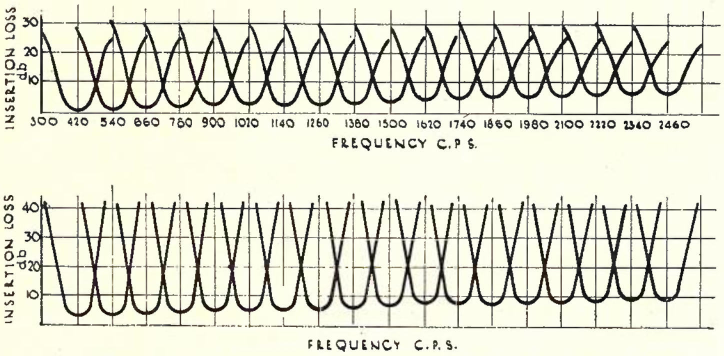


Fig. 12.—Attenuation Characteristics. Send and Receive Filters, 18-Channel V.F. System.

From an examination of the formulae it will be found that condenser C_2 is of constant magnitude if the band width (f_2-f_1) and the impedance R are constants and for the factors given is 4.421 μF. Also, since the band width is small compared with the product of the cut-off frequencies, the value of the inductance L_2 is of small value, and decreases with increase in frequency. From a manufacturing and a cost viewpoint, the values of both C_2 and L_2 are very unsatisfactory, and, in order to avoid the difficulties involved in employing these values, use has been made of impedance transformed filter sections by introducing the equivalent of an ideal step-up transformer in front of the shunt elements, and the equivalent of an ideal step-down transformer immediately after these elements.

The derivation of the equivalence employed in designing such filter sections is shown in Fig. 11b. The resultant filter section is shown in Fig. 11c, but, as the condensers $\frac{1-\phi}{\phi^2}2C_1$ are in parallel with the shunt element condenser of value $\frac{C_2}{\phi^2}$, they can be replaced by a condenser of value $\frac{C_2}{\phi^2} + 2\frac{1-\phi}{\phi^2}2C_1$. The final band pass filter section with internal impedance transformations and electrically equivalent to the prototype band pass filter section is shown in Fig. 11d. This is a single section send filter. A two-section receive filter is shown in Fig. 11e.

It will be noted that the impedance transformations increased the number of elements required per filter, but the advantages gained more than offset such an increase. By a suitable choice of ϕ the shunt condenser across the inductance is reduced in value such that it is manufactured as a mica dielectric type of similar dimensions to the series condensers. Also, the shunt inductance approaches a value of the order of the series inductances and does not then require a difficult manufacturing technique. All filters are of the unbalanced type, and the general attenuation characteristics of a group of 18 send and receive filters are shown in Fig. 12. The filters are mounted in compact form on standard 19in. x 3½in. panels.

Compensating Network: The outputs of the send filters and the receive filters in an 18-channel system are connected in parallel, and at the common point compensating networks are connected across each parallel group of filters. These networks provide a flanking impedance and serve to improve the characteristics of the higher frequency filters. Compensating networks are not usually equipped on 6-, 9-, or 12-channel systems.

Carrier Supply: The individual channel frequencies for M.C.V.F. systems installed at important centres where the ultimate development is likely to exceed 36 channels are supplied from special machine generators. The output per channel is capable of feeding up to a maximum of ten 18-channel systems.

The machine generator consists of a motor and an inductor type alternator fixed to a common shaft. The 18 stator coils of the alternator are located in an outer shell, whilst unwound rotors keyed to the shaft rotate and produce in the stator coils the respective channel frequencies.

In order to maintain the speed of the generator substantially constant over the normal range of variation of input voltage, and with a varying load (from 1 to 10 systems), a centrifugal governor assembly is fixed to a shaft extension on the motor. The governor includes a flat spring which, under the action of centrifugal force makes contact with an adjustable contact screw. Current is applied to the contacts through carbon brushes, and a commutator assembly which reverses the direction of current flow through the contacts, thus minimising the transfer of metal from one contact to the other. When the contacts close they short-circuit portion of the motor field resistance. This resistance is variable, and is set to a value which, when alternately opened and short-circuited, controls the mean value of field current, thus compensating for supply and load variations.

The generator speed is checked stroboscopically by applying the output of a very stable 1,020 cycles per second oscillator (tuning fork control) to either of two neon lamps, which illuminate a stroboscopic disc mounted on the shaft. The stroboscopic disc is divided into 34 black and 34 white sectors, and as the correct speed of the generator is 3,600 r.p.m., a total of 2,040 black and white sectors pass a given point in one second. The speed is checked by viewing the stroboscopic disc by the light of the neon lamp, which flashes 2,040 times per second. If the speed is correct, the disc appears to be stationary. The speed tolerance is ± 0.1%, so that if speed is incorrect adjustment should ensure that not more than 2 white or black sectors pass a given point in one second. Duplicate machine generators are provided at each installation. The motor operates from the 24-volt filament battery and the drain when running is approximately 5 amps.

Oscillators: In small installations comprising one or two systems individual channel oscillators are employed, as the more expensive machine generator installation is not warranted. These oscillators are generally of the resistance stabilised type where the circuit elements are chosen to obtain frequency stability and low harmonic content of the output wave form, and special care in choice of components, particularly the tuned circuit elements, is necessary in order to ensure this required frequency stability with normal temperature and battery supply variations. It is desirable that the carrier frequency of any oscillator be held to within ± 6 cycles per second, with ambient temperature variations between 50 and 115 deg. F., and heater and anode voltage variations up to 10 per cent. of the nominal values. The channel oscillators include a control to adjust the frequency, and in systems employing oscillators the usual routine is to line up the oscillator through the send and receive band pass filters for maximum detected current, thus ensuring that the oscillator frequency is set to the mid point, or point of lowest attenuation, of the filters.

As the oscillator output is interrupted by a static modulator or send relay contacts, it is necessary to arrange that the output be insensitive to the large impedance changes which occur in the change from marking to spacing. This is usually achieved by designing the oscillator for large output, this being then reduced to the required value (of the order of 1 mW) by an attenuator which masks these impedance variations.

An interesting application of carrier supply equipment capable of feeding a large number of systems from channel oscillators controlled by a master oscillator has been employed in the latest American type carrier telegraph systems, some of which are now being installed in the network. This method is an application of the carrier supply arrangements employed in open wire and cable type 12-channel carrier telephone systems. As many as 50 channels of different M.C.V.F. systems may be operated from one oscillator, and this method therefore compares favourably with machine generator supply systems.

Fig. 13 indicates in schematic form the harmonic control arrangements, consisting of a base frequency oscillator, amplifier, harmonic generator, and the connections to the channel frequency oscillators.

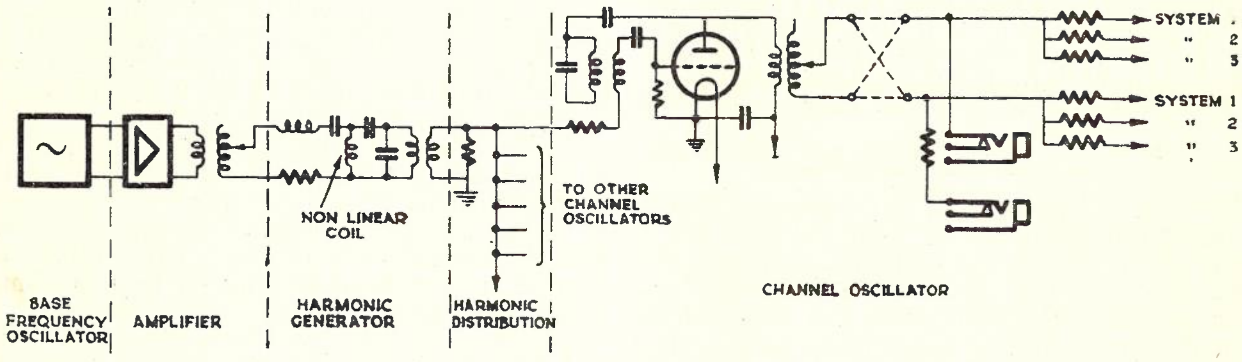


Fig. 13.—Harmonic Oscillator.

When the carrier supply is obtained from valve oscillators operating independently, it is found that at frequent intervals the carrier frequencies have a phase relationship which produces a high peak value of line current. In a machine generator supply system the phase of each carrier frequency is fixed by the design of the machine in a random relationship to all the other frequencies, and the peak current values are normally much lower than with an equivalent system employing individual channel oscillators.

The frequent recurrence of high peak currents in the line tends to overload any amplifier equipment in circuit with a corresponding increase in interchannel interference.

The harmonic control system ensures that all channel oscillators are held in an exact harmonic relationship. The output of the high stability base frequency oscillator is amplified and passed through a special iron core non-linear coil, thus generating a very peaked wave containing all the odd harmonics of the base frequency, which is introduced into the grid circuits of all the channel frequency oscillators. The channel oscillator tuned circuits act as filters to select the particular harmonic to which they are tuned, and each channel oscillator falls in step with the respective harmonic of the base frequency.

The oscillator frequencies are thus held in a synchronous relation by the harmonic control, but, unlike the machine generator case cited above, the phase relationships are no longer random. The phase position of each channel frequency oscillator output depends on its frequency adjustment and varies a little, dependent upon whether the oscillator, when operating independently of the base frequency control, is adjusted to a slightly higher or lower frequency than that of the base frequency harmonic. Investigations have shown that when each oscillator has been adjusted as an independent unit to be close to its correct frequency, and the harmonic control circuit is then applied, the phase of each carrier is, on the average, fairly close to the position where each current reaches a positive maximum at the same instant. This, therefore, is unsatisfactory from the standpoint of high peak values. However, with the carrier current outputs of the various channel oscillators fixed in phase, it becomes possible to reduce the peaks at the sending end by reversing the output leads of a certain number of oscillators. Experiments have shown that a particular combination of reversed channels is superior to any other of the many possible combinations for average applications, and this method has been found in practice to be very satisfactory in keeping peak line current values within reasonable limits.

In large offices containing more than five 18-channel M.C.V.F. systems it is usual to provide two complete banks of channel oscillators and duplicate base frequency oscillators with change-over facilities for use in cases of failure. It is interesting to note that failure of the base frequency oscillator or harmonic control equipment does not cause a service interruption, because the channel frequency oscillators continue to function independently at their tuned frequency. Under this condition the tendency to interchannel interference increases, but the immediate effect on working channels would in general be negligible.

From the foregoing remarks it will be seen that future development in carrier telegraph working will mainly consist of the application of 18-channel M.C.V.F. systems, with a probable derivation of 24 channels on wide band telephone channels, on main trunk routes. The 9-channel M.C.V.F. systems (240 cycle spacing) will be employed between important centres where a maximum of 9 channels would be adequate for traffic purposes. There are other systems of recent development employing other previously unused portions of the frequency spectrum which are particularly applicable to centres where 9 or more channels are not required, and also where the provision of a bearer telephone channel is not justified. A description of these systems forms part of the next article, which will deal more particularly with systems of Departmental manufacture.

(End of Part 1.)

THE MELBOURNE TELEPHONE NETWORK PLAN

C. J. Prosser

Plans have been prepared for renumbering the Melbourne network and for the provision of new exchanges to meet development. Before these plans are discussed, it will be of interest to survey very briefly the early history and growth of the Melbourne metropolitan telephone system.

Past Development: When the first Melbourne telephone exchange was opened in 1879 by the Melbourne Telephone Exchange Company, a single sheet sufficed to list the names of the 23 subscribers. Some months later this was replaced by one thin list showing that there were then 44 subscribers. A few of the original subscribers reappear in the current issue of the Telephone Directory, and, in at least one case, a combination of digits reminiscent of the original number has been retained in the present 6-digit automatic number. After two or four years the exchange was transferred from a building in Collins Street to a site in Wills Street.

Between the years 1887, when the Victorian Government took over all the telephone services in Victoria, and 1900, the first network of exchanges was established and remained basically unaltered for the following eighteen years, the only additional exchanges opened during the period being Yarra in 1907 and Northcote in 1910. Yarra Exchange had a brief existence, closing in 1911 with the transfer of the subscribers to Windsor, but its revival in automatic form may be expected at an early date.

The population of Melbourne within a 10-mile radius had reached 543,115 in 1907, and the number of subscribers in the network had just passed the 10,000 mark. The number connected to each exchange was as shown in Table I.

The absence of exchanges in the Carlton, Collingwood, and South Melbourne areas from this table indicates the extent of the area served by Wills Street, the only exchange in the City at that date. It is interesting to note that of the exchanges listed, only Cheltenham and Williamstown remain as magneto exchanges, the others having been replaced by either C.B. manual or automatic exchanges in later years. The first sections of the present Central C.B. manual exchange were placed in service in 1911.

The conversion of Brighton Exchange to automatic working in 1914 marked the beginning of a new era in the Melbourne network, and, after due consideration, the first numbering scheme was introduced as part of the plan for the conversion to automatic of all the metropolitan exchanges. The first allocations were X for Brighton and F for Central. By 1915 the number of subscribers had grown to 24,000, which represents an increase of 140 per cent. over the eight-year period. That the Great War of 1914-18 did not altogether prevent further progress towards automatic working is evident from the fact that Sandringham was opened as a branch of Brighton in 1918, and Malvern was converted in 1919. In 1921 plans were prepared for a mixed 5 and 6 digit system covering 9 main exchange areas. The prefix letters for the main exchanges were as shown in Table 2.

Table 1.

Exchange.	No. of Exchange Lines Connected in 1907.
Wills Street	5,503
Ascot	246
Brighton	385
Brunswick	233
Canterbury	274
Cheltenham	83
Footscray	135
Hawthorn	980
Heidelberg	71
Malvern	880
Oakleigh	51
Williamstown	134
Windsor	1,268
Yarra	297
Total	10,540

Table 2.

"North"	B	Malvern	U
"City"	F	Canterbury	W
Collingwood	J	Brighton	X
Windsor	L	Hawthorn	Y
South Melbourne	M		

The "North" and "City" Exchanges did not materialise, and the B and F prefixes were employed for Central Manual and Carlton Automatic Exchanges respectively. With these modifications, the scheme was introduced and underwent little alteration until recent years.

The years 1918 to 1925 saw much progress in automatic working, as in addition to the opening of Malvern, the City area was relieved by the establishment of Collingwood and Carlton main exchanges, and a branch of Carlton was opened at Ascot. The number of subscribers in the metropolitan area reached 52,600 in 1925. In the 15-year period between 1925 and 1940, the number of metropolitan subscribers doubled, and by the end of 1943 the number stood at 117,490. Most of the manual exchanges have been wholly or partially converted to automatic working, and many new automatic exchanges have been opened. The small proportion of subscribers still connected to manual exchanges is given in Table 3, which includes all exchanges over 100 lines.

Table 3.

Exchange.	No. of Subscribers Connected.
Central	4,500
Hawthorn Manual	5,800
Windsor Manual	8,300
Cheltenham Manual	1,160
Williamstown	1,000
Mordialloc	350
Ringwood	340
Greensborough	190

Although the Second World War has been responsible for great difficulties and delays in the supply of materials, it has been possible to press on with the automatic conversions, thus meeting urgent Defence requirements and assisting in no small measure the great industrial expansion brought about by the war.

Future Development: As a result of telephone surveys carried out during recent years, it is estimated that the number of exchange lines within a 15-mile radius in Melbourne will reach 228,600 by June, 1963. Allowance has been made in this estimate for increased population and increased telephone density. The estimate of population at 1963 for the area is 1,700,000.

The metropolitan population has increased as follows:

Year	Population	Rate of increase in compound interest per annum
1901	501,580	—
1911	612,190	2%
1921	800,520	2.75%
1931	995,600	2.25%
1941	1,107,000	1.125%
1942	1,196,997	8.13%
1901–1942	—	2.15%
1963 (Estimated)	1,700,000	—

Telephone Density: The telephone density for Melbourne steadily increased from 2.5 per 100 in 1907 to 9.8 in 1942, and is estimated at 16 per hundred of population in 1963.

Suitable New Numbering Scheme: As mentioned previously, the present numbering scheme is based on a mixed 5 and 6 figure system. There are 7 main automatic exchanges; the call letter B is used for Central Manual Exchange, and Y, which was formerly used for Hawthorn Manual Exchange, has been reserved for the Trunk Exchange. The prefix A is not used because of false impulse difficulties.

Details of the network as it existed shortly before the present war were given in an article by Mr. R. V. McKay in the "Telecommunication Journal" for June, 1936. The proposed scheme is illustrated in Fig. 1, which also gives some idea of the geographical layout. It will be understood that junction routes not shown in the figure connect each main to every other main.

causes. It is evident, however, that while no great difficulty would arise in connecting 700,000 to the system, it cannot be assumed that growth will stop at this figure, thus the changeover to a system giving greater capacity must be undertaken at an earlier stage to ensure a smooth transition period.

Melbourne City Area: The present Melbourne

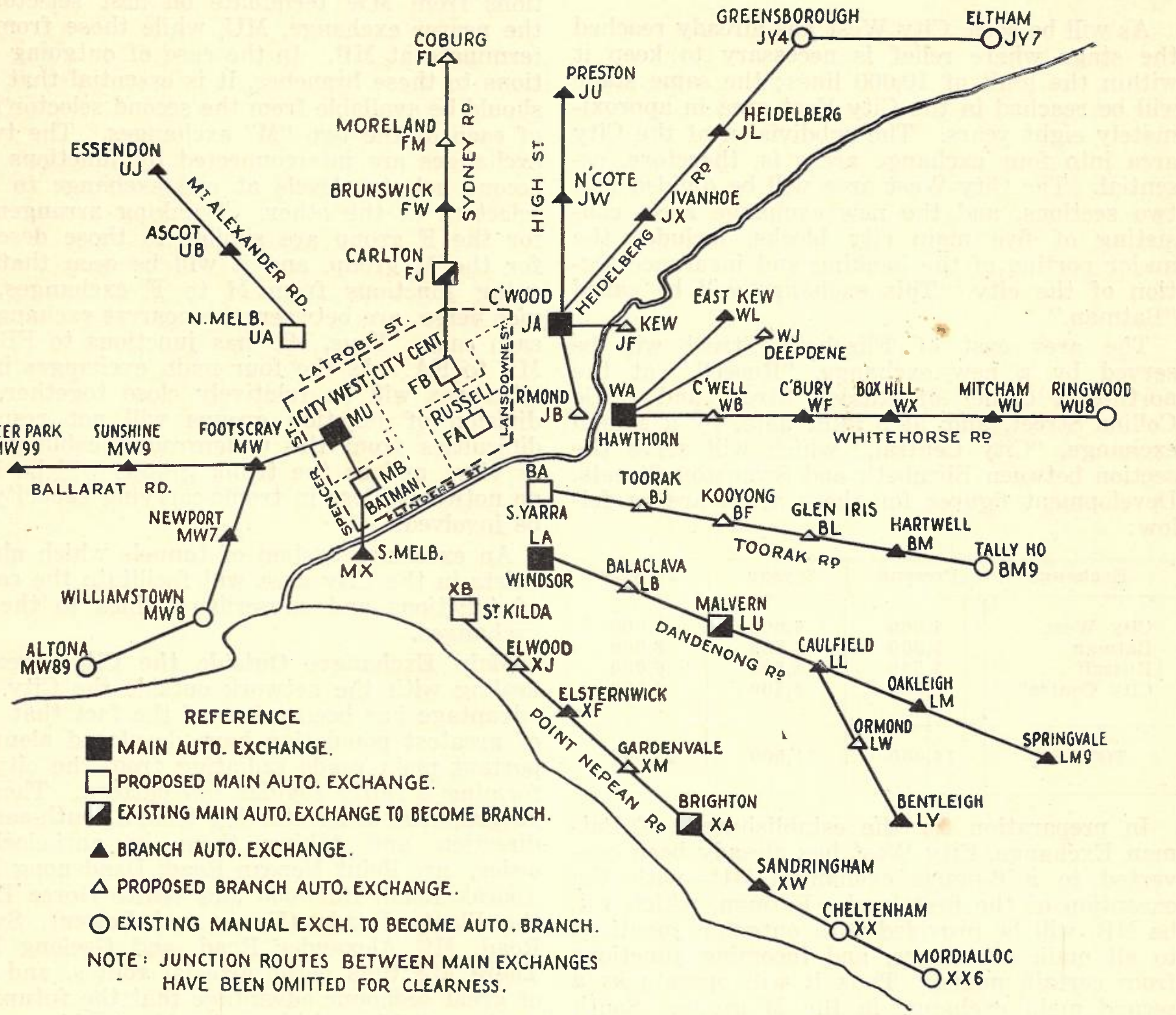


Fig. 1.

The scheme which has been developed to meet future needs involves taking B, used at present for Central manual, for the 8th automatic group, and Y for Central. The latter will be used until all of the C.B. manual subscribers have been transferred to automatic exchanges. The employment of 6-figure working throughout the eight groups will provide a nominal maximum capacity of 80 exchanges, each with a capacity of 10,000 lines. Allowance must, of course, be made for special services which require the use of blocks of numbers, such as test and complaint services, and for the impracticability of reaching full allotment owing to removal, cancellations, and other

City area is mainly served by one automatic exchange of the modern 2,000 type, City West, and the Central C.B. manual exchange. These exchanges adjoin one another. In addition, a small C.B. exchange (JM) with incoming automatic access, has been installed on a separate site. On account of difficulties in meeting development in the area prior to the opening of City West, many city subscribers were connected to automatic exchanges adjacent to the city area, the largest remaining group being 1,888, which are still connected to Carlton.

City West serves the area west of Elizabeth Street, while Central and JM exchange serves the eastern area. Development figures for the two areas are as follow:

Exchange	Present	8 year	20 year
City West	9,000	12,000	15,500
City East	7,000	9,500	12,500

As will be seen, City West has already reached the stage where relief is necessary to keep it within the limit of 10,000 lines; the same stage will be reached in the City East area in approximately eight years. The subdivision of the City area into four exchange areas is, therefore, essential. The City West area will be divided into two sections, and the new exchange area, consisting of five main city blocks, includes the major portion of the banking and insurance section of the city. This exchange will be called "Batman."

The area east of Elizabeth Street will be served by a new exchange, "Russell," at the north-east corner of Russell Street and Little Collins Street, and, at a later date, by a second exchange, "City Central," which will serve the section between Elizabeth and Swanston Streets. Development figures for these areas are as follow:

Exchange	Present	8 year	20 year
City West	4,000	6,000	8,000
Batman	5,000	6,500	8,000
Russell	3,500	4,500	6,000
City Central	3,500	4,500	6,000
TOTALS	16,000	21,500	28,000

In preparation for the establishment of Batman Exchange, City West has already been converted to a 6-figure exchange—MU—with the exception of the first level. Batman, which will be MB, will be provided with outgoing junctions to all main exchanges, and incoming junctions from certain mains. Thus it will operate as a second main exchange in the M group. South Melbourne, MX, at present trunked to City West by the "trombone" system (in and out) will be provided with Switching Selector Repeaters and interaccess with other branches in the M group.

Branches of City West and Footscray, Newport, Sunshine, and Deer Park will be retained with the prefix letters MW, and at a later date Williamstown will be added. Development in these branch areas has lagged in comparison with other areas, but in the event of unforeseen growth occurring, liberal allowance can be arranged in the numbering scheme.

A suitable trunking arrangement for the four exchanges in the City area is shown in Fig. 2. It will be observed that each exchange is provided with a complete set of junctions from first selector levels to the other main exchanges, but incoming junctions from main exchanges terminate on second selectors at the nearer of the two "M" exchanges, and similarly with regard to the two "F" exchanges.

Referring to the branches of the two "M" exchanges, it will be noted that the incoming junctions from MW terminate on first selectors at the nearer exchange, MU, while those from MX terminate at MB. In the case of outgoing junctions to these branches, it is essential that some should be available from the second selector levels of each of the two "M" exchanges. The two M exchanges are interconnected by junctions from second selector levels at one exchange to third selectors at the other. Trunking arrangements for the F group are similar to those described for the M group, and it will be seen that outgoing junctions from M to F exchanges, and vice versa, are between the nearest exchanges in each case. Thus, MU has junctions to FB, and MB to FA. As the four main exchanges in the city area will be relatively close together, this division of junction groups will not result in difficulties from the underground cabling point of view, and as the trunk groups will be large, no noticeable loss in traffic-carrying capacity will be involved.

An extensive system of tunnels which already exists in the City area will facilitate the cabling of junctions and subscribers' lines to the new exchanges.

Main Exchanges Outside the City Area: In dealing with the network outside the City area, advantage has been taken of the fact that areas of greatest population have developed along important main roads radiating from the city and forming a fairly regular fan pattern. These, in geographical order starting from a south-easterly direction and taking them in anti-clockwise order, are Point Nepean Road, Dandenong Road, Toorak Road, Burwood and White Horse Roads, the Plenty Roads (Upper and Lower), Sydney Road, Mt. Alexander Road, and Geelong Road. There are thus eight arterial routes, and it is of great economic advantage that the future network switching design should provide a main exchange to handle the telephone traffic originated along each arterial road area. Under this plan, the main exchanges will be placed towards the convergence of the roads on the outskirts of the city area proper, thus reducing the length of the expensive main conduit and cable routes between the main exchanges to a minimum. There is an added advantage that one of the eight letter prefixes on the dial (disregarding "A" and "Y") is available for each main exchange.

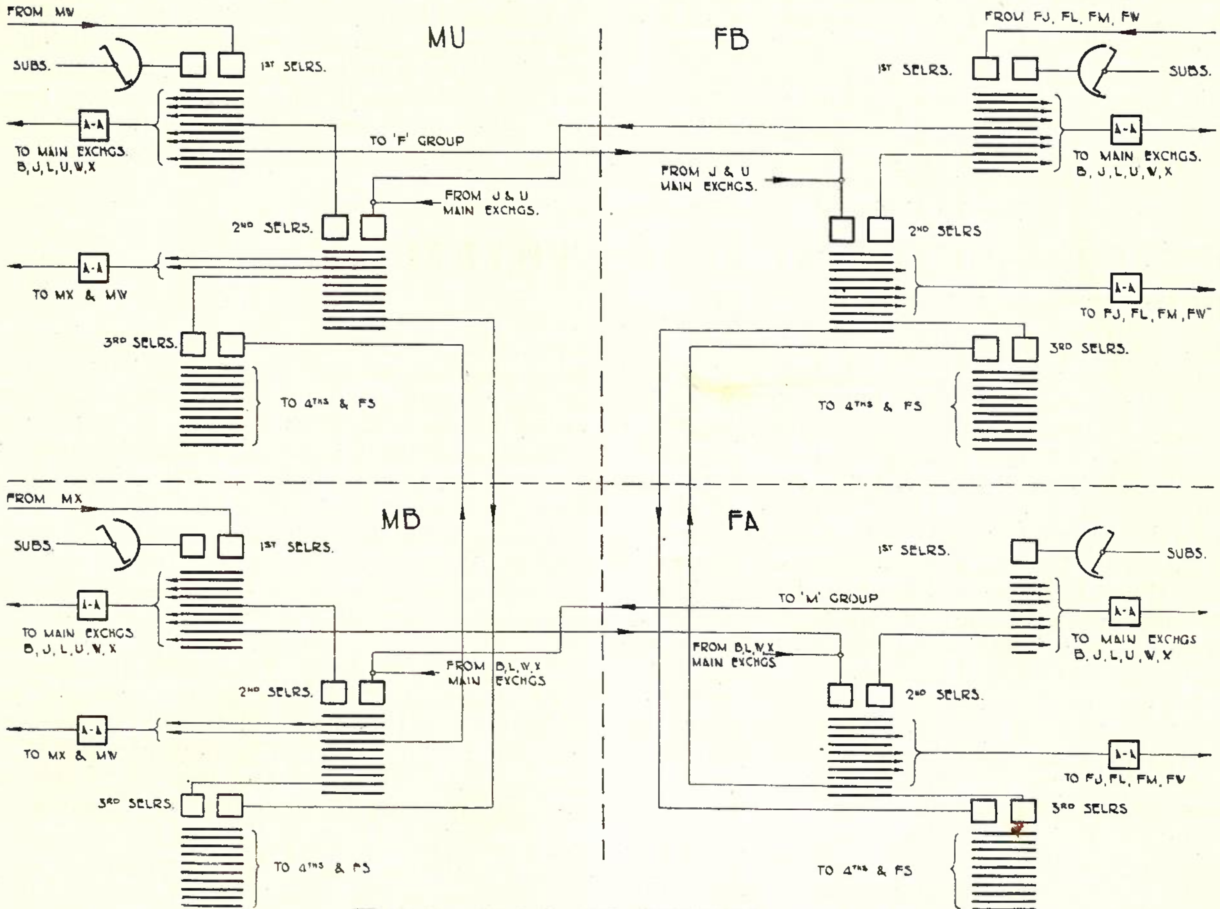
Loading of Each Main Group: From a study of telephone densities over the whole metropolitan area, and taking into account the radiating arterial roads and geographical features, a layout of main and branch areas has been developed whereby seven of the main groups will each include approximately 15,000 subscribers immediately, and will increase to 30,000 by the end of the 20-year period. The seventh group, with main exchange at North Melbourne, will not be established for some years, and is not expected to develop so rapidly as the other groups.

Subdivision of Main Areas: Each main exchange area will be subdivided into smaller branch exchange areas. In the case of six of these main areas, the number of exchanges will be from 5 to 7. The M group will include City West, MU; Batman, MB; South Melbourne, MX; Footscray, MW; and several small exchanges which, owing to their slow development, will be retained as sub-branches of Footscray for some years. The North Melbourne group, when established, will consist of North Melbourne, Ascot, Essendon, and, if warranted by development, a small branch in the Newmarket area.

In the majority of cases, a branch exchange area will include about 2,500 subscribers immediately, and is expected to grow to 5,000 or 6,000 lines over the 20-year period.

It is believed that in the plan outlined an ample margin of safety has been allowed both in the number of branches per main exchange area, and in the loading of each branch exchange. There are, no doubt, many unknown factors which may influence development, and it is for this reason that levels are being left unallotted in each group, and initial loading per exchange is moderate.

Some brief details of the larger changes involved under this scheme are as follow:



TRUNKING SCHEME FOR EXCHANGES IN CITY AREA

Fig. 2.

"X" Group: The present main exchange for the "X" group is Brighton, about 8 miles from the city. The new main "X" exchange will be at St. Kilda, approximately 3 miles from the city, and Brighton will become a branch.

"L" Group: Windsor, which is one of the modern 2,000 type exchanges established just before the war, will be retained as the main exchange for the "L" group, and Malvern, which is now the main for the "U" group, will become a branch of Windsor. This action will free the prefix "U" for use at North Melbourne at a later date.

"B" Group: A new main exchange for the "B" group will be opened at South Yarra, with branches at Toorak, Kooyong, Glen Iris, and Hartwell. The area at present is served by

Windsor, Malvern, and Hawthorn, and the establishment of the new group will afford considerable relief to these exchanges.

"W" Group: Hawthorn, the main "W" exchange, is a new 2,000 type exchange. The area served is large and relief will be provided by transferring Hartwell to the "B" group, and the Kew area to the "J" group.

"J" Group: The main exchange for the "J" group, Collingwood, is of the pre-2,000 type, and to avoid extension and reduce the exchange area to an economic size, a new branch will be opened at Richmond.

"F" Group: Carlton, the present main "F" exchange, is a pre-2,000 type exchange, which, in addition to its own area, serves nearly 2,000 subscribers in the City East area. It is proposed to open City East exchange as early as possible as the main for the "F" group, and convert Carlton to a branch. Further relief for Carlton will result from the opening of an exchange at North Melbourne.

"U" Group: Following on the conversion of Malvern to a branch of Windsor, a new exchange at North Melbourne will be opened as the main for a new "U" group.

Sites and Buildings: To carry out this scheme, an extensive building programme is being prepared. The erection of three large main exchange buildings in the City area, and twenty-three buildings for main and branch exchanges in the suburban areas is involved.

GAS PRESSURE ALARM SYSTEM—

MELBOURNE-SEYMOUR CABLE

E. Corless

Introduction: The primary purpose of this article is to describe the installation methods used and some maintenance experience with the operation of the gas pressure alarm system on the recently-completed Melbourne-Seymour-Mangalore carrier cable. A similar gas pressure alarm system was installed on the Sydney-Maitland carrier cable (Telecommunication Journal, Vol. 2, No. 5, "The Sydney-Newcastle Cable," Part 1, Pages 274-284), and this installation, together with that on Melbourne-Seymour-Mangalore cable has enabled considerable experience to be obtained in installation and maintenance methods. Apart from these two important trunk cables, gas alarm systems have also been installed on short trunk cables and special submarine cables. At present gas alarm systems are in course of installation on the Melbourne-Geelong, Melbourne-Werribee, Melbourne-Dandenong, Melbourne-Frankston, Sydney-Penrith and Sydney-Windsor-Richmond trunk cables and on a series of control cables at a radio station.

As the most experienced administration in the application of gas alarm systems to telephone cable systems is the American Telegraph and Telephone Company (the earliest installation dates back to 1929), the general principles of the gas alarm system used by this company have been adopted. Consequent upon local conditions, appreciable modifications from the A.T. & T. equipment and practice have been made in a number of features of the installation and these will be referred to in the paper.

In considering the application of the gas pressure alarm system to an underground cable it must be appreciated that its function is partly an indicator of incipient trouble on the cable and partly preventative. It is preventative only insofar as it prevents the ingress of moisture through a hole in the sheath after a fault has occurred. It is, of course, still essential to apply mitigation measures for electrolysis, chemical corrosion and other forms of cable damage in order to limit the occurrence of cable sheath faults in the first instance. The old adage that "prevention is better than cure" applies aptly to the gas pressure alarm system. Even with the limited experience to date a number of incipient cable failures which would have eventually caused a complete breakdown of vital circuits have been detected without any interruption to service.

Layout of System: The Melbourne-Seymour-Mangalore cable consists of two 24-pair 40 lb. star quad ("Go" and "Return") cables of 67 route miles, of which 17 miles are installed in conduit and 50 miles are steel tape armoured and laid directly in the ground. The layout of the system is shown in Figure 1.

The cable is separated into gas-tight sections by means of special gas seals, as the normal cable terminal boxes or SILC. terminations will not withstand the gas pressure for any appreciable period. The normal length of gas-filled cable is approximately 10 miles, but for experimental purposes one section of gas-filled cable was extended to 20 miles. At approximately every 1¾ miles there is a special manhole to house a contactor alarm for each of the two cables. The purpose of these alarms is to short circuit a pair in the cable if the pressure falls to 10 lb./sq. inch. This alarm is extended to the test desks at City West and Seymour, where in the event of a contactor operating, a lamp glows and the mechanic can immediately make a loop resistance test to determine the position of the operated contactor. The mechanic then advises the responsible engineer, who arranges for investigation to be made as to the cause of the contactor's operation.

Gas Used in the Cable: The cable is filled with dried air at a pressure of 15 lbs./sq. inch. While oil-pumped nitrogen is used extensively overseas, especially where extremely low temperatures are encountered, dried air is found to meet all local requirements. This is obtained from two sources:

(a) From cylinders containing from 20 to 300 cubic feet of air at atmospheric pressure, compressed to 2,000 lbs./sq. inch. This air is known as commercially-dried air. Actually, the only drying process is that which takes place automatically as the air is compressed; the moisture

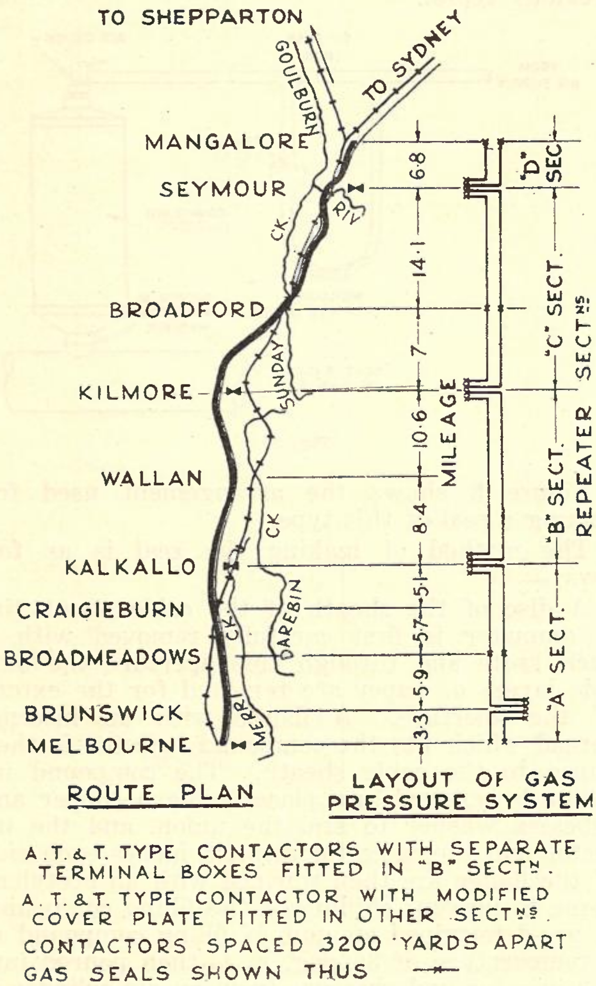


Fig. 1.

which is deposited is trapped during the pumping process and to further the condensation of moisture, the compressed air is cooled at one stage of the process. The resulting air is satisfactory for filling cables providing the precaution is taken of ensuring that no containers are used below a pressure of 25 lbs./sq. inch. The reason for this precaution is that any moisture which may be in the bottom of the cylinder will tend to evaporate as the pressure is reduced.

(b) From calcium chloride desiccators.—The desiccator consists of a petrol engine, driving a piston-type pump which pumps air through cylinders of calcium chloride. It is mounted on pneumatic tyres and is towed behind a utility truck. While the desiccators are not as economical to use where cylinders are easily obtained, they are often more convenient for use in country districts and have advantages under present conditions when the steel cylinders are difficult to obtain in sufficient quantities for charging cables with gas.

An experiment is being carried out at the present time to investigate the possibility of using a large storage tank in conjunction with a calcium chloride desiccator for pumping cables over a longer period from one central point on the cable. This tank will be installed at a country centre and the aim is to eliminate to a large extent the transport of air cylinders or a desiccator along the route of the cable.

Equipment Used on the Gas Alarm System:

(i) Gas-Tight Seals. Three types of gas-tight seals have been used. These are:—

(a) "Factory" type;
(b) "Field" type;
(c) "Pressure-filled" type.

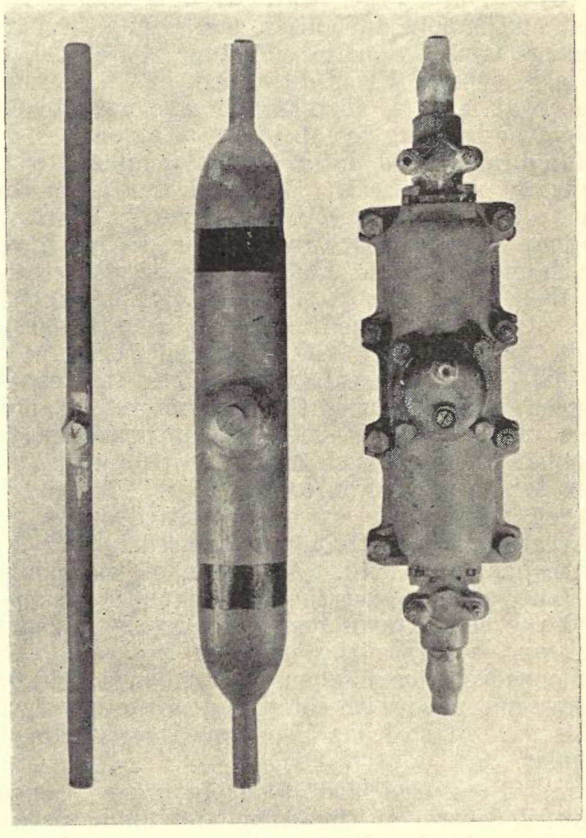


Fig. 2.

Figure 2 shows a plan view of the three types of seal.

(a) **"Factory" Type Seal: This** was the earliest type of seal and consists of a split cast-iron case with gunmetal fittings, into which two tails of paper-insulated cable of suitable length are jointed. The conductors of the cable are stripped for a short distance and jointed near the centre of the casing. An ebonite spacer prevents the wires contacting. The casing is then bolted together and filled with a sealing mixture at 360 deg. F. The filling compound originally used for this type of seal consisted of nine parts of resin and one part of beeswax heated to a temperature of 360 deg. F. Considerable trouble was experienced with this mixture, due to its brittleness and tendency to crack in very cold weather or with slight movement of the cable on each side of the seal. In addition, the compound tended to contract away from the inside of the casing of the coupling, permitting escape of gas past the seal. After a number of experiments with different types of sealing compound the mixture was changed to Mexphalte R.85/40, Resin Grade G, Paraffin Wax in the proportion 2 : 1 : 1. To assist the establishment of good contact between the compound and the inner metal face of the coupling, the surface was primed with a white spirit and Mexphalte mixture before filling.

(b) **"Field" Type Seal:** Arising partly from cost and supply difficulties, and partly from gas leakage troubles on the "Factory" type seal, the "Field" type seal was developed, in which a lead sleeve at least 4" in diameter was used to contain the sealing compound. The cable was jointed and filled in a similar manner to the "Factory" type seal. This seal was more compact and considerably less costly than the "Factory" type seal. In addition, it has proved much more reliable, and experience with twelve of these seals over a period of eighteen months has shown only one failure, as against 50 per cent. failures with the "Factory" type. The "Field" type of seal, which uses the ebonite spacer for separating the conductors, is applicable only to cables with a comparatively few number of pairs, such as the 24-pair 40 lb. carrier type cable. For cables up to 150 pairs or larger, the ebonite spacer is omitted and a type of seal similar to that standardised by the A.T. & T. has been used. A section of the cable is stripped of the lead sheath and paper wrapping and the ends drawn together slightly to balloon out and separate the pairs in the cable. The ballooned section is then enclosed in a field-type sleeve and filled with compound in the usual way. This type of seal has also proved satisfactory in service.

(c) **"Pressure-Filled" Seal:** In order to ensure careful control of the compound filling process, and to enable breakdown pressure tests of 50 lbs. per square inch to be applied to the seals, it has been the practice to make up both the "factory" and "field" type seals in the workshops and then joint them into the cable in the field. Whilst this method of installation is not a very great disadvantage for new cable, it is a serious drawback where a working cable of any size is concerned. Arising from a reference in "Telephony," March 14, 1942, Page 15, and "Association of American Rail Roads" Publication No. 1/A/83 (1942), experiments were made to examine the possibility of injecting sealing compound under pressure into the sheath of the cable without disturbing the cable in any way. As a result, a method of sealing cable was evolved which is expected to replace all the former types of seals, having the advantage of both cost and reliability over all previous types.

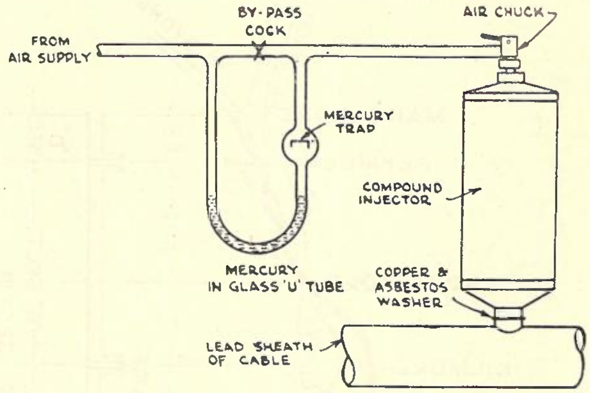


Fig. 3.

Figure 3 shows the arrangement used for making a seal of this type.

The method of making the seal is as follows:—

A disc of the sheath of the cable about ¾in. in diameter is first carefully removed with a hack knife and through this aperture the outside layers of paper are removed for the extent of the aperture. A flange with an internal thread which fits the compound injector is then wiped to the cable sheath. The compound injector is screwed into place, using a copper and asbestos washer to seal the union, and the injector and the cable for about 3 inches each side of the flange are then warmed with an acetylene flame to prevent chilling of the filling compound. A pre-determined amount of filling compound at a temperature of 360deg. F. is then poured into the injector and pressure from an air cylinder is applied through a Schrader valve holder fitted to the cap of the injector. A pressure of 30 lb./sq. in. will be found sufficient to drive the compound into the cable sheath, and as soon as air is heard passing into the cable through the compound, pressure is removed and the compound injector is again half filled. Pressure is again applied to the sheath, this time at about 10 lb./sq. in., and this pressure is increased by approximately 1 lb./sq. in. per minute until 30 lb./sq. in. is reached; the seal can then be allowed to cool under this pressure.

During this process the flow indicator shown in Fig. 3 need not be used; if the by-pass cock is left open air will pass from the cylinder to the injector without disturbing the mercury. However, if there is any doubt as to whether the pressure is causing more compound to flow into the seal, the flow can be checked by closing the by-pass cock so that any air passing into the injector will cause a movement of the mercury. It is desirable of course that no appreciable amount of compound should enter the seal after the initial injection and if movement is apparent the pressure should be temporarily reduced.

In the case of important cables where it is essential for any reason to keep a seal short, 30 per cent. less compound than is normally used will suffice if the flow indicator is used, and the pressure on the second amount of compound is increased rapidly, using the flow indicator after each increase of pressure to ensure that no movement is taking place.

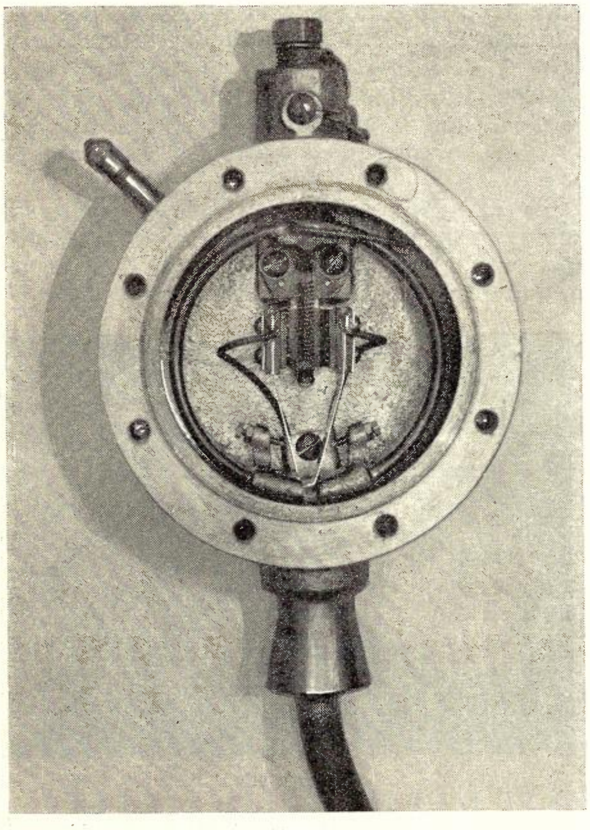


Fig. 4.

The amount of compound listed hereunder has been found suitable for the initial injection of a normal seal in Star Quad Cables:—

Cable up to 1 in. diameter, 1 pint.
Cable up to 2 in. diameter, 1½ pints.
Cable over 2 in. diameter, 2 pints.

No attempt should be made to apply a pressure test to a seal until at least 8 hours after the seal has been made.

This type of seal can be placed in a working cable in any place where there is a two foot length of straight cable, and working circuits are not in any way affected. Seals of this type are now in service on the Melbourne-Geelong and the Melbourne-Werribee Cables, and up to date have proved satisfactory. In making not only this type of seal, but all types of gas seal, it is essential that a careful control of the filling process be exercised as only a slight variation from the proved method is necessary to cause gas leakage and a failure of the seal.

Contactor Alarms: As in the case of gas tight seals, considerable experimenting has been done with various types of contactor alarm units. The main types which have been used to date are:—

(a) A.T. and T. type.
(b) A.T. and T. type, modified to include test terminals on the face plate.
(c) Contactor-Terminal.
(d) Contactor-Gauge Alarm.

(a) A.T. and T. Stub-type Contactor.— This type of contactor, which is in most general use in Australia at present, is shown in Figure

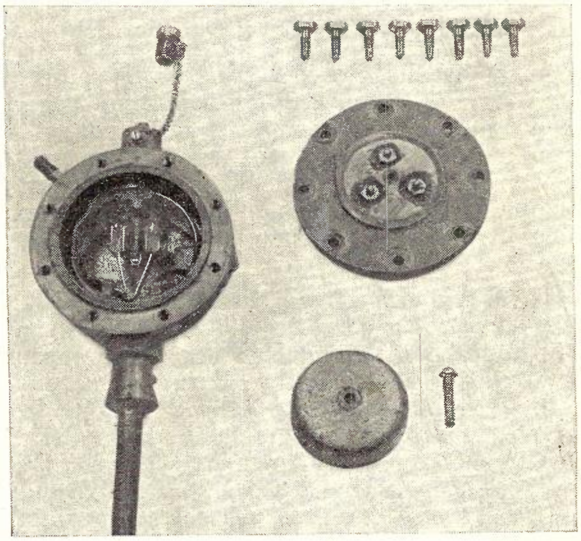


Fig. 5.

4. In this contactor the Bourdon tube is sealed and the gas pressure in the cable is introduced via ½ in. lead tubing into the air tight chamber containing the Bourdon tube. Adjustable screws with insulated tips are mounted on the ends of the Bourdon tube, and as the pressure in the airtight case increases the Bourdon tube closes and the tips bear against and open the spring contacts. Conversely as the pressure falls the Bourdon tube opens and the spring contacts close to short circuit the pair in the cable and operate an alarm at the repeater station. Final adjustment is obtained after the case is closed by operating a screw at top of the contactor. This raises or lowers the whole spring assembly, thus varying the operating pressure. The alarm pair is connected via a

terminal box (see Fig. 8) the function of which is to facilitate access to the alarm pair for testing the operating pressures of contactors, or, in the case of a fault, for disconnecting an operated contactor from the pair and for speaking on the pair. One of the main troubles experienced with the contactor to date is change of operating pressure from the set

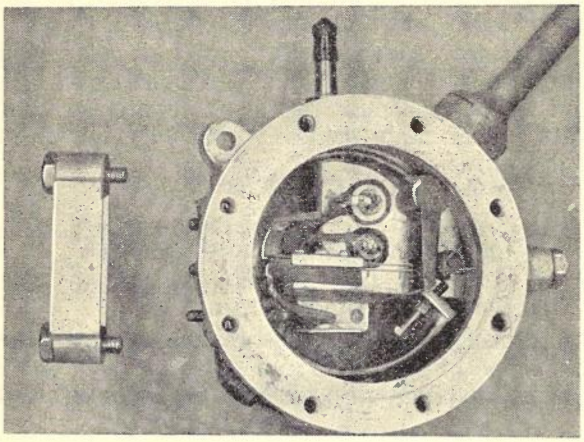


Fig. 6.

value of 10 lb./sq. in. This is due, in most cases, to the springs taking up some degree of permanent set. Although this is partly attributable to the treatment of spring material during manufacture, this type of contactor has the inherent disadvantage that the springs are constantly under tension in the non-operated position.

(b) A.T. and T. Type Modified to Include Test Terminals: In order to obviate the necessity for a terminal box external to the contactor alarm to provide access to the alarm pair and contactor, the cover plate of the A.T. and T. contactor was modified to include terminals. This type of contactor is shown in Figure 5. Three terminals are inserted through the cover plate of the A.T. and T. type contactor, one terminal being used as common terminal for one contact of the contactor and one wire of the alarm pair and the other two terminals for the other contact of the contactor and the second wire of the alarm pair respectively; thus by strapping two terminals together on the outside of the plate with a removable strap, all the useful facilities of a terminal box are retained. The terminals are insulated from the cover plate and sealed against air pressure leaks with fibre or rubber washers and bostik cement. Over a period of about two years during which these units have been in use their operation has been satisfactory. The advantages of the combined unit over the two unit type are as follow:—

(i.) Saving in cost.

(ii.) Compactness — an important feature in city manholes; also this compactness allows the use of smaller gas alarm manholes.

(iii.) As considerably less lead tubing and wiping is involved, the new unit is less liable to cause pressure leaks.

(iv.) In the event of the terminal assembly on the front plate leaking, the front plate can be quickly removed, terminals tightened, and the plate replaced, whilst with the terminal box, it is necessary to dismantle the unit, clean out sealing compound and reseal the box.

(c) Contactor Terminals: The modification of the stub-type contactor alarm to incorporate the terminals in the cover plate was only an intermediate stage in combining the terminal box and the contactor alarm. At the same time a design was prepared for a complete contactor terminal and this is shown in Figure 6. No field experience has yet been obtained with this unit, but Laboratory tests suggest that it will supersede in the majority of cases the separate arrangement of a stub-type contactor and terminal box. The main features of this contactor terminal are:—

(i.) The cable pressure is applied to the Bourdon tube instead of into the case as in the A.T. and T. type. This allows the movement to be inspected without losing air pressure.

(ii.) Standard 2000 type relay springs with double platinum contacts are used — these are superior to the contacts used in the previous contactors. The action of the contactors embodies the wiping action in the spring contacts.

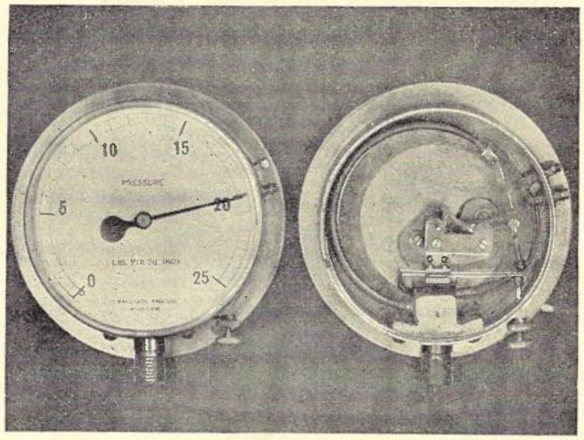


Fig. 7.

(iii.) The springs are operated by positive pressure from the Bourdon tube, while a stop protects the springs from strain.

(iv.) The terminal unit is mounted on the side of the box, allowing the cover to be freely removed.

(d) Contactor Pressure Gauges: A contactor pressure gauge is an ordinary 6 in. dial Bourdon gauge fitted with contacts which may be adjusted to close at any desired pressure by turning a screw on the outside of the case. This type was first developed for use on submarine cables which on account of the hydrostatic head of water, had to operate at a pressure above the range of the ordinary contactor alarm. For that purpose, they are mounted in waterproof boxes near the ends of the cable, and the contacts are connected to the alarm pairs at the cable termination in the exchange. However, it has since become apparent that these units are particularly suited to mounting on the terminal end of any cable under gas pressure for the following reasons:—

(1) As the alarm pair can be taken from the cable termination at the exchange, there is no need for special air-tight terminating arrangements as with the contactor alarms.

(2) As the gauge always shows the pressure in the cable when the alarm is not operating (the pointer will not drop below operating pressure) it is possible for an officer to telephone a distant station and have the cable pressure read. A particular instance of the application of this feature is where a short cable (up to 4 miles) is being re-charged. Where a cable is to be pumped to, say, 15 lb./sq. inch, a cylinder at a regulated pressure of 17 lb./sq. inch is connected at the end of the cable where staff is stationed. The gauge at the other end is located within sight of an officer who can advise the officer operating the cylinder when the gauge shows 13 lb./sq. inch. The cylinder is then dis-

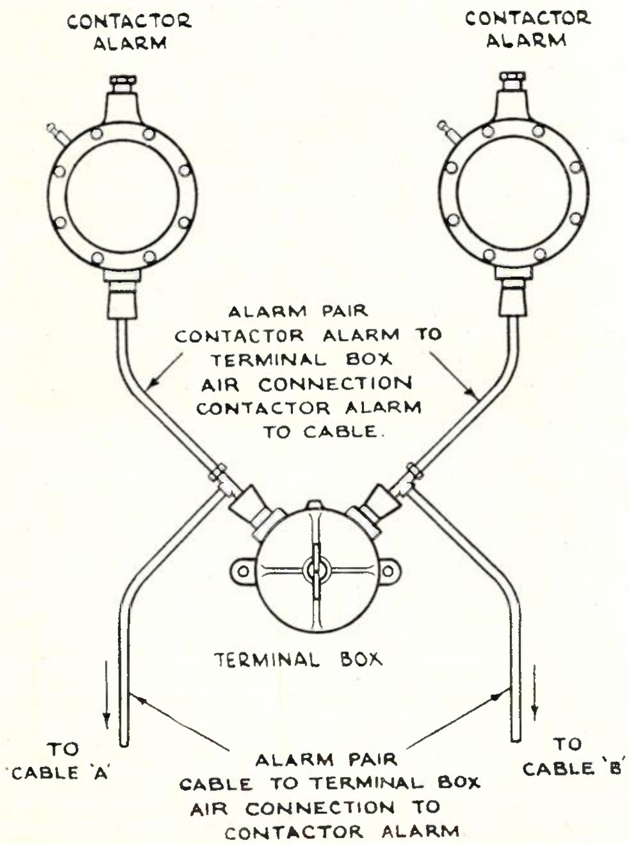


Fig. 8A.

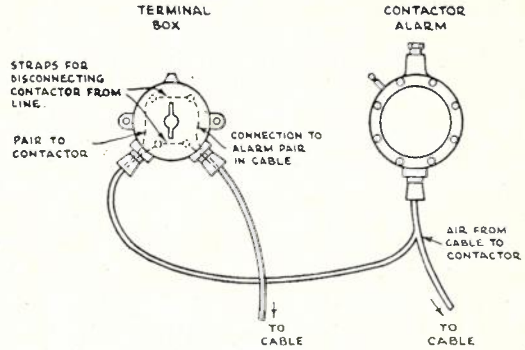


Fig. 8B.

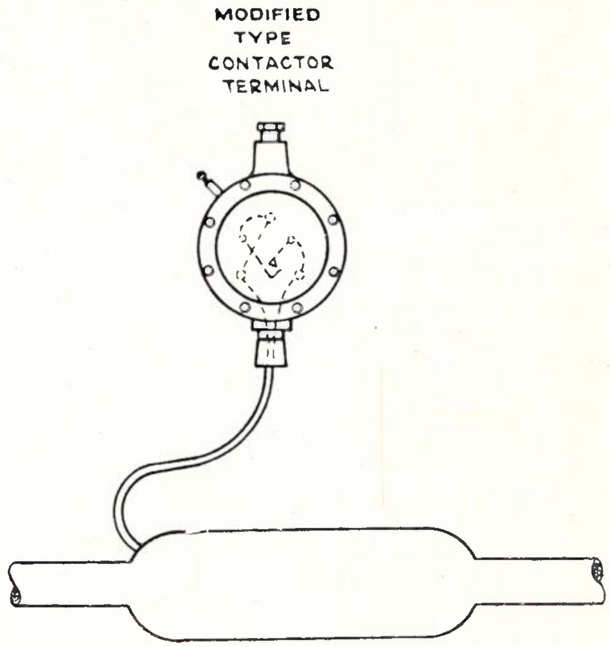


Fig. 8C.

connected, and it has been found in practice that the cable will stabilize at approximately 15 lb./sq. inch.

While this method of charging the cable is slow, no staff or transport is held up during the charging process and it is, therefore, a very convenient means of charging a short cable. One particular instance where this system is being used is on the Shepparton-Mooroopna minor trunk cable.

Terminal Boxes: Three main arrangements of terminal boxes have been used involving two types of terminal box. These arrangements are shown in Fig. 8. The type shown in Fig. 8 (a) provided for two entry points into the terminal box and four pairs of terminals on the faceplate of the terminal box to enable the test and contactor alarm pairs for two cables to be brought into the one terminal box. This arrangement has not been very satisfactory in practice owing to the difficulties of preventing gas leakage between the two entry points of the two lead tubings from each cable, associated with contraction of the filling compound in the terminal box. For later installations one terminal box of this type was provided for each cable. (See Fig. 8b.) This obviated the possibility of leakage of gas from one cable to the other. The latest type of cable terminal box shown in Figure 8 (c) eliminates the two points of entry for lead tubing and provides for other improved features. As referred to under contactor alarms, it is probable that the the future application of this latter type of terminal box will be comparatively limited due to the more extensive use of the contactor terminal.

Adjustment of Contactor Alarms and Contactor Terminals: In the maintenance procedure for cables under gas pressure, arrangements are made to test the operating pressure of contactor alarms each three months. The method of adjustment is as follows:—

(a) Disconnect the contactor from the line.

(b) Connect a buzzer and battery in series with the contacts of the contactor.

(c) Connect an accurate Bourdon test gauge to the contactor so that the gauge shows the pressure at the contactor. This gauge should have a "Tee" piece in the tail and a "Renrut" chuck which opens the valve at which the gauge is connected. A tap in the "Tee" piece prevents air escaping.

(d) Open the tap and allow air to escape gradually so that the contactor pressure drops back. Note **on the test gauge** the pressure at which the buzzer operates.

(e) Close the tap and allow gas to creep along the cable to remove the short circuit from the contacts and repeat the operation. Average the two readings and if necessary adjust the operating pressure.

Schrader Valve and Fittings: For charging the cable and reading pressures on contactors and on the cable a valve holder is used which accommodates standard Schrader valve cores and caps. A valve holder is fitted to every contactor alarm, and where test points are required on the cable, a flange is wiped on (preferably on the joint) and after the sheath is punctured, the valve holder is screwed into the flange. If it is desired to remove the valve, the hole can be sealed by screwing a hexagon-headed screw into the flange. When fitting, it is important always to coat the thread of the screw or valve holder with gasket cement as this has been found a very good insurance against leaks at this point. In positions where it is desirable to leave the valve holder permanently for urgent charging purposes, a valve cap can be fitted, and if the thread is sealed with gasket cement, the valve will not leak even if the rubber insert in the cap or the valve core fails.

Length of Gas Sections: A long gas section of cable has the advantage that there is a greater amount of gas to protect the cable in the event of a hole occurring in the sheath; on the other hand with too long a section, leaks due to jointers working on the cable release a greater quantity of gas with consequent higher

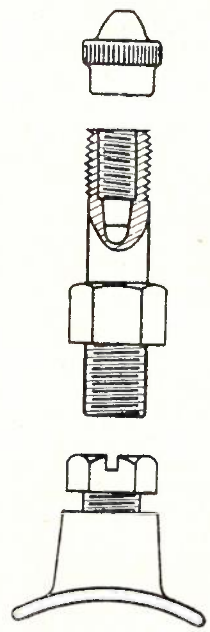


Fig. 9.

cost of re-pumping the cable. A point in favour of long sections is that it is difficult to locate leaks near a gas seal as there is a gradient on only one side of the fault. By using a by-pass valve which has been developed for the purpose, the advantages of both long and short gas sections are obtained by by-passing at will gas seals installed along the section. The general trend is to divide the cables into sections of about 10 miles with gas seals, and by-pass certain seals through a by-pass valve, thus making in effect longer sections. In the event of work requiring some sections to lose gas, the sections can be isolated by closing the by-pass valves. While the valves are open, all the advantages of longer sections are retained.

Charging the Cable with Gas: In charging a cable or topping a partly discharged cable, the general practice is to determine from a chart the amount of gas to be admitted to the cable and to allow this gas to enter by means of a single stage pressure regulator. This regulator is fitted with two gauges, one showing the pressure of the gas, and the quantity of gas at atmospheric pressure in the cylinders while the low pressure gauge shows the pressure at which gas is being admitted to the cable. While the cable will safely stand a little more pressure, it has been made a rigid rule for the safety of the contactors never to admit gas to the cable above 20 lb./sq. inch. There are exceptional circumstances with which the ruling would have to vary, such as for a submarine cable where some increase in normal and operating pressures must be made to allow for the hydrostatic head. In this case, however, standard contactor alarms are not fitted. As a general indication of the amount of gas required for charging a cable a 24-pair 40 lb. carrier type star quad cable which has an internal diameter of 0.98 in. requires approximately 20 cubic feet to pump one mile of cable from atmospheric to 15 lb./sq. inch above atmospheric pressure.

Fault Location: It is the standard practice overseas to make adjustment for the effect of the temperature of the cable upon the gas in the cable. In order to make this correction the temperature of a cable is measured by placing a thermometer in the vicinity of the cable, either in a duct or in the earth. Experience with the installation here, however, indicates that it is impractical to measure the temperature with any degree of accuracy by this means, and experiments are being carried out to endeavour to correlate the loop resistance of a pair in a cable with the temperature of the cable. It is hoped by continuing these investigations over a number of seasons to establish a chart of average cable temperatures in a particular cable against all months of the year.

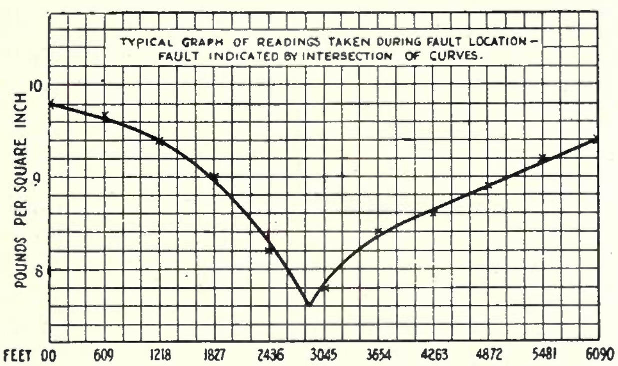


Fig. 10.

The above investigations are based upon the fact that the temperature of the soil at depths of over 12 in. varies from season to season in a gradual curve, and it does not have any direct relationship to day-to-day changes of atmospheric temperature. It is considered from the data so far to hand that an average monthly temperature calculated from the loop resistance of the cable, will be more accurate for practical purposes than attempting to arrive at the temperature by direct measurements.

The main reasons for making corrections for the effect of temperature on the pressure of the gas are:—

(a) To determine whether the drop of pressure in a cable is due to change of temperature or to leakage of gas.

(b) To correct the operating pressure of Bourdon type contactor alarms and contactor gauges.

Method of Locating Gas Leaks: A gas leak may become evident by alterations in the pressure readings during periodic inspection or by operation of the alarm at a repeater station. In the latter case an approximate idea of the location of the fault is given by a loop resistance measurement to the short circuited contactor alarm. The usual method of locating a gas leak is to first take readings by means of a sensitive 6 in. dial Bourdon gauge at the test points normally installed at $1\frac{3}{4}$ mile intervals. These readings are then plotted against the distance between the test points and an approximate location of the fault will be obtained from the intersection of the pressure gradient on each side of the fault. A typical fault location graph is shown in Figure 10.

The next step is to fit three additional valves at $\frac{1}{2}$ mile intervals on each side of the apparent position of the leak. After allowing the pressure to settle for half an hour, readings are taken at these points and the results plotted as before. This graph should give the position of the leak to within plus or minus 150 yards.

Further valves are then fitted at each 200 yards (each selected joint) for a distance of 600 yards each side of the suspected position of the fault, and, after allowing the pressure to settle for a further hour, readings are taken at these points and a further graph plotted. This method will give a location to within a few yards when the drop in pressure is of the order of 1 lb./sq. inch or more. With smaller leaks—those causing a drop of pressure down to $\frac{1}{2}$ lb./sq. inch per mile, the same degree of accuracy of location is not obtained by the above method owing to the relative inaccuracy of the measuring equipment in relation to the pressure gradient. For gas leaks of this type a more accurate method of location which will be referred to later is being developed. An important point in obtaining accuracy with a large leak is to maintain the pressure gradient with a minimum pressure of 5 lb./sq. inch in the vicinity of the fault. In order to do this cylinders of air should be connected at about 4 miles each side of the fault with regulators set at 20 lb./sq. inch. These cylinders should be connected only when it becomes apparent that the pressure in the cable has become too low for fault location. After raising the pressure by pumping at several points, the cylinders should be connected and the regulators constantly watched so that the pressure does not vary from the 20 lb. By this means, when the gradient does settle it can be maintained during location of process and the necessity for repumping before the fault is located is obviated.

A further aid to the location of leaks is a gas-flow indicator. The indicator at present in use is shown in Figure 11 and has proved of considerable assistance in the location of leaks. When the connecting tubes of this indicator are connected to two points normally 2 to 3 feet apart in a leaking cable, the difference in pressure between the two points of the cable (due to the leak) will cause air to flow through the instrument in the same direction in which it is flowing in the cable. This air carries ammonia gas from the central chamber over the paper which is impregnated with phenolthallin, and discolouration of the phenolthallin on one of the pieces of paper indicates the direction of flow. One particular application of the indicator is to give a definite indication of leak location when the pressure gradient method shows a leak to be in the vicinity of a joint. A further use is to determine definitely the length in which a leak is located when the leak is in

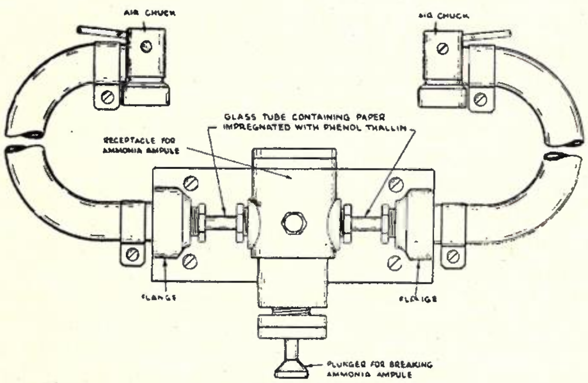


Fig. 11.

cable laid in ducts. This, of course, removes the possibility of pulling a wrong section of cable out of the ducts. The method of using the indicator is as follows:—

(a) Introduce an ammonia ampoule (a small glass phial of ammonia) into the centre chamber of the instrument, and insert a small quantity of filter paper impregnated with phenolthallin into the glass tubes.

(b) Connect the instrument simultaneously to two points on the cable 2 to 3 feet apart.

(c) Allow the pressure to settle for 15 minutes (longer if gas was lost while making connections).

(d) Soap all connections and the instruments to ensure freedom from gas leaks.

(e) Fracture the ampoule with the plunger and immediately tighten the plunger gland and apply soap suds to ensure that there is no leakage at this point.

Where a fault has been of the order of a pin-hole or larger, the method of leak location described in the foregoing paragraphs has generally located the fault to within about 100 feet. However, where the fault has been smaller than this as is often the case with a hole due to impurities becoming embedded in the sheath during the manufacturing process, location is not as accurate due to the fact that the practical limit of accuracy of the Bourdon gauge or mercury manometer in the field is $^{1}/_{20}$ of 1 lb./sq. in.; the fact that the cable is losing pressure while the readings are being taken further reduces the practical accuracy of these readings to about $^{1}/_{10}$ of 1 lb./sq. in.

Experiments are now being carried out with means of measuring the difference in pressure between cable joints (approximately 200 yds. apart). The glass "U" tube containing coloured spirit is connected by means of lengths of rubber tube to adjacent joints, and by this means the difference in pressure between the two joints is measured in terms of inches of spirit. Measurements are taken by this means for a series of pairs of joints extending each side of the fault, and, assuming an arbitrary figure for the lowest readings, the pressures at the other points can be calculated from the differences read on the "U" tube.

It will be appreciated that the differences in pressure between adjacent joints can be read to a greater degree of accuracy by this method than with a mercury manometer; the movement of liquid can be further magnified by using two different coloured liquids of different specific gravities in containers of about 2 inches in diameter joined together by a ½ in. diameter "U" tube.

In practice the "U" tube is fitted with a by-pass valve to allow the length of rubber hose to be charged to a pressure approximating that of the cable. After charging, the tubes are then connected to the cable and a reading can be taken after 15 minutes has elapsed to allow the cable and tube pressures to stabilize.

As differences of pressures and not actual pressures are being read by this method, the fact that the cable is losing pressure during the time when the readings are being taken is of no great importance; this factor allows of more time being taken to obtain accurate results. A fault recently dealt with by this method was located to within 20 yds., and on examination proved to be considerably smaller than a pinhole.

Experience to date with the Melbourne-Seymour cables is that six faults have been located by means of the alarm system; most of these faults would definitely have resulted in failure of the insulation of the cable. On two other trunk cables in process of being placed under pressure, six sheath faults which have been located would also have become faults in insulation at a later date. An interesting case of the psychological effect of gas pressure in cables occurred recently on a cable under pressure. Some unauthorised person removed a cover from a jointing pit and attempted to cut a hole in the cable with a sharp instrument. Apparently as soon as the sheath was pierced he became alarmed at the sound of gas leaving the cable, and attempted to plug the hole with clay. The fault was found on the following monthly patrol as the damage had not extended to the conductors of the cable.

Maintenance: As in the case of any equipment performing an important function with which reliability is essential, it is most important that accurate and regular maintenance of the gas pressure alarm system should be carried out. On the system dealt with in the foregoing notes, a monthly reading of all test points is taken, and the whole route is inspected and the contactor alarm units adjusted each quarter. Incipient leaks in equipment are usually picked up from irregularities in the monthly patrol readings, and the quarterly routine ensures that the alarms shall operate reliably in the event of a major leak. Regular maintenance is also carried out on associated equipment such as Bourdon gauges, air regulators, etc., as the equipment is of a sensitive nature and is easily thrown out of adjustment. A mercury manometer is used for periodical calibration of test gauges.

Conclusion: The increasing application of gas pressure alarm equipment to underground cable networks is symptomatic of the desire of Lines Engineers to achieve the highest grade of service free from interruptions, and present indications are that the application of gas pressure alarm systems to underground cable will be considerably extended in the future. It is probable that the practice will be extended from main trunk cables to minor trunks, junction cables, and even to long or important subscribers' cables. Much work still remains to be done, and as the system extends the experience gained will undoubtedly lead to further improvements in equipment and operating technique.

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CABLE DISTRIBUTION BY MEANS OF LARGE OUTDOOR TERMINAL PILLARS: PART 2—THE USE OF LARGE PILLARS

L. E. Calame, B.Sc.

Aspects Regarding Distribution by Means of Large Type Pillars and 120-pair Pillars: The large type pillars have, in general, been installed with the primary object of temporarily conserving main pairs in heavily loaded cables pending relief, but at the same time, when once installed, they have become the permanent means of distribution for that area. It will be of interest to examine the cases of three 800-pair cables, two of which are wholly distributed by large type pillars and one by small size pillars of 120-pair and 160-pair capacity. (See Figs. 8, 9, and 10.) Any comparisons between large and small pillar distribution made in this section are offered for the reader's consideration as the views of the writer on the subject.

The following information is given in each Figure:

(a) Size of main cables.

(b) Total capacity of the pillar—the numerator of the fraction alongside the pillar gives the total main pair capacity, the denominator the total secondary pair capacity.

(c) Number of main cable pairs actually terminated on the panel.

(d) Number of working services connected to the exchange via the pillar panel.

In the case of Fig. 8 the installation of the pillars was completed in June, 1940. Since their installation no alteration whatsoever has been made to main pairs originally terminated on the panels.

The great flexibility of the large type panel whereby, by means of grouping a comparatively large number of main pairs on one panel, 100 per cent. availability to those mains can be obtained has already been described for the original pillar installed. The pillar network shown in Fig. 8 was initially installed to exploit this capacity and to obtain maximum access to pairs of the 800-pair cable shown, pending establishment of a proposed new exchange. The installation has attained this object very successfully, and at the same time has extended the use of the large type pillar to meet normal demands on distribution of an 800-pair cable, and has succeeded in meeting those demands up to the stage where the main cable is now 95 per cent. loaded without any cable rearrangement work having been necessary. A study of the multipling diagram shows that the 43 spare mains still available in the 800-pair cable to the exchange M.D.F. are distributed over the various panels in such a manner that further lines can be added in any part of the area served by the 800-pair cable until access very close to 100 per cent. would be attained. Such a layout gives remarkable flexibility, when high percentage occupancy of main cable pairs is reached, in handling pairs made spare by removals and disconnections, and allowing immediate use of such spares for new connections over an extremely wide area.

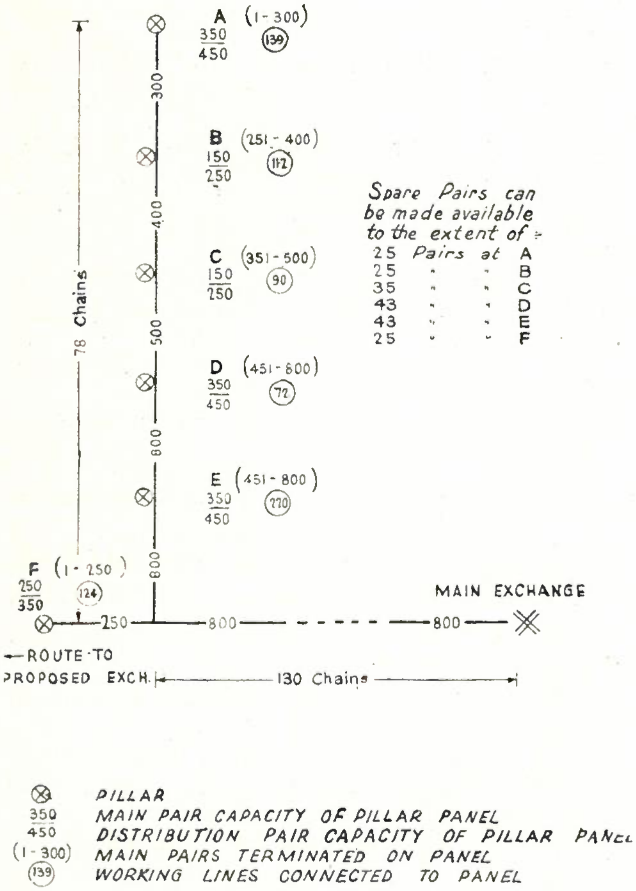


Fig. 8.

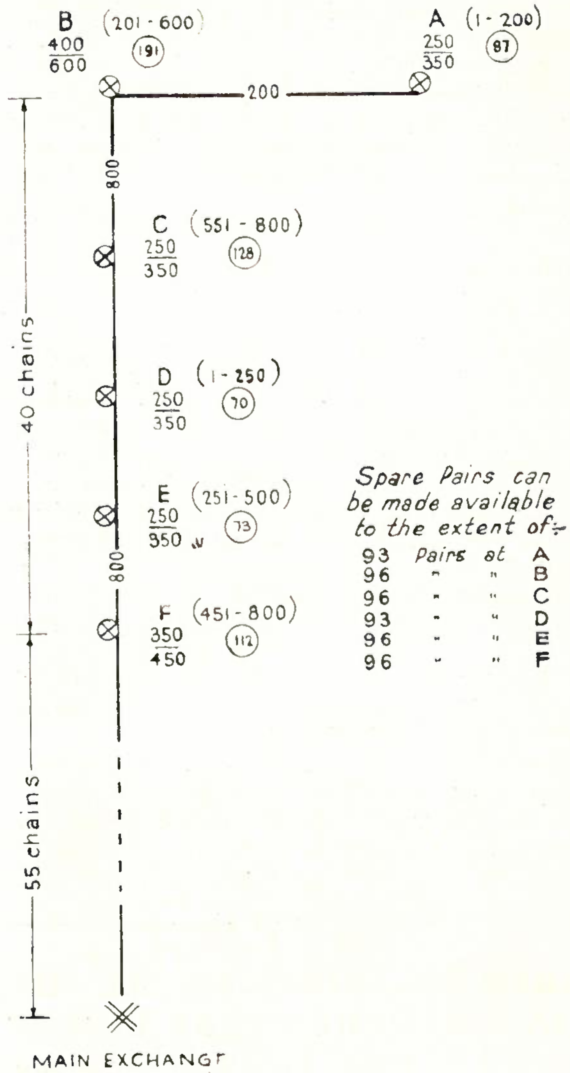


Fig. 9.

Fig. 9 shows the distribution of main pairs by means of large type pillars for an 800-pair cable 83 per cent. loaded. An examination of the multiple and the working lines at each pillar shows that at the present time we can obtain access to spare main pairs at any one pillar to the extent of:—

At Pillar A—93. At Pillar B—96. At Pillar C—96. At Pillar D—93. At Pillar E—96. At Pillar F—96, by jumper transpositions at the pillar panels only.

As was the case with the installation shown in Fig. 8, these pillars have been primarily used to obtain maximum access to main pairs of the 800-pair cable. There is in situ along the same route another main cable which serves an adjacent area and connects it to the same main exchange. In the near future this adjacent area will be diverted to a proposed new exchange, and the main cable thus thrown spare will serve to give relief to the heavily loaded cable. When such relief is given, the large type pillars can still effectively meet normal distribution requirements, with the advantages of a very high order of accessibility to main pairs, and of flexibility in the use of main pairs continually thrown spare by removals and disconnections, by virtue of the large group of mains concentrated on the panels. In both cases the multipling scheme pays due regard to the state of existing and forecasted telephone development in each pillar area. In both cases also the type of telephone areas served are similar. It can, therefore, be expected that the distribution in Fig. 9 will achieve similar availability to main pairs to that already obtained in the case shown in Fig. 8.

Fig. 10 shows an 800-pair cable distributed with a network of small type pillars and giving service to 625 lines. With the multipling arrangement adopted the present position is that over the network a minimum of 20 spares and a maximum of 41 spares are available to any one panel by jumper transposition only. As the area controlled by each pillar is small, the probability of development being accurately forecast is thereby reduced. The comparatively small number of spare mains available to each panel (due to the small capacity of the panel) will, it is thought, tend to bring about congestion at many points sooner than would be the case with the larger panels unless the forecast rate of development is followed with sufficient accuracy to avoid this. With such a large number of small areas, this is not considered likely to occur in all cases, and it is probable that several pillars will become so heavily loaded that additional main cable may be required to relieve the position, in some sections at least, soon after 80 per cent. load is reached.

Comparing Fig. 10 with Fig. 9, we find with the latter a cable 83 per cent. loaded, but with greater capability of meeting yet further development as well as of handling removals and disconnections with greater flexibility. At 83 per cent. load, the network of large pillars (Fig. 9) makes available a minimum of 93 spares and a maximum of 96 spares to any one panel. In addition to having greater access to spares at greater load, each large pillar has the added advantage that, as the area controlled is large, the probability of development being forecast with accuracy is increased, and the main pair provision is more likely to compare with actual development than will be the case for the smaller pillars.

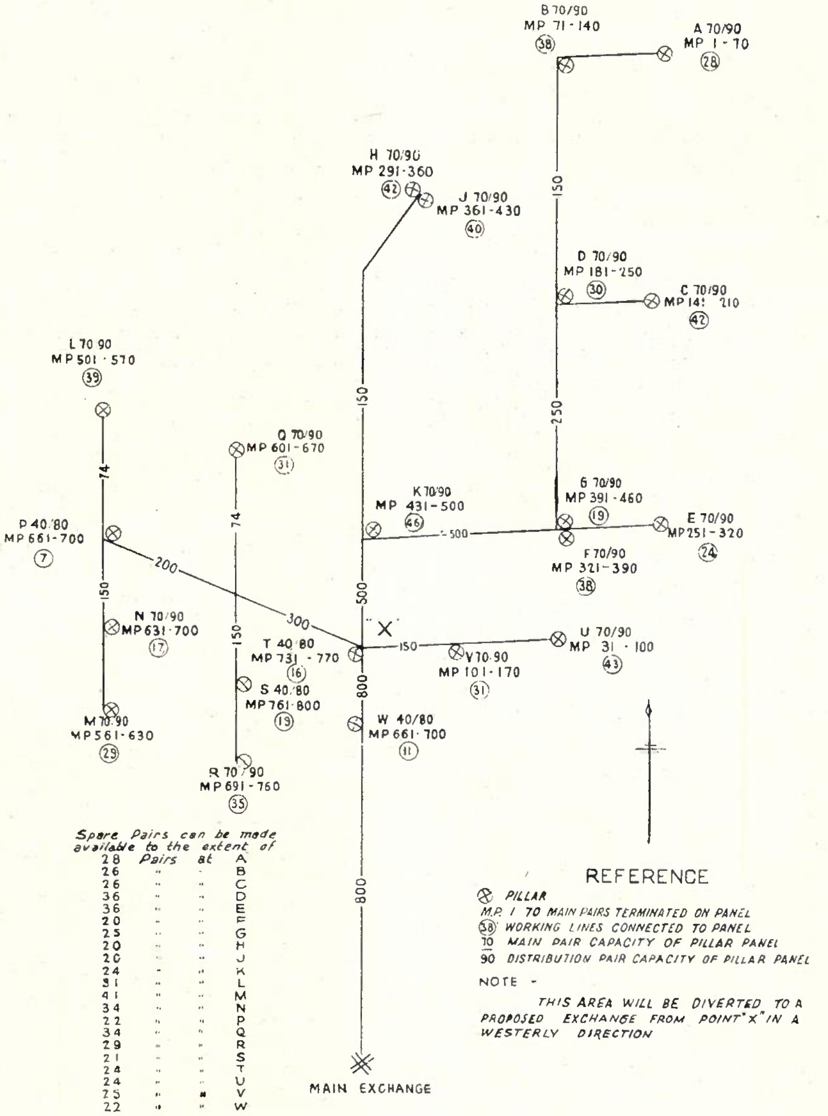


Fig. 10.

It might be noted that the distribution shown in Fig. 10 has, for the greater part, been effected by 160-pair panels attained by adding one strip to the standard 120-pair panel, thus allowing an increase in the main pair groups to 70. If 120-pair panels had been used throughout, the number of pillars required would have been greater, with a corresponding reduction in flexibility and access to spare mains.

It is very important to remember, when considering the question of cable distribution, that the success of a multipling scheme depends basically on the accuracy of development forecast plus the proper distribution by the engineer and the proper determination of each pillar area. The real problem the Lines Engineer then encounters is to determine a multipling scheme for a cable which is comparatively lightly loaded, say below 60 per cent. If such a cable is distributed in small pillars, successful handling of alterations and additions by jumper transpositions only at pillar panels is more limited than with large type pillars, unless the development rate in each pillar area closely follows that forecast, and this, it is thought, will not generally occur in practice. With the larger type pillars successful handling will be possible for a greater load due to the relatively large group of main pairs under control at one panel, and to the relatively larger area in which development is required to follow that forecast. There are cases, however, where a small pillar network is operating at a percentage load on the cable above 80 per cent. and will successfully continue to do so, provided the relative development in pillar areas continues as forecast.

From the typical examples of distribution given in Figs. 8, 9, and 10, the conclusions which may be drawn are:—

(a) That with the use of a network of large type pillars for main pair distribution of cable, availability of access to main pairs without resort to cable rearrangements approaches very close to 100 per cent., the larger the pillar capacities the closer we approach maximum availability.

One result of major importance which strikes the Lines Engineer handling cable design with a network of large type pillars is that immediate savings become apparent when deciding on the size of main cable required to meet forecast development. For example, if the development figure to be catered for is of the order of, say, 390 to 410, it would be economically sound to provide a 400-pair cable with a network of large pillars, whereas with a network of 120-pair pillars, a 500-pair cable should be laid to be reasonably sure that the development over the eight-year period can be met. Such saving becomes more apparent with larger cables which increase in size in steps of 200 pairs.

(b) That with the use of 120-pair pillars maximum availability is lower than is the case with larger type pillars.

Installation Costs for Large Type Pillars and 120-pair Pillars: The figures given include the costs of the pillar equipment, the assembly of the pillars, and the installation of the pillar, including identification, testing, and jointing of main and secondary cables in the pillar manhole, but do not take account of any other work such as identification, jointing, and maintenance associated with secondary cables, as such work has been regarded as common to any type of pillar network.

The equipment costs given are current prices. The labour costs given are based on average man-hours expended for actual installations, as different jointers, it will be accepted, will vary their speed of work.

Three large type pillar sizes have been chosen (400 pair, 600 pair, and 800 pair), as these sizes are considered to be most suitable for general use for distribution.

	800-Pair Pillar		600-Pair Pillar		400-Pair Pillar		120-Pair Pillar	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Panel, including tags mounted	1	£15	1	£13		£9/10/-	1	£2/7/-
Case and framework complete	1	£14	1	£13		£12/7/-	1	£1/3/-
Cable tails (8-yd. lengths)	8 yds. 1/250, 2/200, 1/150	£10	8 yds. 1/200, 2/150, 1/100	£8	1/250, 1/150	£5	8 yds. 1/54, 1/74	£2
Troughing, sand, stone, cement for base		£1/5/-		£1		15/-		8/-
Sundries		15/-		10/-		8/-		5/-
Manhours	300	£45	230	£35	160	£24	60	£9
Reinstatement		30/-		30/-		£1		£1
Cartage		5/-		5/-		5/-		2/6
TOTAL COST		£88		£72		£53		£16

Cable Terminal Pillars—Installation Costs.

In order that an area, satisfactorily controlled by, say, an 800-pair pillar with provision for 350 main pairs, can be similarly controlled by a network of 120-pair pillars, each with provision for 50 main pairs, the equivalent number of 120-pair pillars will, in general, be greater than the result obtained by dividing 350 by 50, owing to inevitable loss due to over-provision of pillar capacity in parts of the network. Examination of many areas served by 800-pair, 600-pair, and 400-pair pillars indicates that average equivalents will be of the following order:—

800-pair equiv. No. of 120-pair pillars—9.
600-pair equiv. No. of 120-pair pillars—7.
400-pair equiv. No. of 120-pair pillars—5.

The capital costs of the installations, therefore, show considerable savings in favour of the large type pillars.

Maintenance charges for equivalent networks of large type and 120-pair pillars will be common except for the following:—

(a) The large type pillar requires annual inspection to ensure that paint work is kept in good order to prevent rust on the outer portion of the case. The cost involved is a few shillings per year.

(b) Assuming that annual or other periodical maintenance work is carried out on pillar panels, such cost would probably be less for the large type pillar than for the 120-pair pillars, as more plant is concentrated at one point and less travelling time is involved with the former.

However, even if we assume that costs are equal in the case of (b) and that £1 per annum is incurred for (a), the savings on present value of annual charges (summarised below) are in favour of the large type pillar.

as the 120-pair pillars are obtained in large quantities for Commonwealth requirements. It is reasonable to expect that, if large pillars were applied generally to distribution, with corresponding increase in requirements, contract prices for mass production would considerably reduce costs, and thus effect greater capital savings;

(b) The joints for secondary cables of a large type pillar can often be accommodated in a jointing pit at points where an equivalent network of 120-pair pillars would require a manhole to accommodate the pillar joints and to permit of jointing work being carried out under proper working conditions. In this respect the large type pillar generally introduces further capital savings.

Other Comparative Points Between Large Type and 120-pair Pillars: Perhaps the most common problem of distribution facing the Lines Engineer is that of a main cable laid to meet forecast development during the succeeding eight years. An examination will be made of distribution by a network of:—

(a) large type pillars;
(b) 120-pair pillars.

As the secondary cables from the 120-pair pillars will be 20-year cables, and will be common to both methods of distribution, these can be ignored and the comparison confined to that portion of the reticulation which will be main cable serving the 120-pair pillar network.

It is assumed that it is usual, when determining the size of a new cable, to provide sufficient pairs to meet 20 years' requirements if such requirements necessitate a cable of 300 pairs or less. Careful examination of such cases can show that to lay a comparatively small eight-year cable

Large Size Pillar		Equivalent Network of 120-Pair Pillars	
800 pr. Capital Expenditure £88		9/120 pr. Capital Expenditure £144	
PVAC	£88	PVAC	£144
Maintenance AC £1			
PVAC	£20		
Total PV of Charges	£108	Total PV of Charges	£144
600 pr. Capital Expenditure £72		7/120 pr. Capital Expenditure £114	
PVAC	£72	PVAC	£114
Maintenance AC £1			
PVAC	£20		
Total PV of Charges	£92	Total PV of Charges	£114
400 pr. Capital Expenditure £53		5/120 pr. Capital Expenditure £80	
PVAC	£53	PVAC	£80
Maintenance AC £1			
PVAC	£20		
Total PV of Charges	£73	Total PV of Charges	£80

The costs given are unfavourable to the large pillar in two respects:—

(a) Current production of the panel and cases is on the basis of extremely small supplies, where-

initially, to be augmented by a second small cable at the end of eight years, is neither economical nor a very sound engineering proposition, as the number of pairs provided initially is so small that unless rate of development is very accurately forecast, relief will, in many cases, be required before the eight-year period has elapsed. Therefore, in the case of the large pillar network we can have with each pillar eight-year main cable, and on the secondary side part eight-year cable and part 20-year cable. This assumes at the moment that there is no particular limit to the capacity of the pillar panel. As previously indicated, access can be expected very close to 100 per cent. of main cable pairs without rearrangement being necessary, while on the secondary side about 75 per cent. access could be expected. In the case of the 120-pair pillars, access of a somewhat lower order will, it is thought, be generally achieved.

It may, therefore, be said that with large pillar distribution, relief on the main side is required later than with 120-pair pillar distribution, but relief for the eight-year portion of secondary cables is required earlier than with 120-pair pillars. This means, in other words, that if the main pair wire mileage gain is greater than the secondary pair wire mileage loss with a large type pillar network, this means of distribution is more economical than a network of small pillars, and the converse is also true.

Except in a few rare cases where very large pillars of 1,200 pairs and upwards have been installed to meet exceptional circumstances, the great majority of large pillars installed are of 400 pair to 1,000 pair capacity, and have secondary cables of sufficient size to meet the 20-year requirements, and such installations should therefore be more economical than 120-pair pillar networks, both on the basis of the argument just set forward and because their capital costs and annual charges are less.

It will be of interest to note that in one exceptional case where a pillar of 1,600-pair capacity was urgently installed to conserve main pairs serving a very large area, the secondary cables were not of sufficient sizes to meet the forecast 20-year development, and would not, therefore, permit of a layout of secondary pairs to meet all telephone possibilities. To overcome the undesirable multipling of distribution pairs, use was made of 120-pair pillars as subsidiary means of distribution for the large pillar, thus increasing the availability between the point of installation of the 120-pair pillars and the secondary side of the panel of the large pillar. Each such small pillar has its individual pillar card and pillar diagram, the only difference to the usual practice being that main pair numbers are prefixed by 0 and secondary pairs by 00, since the main pairs to such pillars are actually corresponding secondary pairs from the large pillar. On the pillar card for the large pillar the groups of secondary pairs terminating at the 120-pair pillar are indicated as such. This installation has been operating satisfactorily for some months, and while not coming within the category of normal distribution conditions, at the same time clearly points to the practical possibilities of the large terminal to control a large group of main pairs. An installation of this kind, it is thought, would usually require a pillar of very large size (2,000-pair capacity upwards), and would be best suited and probably confined to the case mentioned or to one where two or more large size cables start to distribute at the same point. The basis of installation would be purely one of economic comparison between capital costs and annual charges for:—

(a) expenditure incurred for the large pillar installation;
(b) expenditure saved by the wire mileage gain between the exchange and the large pillar,

each considered over the period the wire mileage gain would meet forecast telephone development for the area served by the main cables in question.

In regard to the preparation of cable diagrams and pillar cards for large type pillars it has been suggested that the layout of such plans and the preparation of the record cards are of greater complexity than for 120 pillars, the general reason given being that more secondary pairs have to be dealt with and a larger area considered, thus tending to introduce error. In reply to such objection, it can only be said that every engineer who has installed the large type pillars has encountered no difficulty with estimating foremen assisting him in preparing the plans, or with the manipulative staff carrying out the installation and preparing the records, or with the cable recorder and statistical officer who maintain records subsequent to installation, and no such objection has been apparent to these engineering officers to date. It might be further emphasised that in the areas where large type pillars have been installed in Sydney the estimating foremen who assist in the design, the jointers who install the terminals, and the officers who maintain the records are the same staff who carry out these duties in relation to 120-pair pillars installed in such areas; in other words, it has been the experience during the past eight years that lines officers who are capable of handling 120-pair pillar installations are also equally capable of handling large type pillar installations.

The design of the panel of the large type pillar also appears to have considerable advantage over the present 120-pair pillar panel. The greater space provided, and the presence of jumper rings, aid towards more orderly jumpering and standardisation of method of jumpering, and thereby should increase the life of jumpers. This would particularly apply when additions and alterations are made, because with the jumper rings there is less, if any, chance of jumpering being disturbed and damaged.

Sizes of Large Type Pillars for Use in Cable Distribution: From the arguments set forward so far, the only limitation to the size of panels for a large pillar network is that the gain in main pair availability must equal or be greater than the loss in secondary pair availability as compared with a network of 120-pair pillars. For normal distribution in practice, however, it is desirable that secondary cable for any type of pillar should be capable of meeting the forecast 20-year telephone development to permit of distribution of pairs to meet all telephone possibilities over this period. Where such conditions apply, the large type pillar should prove to be a better economic proposition for distribution of cable pairs than 120-pair pillars.

The largest cable usually laid initially to meet 20-year requirements is 300 pair, and would, therefore, be the largest cable which could normally be expected to be available as suitable secondary cable for a large type pillar. For a first-class residential or flat area (the installation of large type pillars have been confined to this class of area to date) the general ratio of main to distribution pair terminal provision adopted is of the order of 1 : 1.4. With an 800-pair terminal, therefore, installed to meet 20-year requirements, there would be provision for 450 to 475 secondary cable pairs. Of the large type pillars installed to date:—

2 are 1,800-pair capacity,
3 are 1,600-pair capacity,
1 is 1,400-pair capacity,
2 are 1,200-pair capacity,
8 are 1,000-pair capacity,
20 are 800-pair capacity,
18 are 600-pair capacity,
5 are 400-pair capacity.

Pillars of 800-pair capacity and smaller predominate, as these have found a natural location determined by the meeting point of several cables of 300-pair capacity downwards, which are capable of meeting 20-year development forecast. With the 800-pair terminal suggested as a maximum for general use, the 450 to 475 secondary pairs have from experience been found to be capable generally of meeting any combination of 20-year cables which will normally require to be controlled. Special cases have arisen, and will arise, where cables considerably larger than 300 pair, available and suitably located for use as pillar secondary cables, may call for pillars of larger capacity than 800 pair. From experience, while such cases will generally justify the use of the large type pillar, they will be found to be comparatively rare, and might better be regarded as ones for special consideration and outside the ambit of normal distribution. Four hundred pair is probably the best minimum, as areas requiring smaller panel capacity could better be treated with 120-pair pillars. It might be noted that panel sizes suggested change in steps of 200. This was decided upon from experience of manufacturing process, which shows that the saving effected by reducing the number of sizes is greater than the small value of material which might be saved if intermediate sizes were introduced. In practice it is found, for example, that a manufacturer will prefer to construct the same case and framework whether a 700-pair or an 800-pair pillar is ordered.

Suitability of Large Type Pillar for Normal Cable Distribution: The desirability of introducing the large type pillar as a standard part of cable reticulation has not yet been accepted. Some arguments put forward against their use and replies to such arguments are given in the following:—

(a) Complexity of the work, due to the size of area controlled, may require special staff to avoid errors in recording, and construction. This has been dealt with previously where it was pointed out that the staff, who deal with the various aspects of large pillar installations, are the staff who have dealt with, and still deal with, 120-pair installations. In any case if the large type pillar is justified on the grounds of efficiency and economy, the best procedure would seem to be to train staff to meet the special requirements, assuming there is actually any difficulty in this regard.

(b) The 120-pair pillar network has met practical requirements well, and the introduction of various pillars of larger size appears unnecessary. In this regard the large type pillar is in the opinion of the author more economical, and where the reticulation calls for such installation it should meet practical requirements better than the 120-pair pillar.

It must be remembered that, after all, the history of the 120-pair pillar shows that its size is largely empirical, and has no particular relation to sizes of secondary cables found in the field to be suitable for control. Often we find two or more 120-pair pillars installed at the one street intersection (some may be at different corners). This situation is actually brought about by the fixed size of the pillar deciding the design, whereas the deciding factor should be the number of secondary cable pairs requiring control. One large type pillar of suitable size in such a case would be cheaper and more effective.

(c) The large type pillars on account of their size are obstructions, and because of their frequent location near the kerb line are subject to damage which may cause interruption to a large number of working lines. Sixty pillars have been installed in Sydney since 1936, 37 of which are erected close to the kerb. No complaints either from councils or members of the public have been made in the six municipalities concerned, and willing assistance and co-operation has been received from Municipal Engineers in selecting suitable locations for the pillars. No damage has occurred since the first pillar was installed in 1936, and any likelihood of such must therefore be regarded as sufficiently remote to not be a valid argument. The robust nature of the pillar will in any case render total destruction highly improbable.

(d) A large mass of jumpers are difficult to control and may give rise to trouble due to jumpers tangling and deteriorating on account of handling when additions and alterations are made. Fig. 4 has shown a large type panel with jumpers run. It is asserted from experience with 120-pair panels that the present design of the large type panels permits of greater freedom and facility for additions and alterations. The jumpers are retained in position with the rings, and actually it has been found in practice that it is with the 120-pair panel, where there are no means of retaining jumpers in position, that tangling and deterioration of jumpering occurs, and that the large type panel is superior in this regard.

(e) Greater possibility of loss in insulation due to condensation or entrance of moisture. The rubber door gasket and the locking device which exerts door pressure on the gasket has proved to be effective in rendering the pillar entirely air-tight. These installations have been closely watched over the past eight years, and no low insulation faults have occurred.

(f) Portion of the secondary cables of large type pillars are of comparatively large size, and if an isolated pair becomes faulty in such a large secondary cable it is necessary to open cable joints to rectify the fault or to transpose the working service. If 120-pair pillars were installed the pairs of such cables would be terminated on pillar panels and transposing could be effected by jumpering only. This argument is valid so far as it goes, but when we consider that such faults are comparatively rare and can, it is thought, be attributed largely to faulty jointing which is being eliminated in recent years by modern methods for training staff and by improved supervision, the objection might perhaps be regarded as a minor one when compared with the advantages derived from the use of large type pillars in regard to distribution of main pairs and to economy.

The Effect of Type of Area on Pillar Terminals: A large metropolitan area may be divided into four general types from the point of view of telephone survey and telephone cable reticulation:—

Type 1—First-class residential or flat areas.

Type 2—Shop areas.

Type 3—Second-class residential and flat areas.

Type 4—Third-class areas.

With Type 1, the estimated 20-year development may be based on the expectation of one telephone per residential building block, or for flats, one telephone per flat, with an additional margin of up to perhaps 10 per cent. for extensions, private lines, etc., and in such areas the main pair provision on pillar panels would equal the secondary pair provision but for the following factors:—

(a) Deaths, changes of residence, departure of people for various personal reasons, reduce the necessary main pair provision by something of the order of 7 per cent.

(b) The inevitable over-provision of pairs on the distribution side on account of the available sizes of cable.

(c) Survey inaccuracies, to provide against which a margin of the order of 20 per cent. to 25 per cent. is probably made.

These three factors suggest that the ratio of main pair to secondary pair terminal provision should not be less than 1 : 1.3.

The Type 1 area, which may be regarded as an area of heavy telephone density, is one in which a telephone, when once connected, can be regarded as always being required. In other words, if such a service becomes disconnected it will become reconnected within a reasonable period. The Type 1 area is, therefore, a stable one which permits of the layout of pairs of secondary cables with considerable certainty, and in which fluctuations in forecast development are unlikely to occur, and for these reasons is very suitable for the installation of the large type terminals. In fact, where secondary cables call for large type terminals in a Type 1 area, their installation should produce a superior design to that obtained by a network of 120-pair terminals.

With the Type 2 area, the 20-year development, generally speaking, may be regarded as being based on one line per shop with a margin up to a maximum of about 25 per cent. for extensions. In this type of area it would probably be customary to provide two cable pairs per shop for possible extensions, as even a shop with a residence attached is often let on the "lock-up" basis. Assuming that each extension requires a main pair, the ratio of main pair to secondary pair terminal provision in the Type 2 area would vary from 1 : 2 to 1.25 : 2, and for safe standardisation the ratio should be 1 : 2. The Type 2 area can also be regarded as a stable one of heavy telephone density, and where the shopping areas are large enough, control by large type pillars should be a better proposition than 120-pair pillars.

With the Type 3 area, the 20-year development may generally be based on one telephone for about three building blocks, with a small additional margin for extensions. In such areas the total value of land and residence would probably be in the vicinity of £1,000 to £1,500, and any house in a street is a potential service, and removals would be very common. In order to avoid multipling, or alterations to the initial layout of secondary cables, the tendency would probably be to make the size of the secondary cable as generous as possible. Each such case, of course, has to be considered on its merits, and if experience indicated telephonic stability there would be no call to provide a comparatively large secondary cable. It is more likely, however, that the large size cable is generally laid in such areas, and the ratio of main pair to distribution pair terminal provision should be, say, 1 : 2 to cater for this. As it is obviously desirable that such cable provision be confined to the smaller cables, with a maximum of, say, 74 pair, the Type 3 area offers the best field for the use of 120-pair pillars. In fact, in such areas, the large type pillar should rarely prove economical unless exceptional conditions exist, such as the vital necessity to conserve main pairs over a considerable distance irrespective of secondary cable sizes, or the existence of large oversize secondary cables which it is uneconomical to recover and replace with smaller cables.

With the Type 4 area, the 20-year development would probably be based on approximately one line for seven building blocks. In such an area with, say, 40ft. frontages, there would be six possible services in a street block of approximately 300 yards, and it would be difficult to find such an area where underground distribution could be economically justified, and aerial distribution would generally be used. A cable serving the aerial heads in such localities would probably require about a 25 per cent. margin over and above the survey development. In effect, the aerial heads in this case are small distributing pillars, but on account of their small size, availability to main cable pairs is reduced. The only suitable means of improving availability in the Type 4 area will be by means of the larger type terminals. The deciding factor for such an installation will be a balance between its cost and the saving it effects in increased availability to main cable pairs.

Conclusion: This article is based on experience of pillar networks for distributing cable pairs both by large type pillars and 120-pair pillars. It has endeavoured to show that the large type pillar is thoroughly efficient in design, has proved its reliability, and is highly effective and economical for use in normal cable distribution, and that no valid objection can be raised to its use for this purpose where reticulation is such that 20-year cables can be more effectively and economically controlled by one pillar rather than by a network of pillars of small predetermined size.

Some general idea of the magnitude of the saving which could be expected to be effected by the general use of large type pillars is obtained from the following:—

(a) Approximate total pair mileage of main cables Sydney Exchanges, assuming that the average pair mileage is 0.5 miles per main pair (excluding City North, City South and East)—125,000.

(b) Approximate pair mileage in areas where large type pillars are suitable—90,000.

(c) Saving in main pair mileage by use of large type pillars, assuming 15 per cent. greater availability is obtained by their use—£40,500.

As main cables usually cater for periods up to eight years, this represents an annual saving on main cable plant of at least £5,000, which represents a capitalised saving of £100,000. This saving would be subject to reduction to the extent of the increase in expenditure necessary on large type pillar secondary cables, to permit of them having the same flexibility as cables controlled by a network of small pillars, but even with such reduction the saving will, it is considered, still be very considerable.

THE DESIGN AND CONSTRUCTION OF UNDERGROUND CONDUITS FOR TELEPHONE CABLES

A. N. Hoggart, B.Sc.

PART II.—CLASSES OF CONDUITS

Materials: A number of materials are suitable for use as conduits, the chief requirements being mechanical strength and stability, long life under varying conditions, no deleterious effect on the lead cable sheath, and suitability for manufacture into the desired form. The materials commonly used in Australia are:

Glazed earthenware, reinforced concrete, iron. Fibro-cement has also been used to a limited extent for special applications in this country, and in recent years has found favour with some overseas administrations. A form of fibre conduit is also in use in the U.S.A.

The non-metallic conduits have most general application, having the advantage of being virtually not affected by corrosion, and, therefore, everlasting. Iron conduits now used in the form of wrought iron (gas) pipe, are restricted to special applications as detailed later, where special mechanical strength is required, except for small sizes of iron pipe (up to 2-inch internal diameter), which are used and laid shallow in footways for small cables, particularly for subscribers' distribution. Cast iron pipe was used to some extent in the past, but this form of construction has now been discontinued.

General Requirements of Conduits: The specification requirements of conduits must take into account the function of the conduits and conditions of use. Bearing in mind that conduits, when assembled together, are required to form pipes or ducts into which lead-covered cable may be drawn, it is apparent that:

(a) The interior surface of the duct should be smooth and free from excrescences.

(b) The bore of the duct should be uniform and straight. (In practice a slight curvature in one direction only is permitted, the curvature not to exceed a dip of 3-16in. in a length of 2ft.)

(c) The inside edges of the ends of the duct should be rounded off.

(d) The finished conduit should be free from soluble acids and alkalis.

The above requirements are necessary to protect the cable against injury during and after the drawing-in process.

The material of the conduits is subject to tests regarding quality; e.g., a water absorption test, whilst the completed conduits are required to pass tests in regard to mechanical strength, the usual being:

(a) **Hydraulic Pressure.** In which the conduit is subjected to an internal hydraulic pressure equal to a head of 30ft. of water, and should not show signs of injury or leakage. Iron pipes are required to withstand a pressure of 500lb. per square inch.

(b) **Crushing Test.** In which the conduit is subjected to a crushing load applied by bearers placed along its full strength.

Earthenware conduits are required to withstand a load of 900lb. per lineal foot, and reinforced concrete conduits a load of 850lb. per lineal foot without showing any clearly visible cracks. The ultimate failure is to be not less than 1300lb. per lineal foot.

Earthenware Conduits: Earthenware conduits are made from finely ground clay free from pebbles and stones. After moulding into shape the conduits are thoroughly baked in a kiln and at the same time are glazed by the action of salt fumes. Conduits manufactured in this way are virtually everlasting, are of adequate mechanical strength for all ordinary requirements and can be readily produced in both single and multiple duct forms. The glazed surface of these

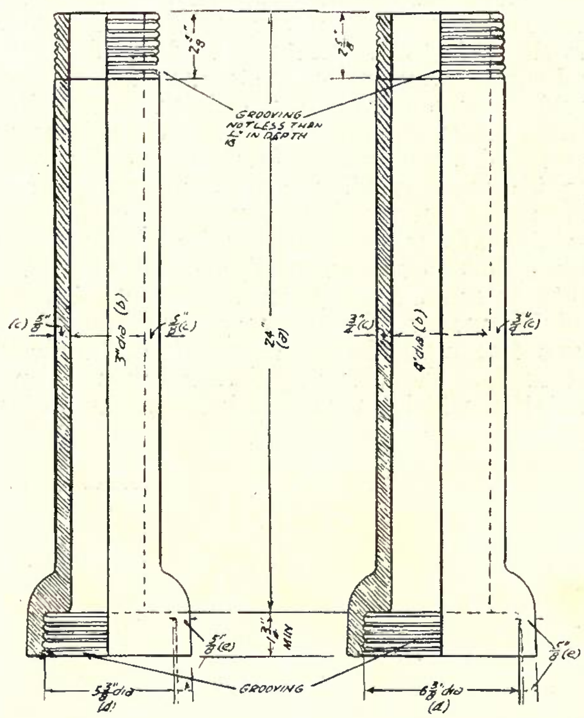


Fig. 5.—Earthenware Pipe, 3" and 4".

conduits presents a low coefficient of friction to cable being drawn in, and for this reason longer cable lengths can be readily drawn into earthenware conduits than in the case of most other types. Earthenware conduits, however, are only available in short lengths (usually 24 to 30 inches). The greater frequency of joints compared with other types tends to increase laying costs, and, as the joints are the weakest points in a conduit run, risk of damage due to subsidence, etc., is increased. Earthenware conduits are also subject to distortion during the manufacturing process; slight curvature is permitted as indicated above, as generally no inconvenience is caused thereby if careful attention is given to the laying process.

Single Earthenware (Drain) Pipes: The ordinary earthenware drain pipe has found considerable application in conduits where the use of single pipes is satisfactory, although in recent years they have been superseded by earthenware or concrete self aligning pipes. Untested earthenware pipes are still used for outlet drains from manholes where a high quality pipe is not necessary and the normal laying technique can be modified.

Fig. 5 illustrates the two sizes, 3 inch and 4 inch, of earthenware pipes which have been commonly used for conduits. In addition to straight pipes, bends and junctions are available for special applications. Details of these are as follow:—

1. Bend 15 degrees 12 inches Long
2. Bend 30 degrees 12 inches Long
3. Bend 45 degrees 24 inches Long
4. Bend 60 degrees 24 inches Long
5. Bend 90 degrees 24 inches Long
6. Single square junction 24 inches Long
7. Double square junction 24 inches Long
8. Single oblique junction 45 degrees Right Hand (Branch inclined towards main socket) 24 inches Long.
9. Single oblique junction 45 degrees Left Hand (Branch inclined away from main socket) 24 inches Long.
10. Double oblique junction 45 degrees Right Hand (Branch inclined towards main socket) 24 inches Long.
11. Double oblique junction Left Hand (Branch inclined away from main socket) 24 inches Long.

Any of the above (including straight pipes) can be obtained in the form of split pipes, i.e., split or capable of being split into two halves along the longitudinal axis.

Earthenware Butt Jointed, Square, Conduits: These conduits were for many years the standard multi-duct conduits used in Australia; they are, however, difficult and costly to lay, and have been superseded for general use by the self-aligning type. As indicated in Fig. 6, these conduits are square in form, and have been made in 2-way, 3-way, 4-way and 6-way types. Square conduits require a concrete foundation, except where they are to be laid on rock. The joints are formed by means of a layer of cement mortar round the junction of the conduits which are butted together, a wrapping of calico being used to prevent ingress of mortar into the ducts. To ensure that when laid, adjacent conduits are properly aligned together, it is necessary to make used of mandrels. This method of laying is necessarily very expensive and for this reason the self-aligning type is now generally preferred. The square conduit occupies less space than other types, and on this account its use is occasionally justified in particular when existing conduits of this type are being added to in a congested footpath. Conduits of this type are extensively used in the U.S.A. and appear to be the standard practice there for multi-duct runs. The American type of conduit is, however, provided with several longitudinal holes in the walls of the conduit; these are used in conjunction with dowel pins to assist in aligning the ducts.

Earthenware Self-Aligning Conduits: Earthenware self-aligning conduits were introduced in Australia approximately ten years ago, and have been the standard type used by the British Post Office for a number of years. These conduits are available in both single and multi-duct types, viz., one-way, four-way and six-way. Designs for two and three-way have been prepared but it is usually found more economical to use two or three single pipes rather than multi-way conduits where two or three-ways only are required. Fig. 7 gives details of the single, four and six-way types. Fig. 7 shows the bore of the multi-way ducts as 3½in. which is the present standard dimension; 3¼in. and 4in. diameter ducts are, however, sometimes supplied by contractors who are equipped to make these sizes only. 3½in. diameter ducts are considered to be of adequate size for all types and sizes of cable now in use; conduits with 4in. diameter bores are, therefore, unnecessarily large and heavy. 3¼in. diameter conduits are suitable for most purposes but it is considered that these do not provide a sufficient margin over the largest sized cable, particularly for long lengths,

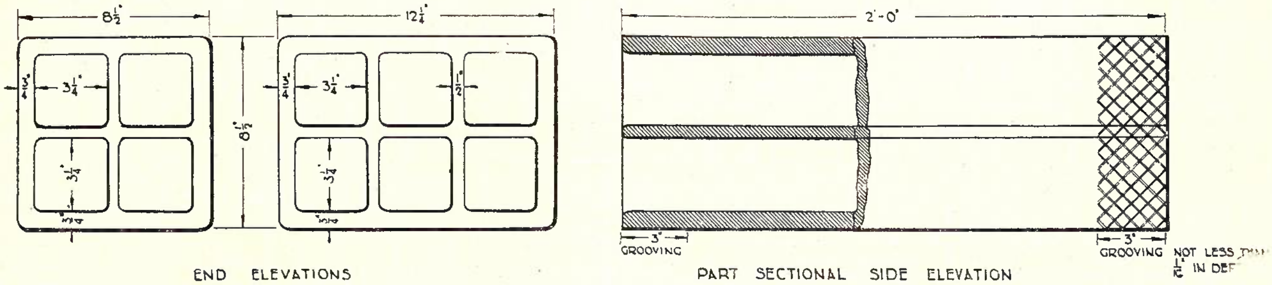


Fig. 6.—Conduit, Earthenware, Square, Butt Jointed.

between manholes.

The normal effective lengths are:—

Single way—24 inches

4 and 6 way—30 inches

Four and six way are, however, frequently supplied in 24in. lengths.

The self-aligning conduits are of the spigot and socket type but a strip of bituminous compound is moulded on the inside of the socket and the outside of the spigot. The compound consists of fine sand or stone dust 58 per cent., sulphur 20 per cent. and coal tar pitch 22 per

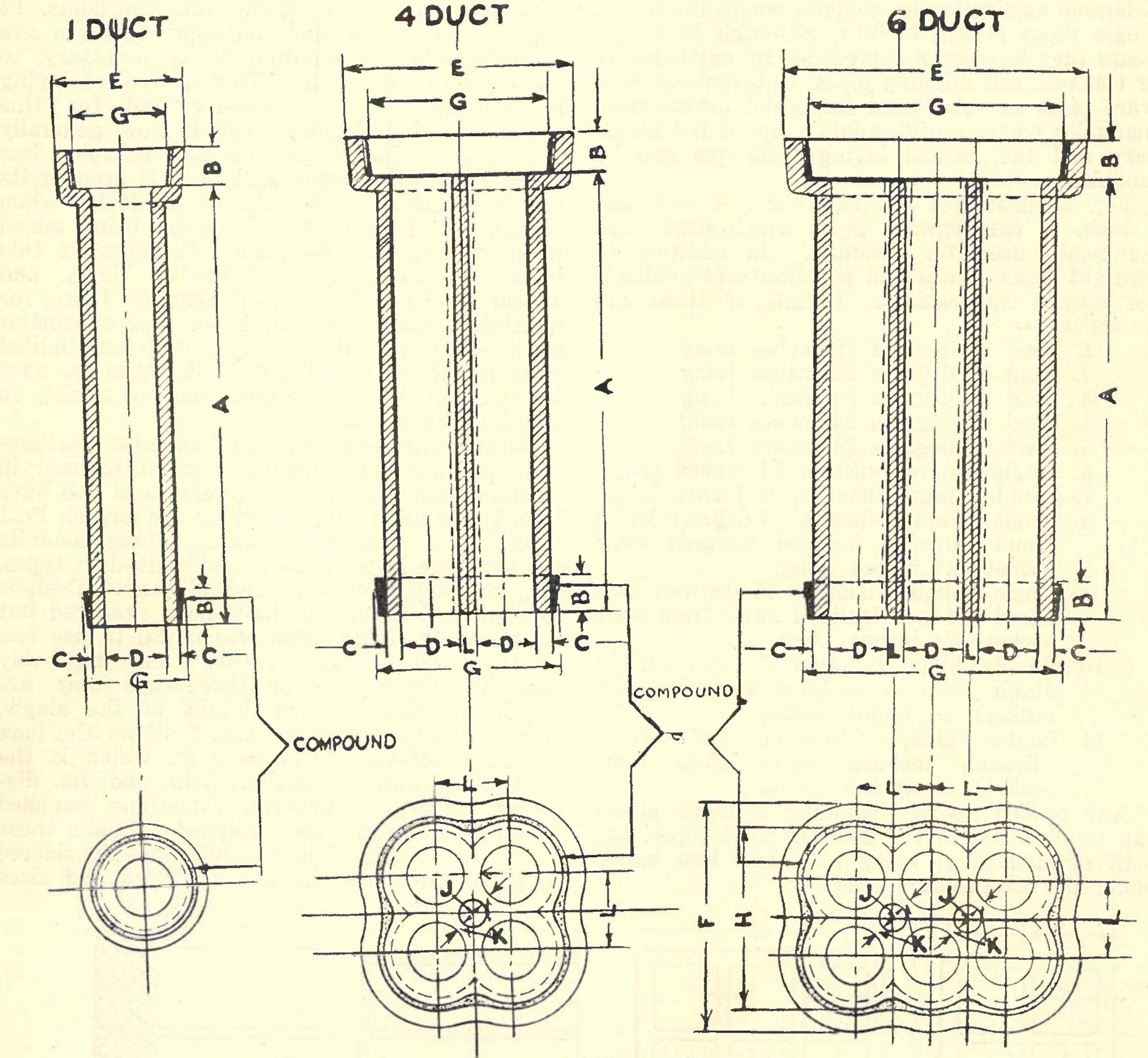


Fig. 7.—Conduit Earthenware Self-Aligning.

TABLE OF DIMENSIONS (NORMAL DIMENSIONS ONLY)

DIMENSION	1 DUCT	4 DUCT	6 DUCT
A Effective length	24″	30″	30″
B Depth of socket	1¾″	2″	2″
C Thickness outside wall	⅝″	¾″	¾″
D Internal diameter	3½″	3½″	3½″
E External dimension of flange (major)	7″	12½″	16⅝″
F External dimension of flange (minor)	—	—	12½″
G External dimension of compound (major)	5 7/16″	10¼″	14⅝″
H External dimension of compound (minor)	—	—	10¼″
J Diameter of centre hole	—	1⅜″	1⅜″
K Thickness between duct and centre hole	—	9/16″	9/16″
L Distance between centres adjacent ducts	—	4¼″	4¼″

cent., melted together to form a homogeneous mass. Both strips are given a slight and corresponding taper so arranged that when the spigot of one conduit is inserted in the socket of another, the strips are in close contact throughout and the ducts are directly in alignment. The only additional material required for laying is a special jointing compound which is applied hot to the spigot and socket just prior to making the joint. This sets hard and provides a satisfactory joint.

The use of self-aligning conduits simplifies laying procedure, obviates the necessity for concrete foundation (except in unfavourable soils) and they are, therefore, generally more economical than the square butt jointed type. They do, however, occupy slightly more space which is, of course, of little consequence, except where congestion of services restricts the space available for conduits. The self-aligning feature is important as it ensures that ducts are directly in alignment, thereby providing best conditions for drawing in of the cable. The rubber ring joint which will be referred to later in connection with concrete conduits has recently been extended to single way earthenware conduits, in the case of supplies from one manufacturer in New South Wales.

Concrete Conduits: Concrete conduits are usually in the form of single pipes, 6 ft. long by 4 in. internal diameter. Some use has been made of multi-duct concrete conduits but concrete does not appear so suitable as earthenware for these. The most suitable method of providing a number of ways with concrete is to use the appropriate number of single pipes nested together. Owing to the size of the pipes and the extra space taken up by the collars of the pipes, the overall dimensions of the nest of pipes is larger than for earthenware multi-duct conduits and, consequently, this form of construction may become uneconomical with a large number of ways. An alteration to the design and jointing methods of concrete pipes enabling the pipes to nest closer together could possibly overcome this disadvantage.

A particular advantage of the concrete pipe conduits is that they are available in lengths of 6 ft., thereby reducing the number of joints and accelerating laying. This also improves the stability of the route particularly against isolated subsidence or washouts.

Concrete pipes are now provided with the rubber ring joint, which is probably the most efficient method yet evolved for jointing conduits. This joint is rapidly made, is air and water tight and at the same time flexible. It also ensures that the conduits are self-aligning. Although rubber, when exposed to the weather, deteriorates after a short space of time, no such deterioration takes place when the rubber is kept in a state of compression and protected from light and air. Instances have been recorded of rubber joints on underground pipes remaining in good condition after periods of 40 or more years, hence no question of their suitability for conduits on this account need arise. Prior to the introduction of the rubber ring joint, concrete conduits made use of the self-aligning compound joint as used for earthenware conduits.

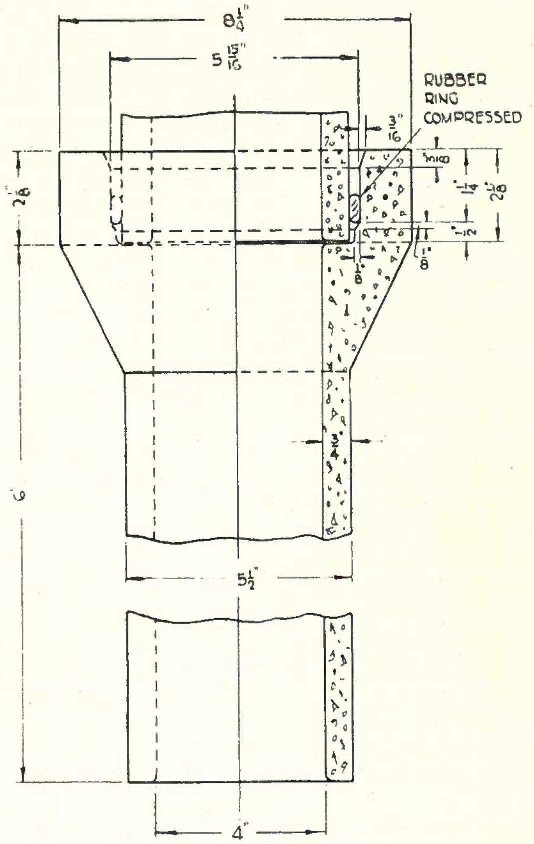


Fig. 8.—Reinforced Concrete Pipe, Rubber Ring Joint.

Fig. 8 illustrates a concrete conduit and rubber ring joint. The reinforcing consists of No. 14 S.W.G. steel reinforcing wound in the form of a helix giving six turns per foot of conduit, together with six straights of No. 12 S.W.G. steel wire evenly spaced round the cross-section of the conduit; the turns of the helix and the straights being electrically spot welded together at each point of contact. (See Fig. 9.) Short

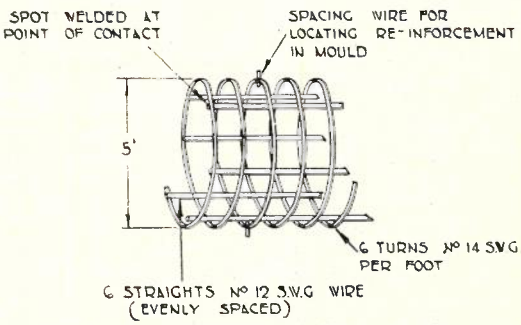


Fig. 9.—Reinforcement of Concrete Pipe.

radial pieces of reinforcing wire are welded on to the reinforcement at several points to correctly position the reinforcement in the mould and thereby ensure that there is a minimum cover of ¼ in. of concrete over the reinforcement. (If the wire is too close to the surface, corrosion of the steel may take place, with consequent failure of the pipe.)

The pipes are generally manufactured by the centrifugal process. The reinforcement is placed in a mould which is rapidly rotated. The concrete is served into the mould, and is forced outward against the wall of the mould by centrifugal force. The interior of the pipe is formed by passing a mandrel through the mould to remove any excess concrete. When the concrete has set sufficiently, the pipe is removed from the mould, for curing and final check over when the edges are rounded off by grinding and the socket is cleaned out and ground to correct size. The pipes comply generally with the requirements of Australian Standard Specification A35 for Class "X" Extra Strength Reinforced Concrete Pipes.

Iron Pipes: Wrought iron pipes are used in the form of galvanised or black iron (gas pipe) principally for small cables and as such, in conjunction with small precast jointing pits, constitute the conduit system for subscribers' underground cable distribution which has now largely replaced aerial distribution.

Ordinary commercial type of pipe is used but it is required to be of uniform quality, circular in cross section of smooth clean bore and free from all defects. Such pipes are obtained in random trade lengths, 18 to 20 feet, each length being screwed each end, one being fitted with a screwed coupling. Various standard fittings such as reducing sockets, bends can be used as required for special purposes. Fig. 10 gives particulars of sizes of iron pipe used for conduit purposes.

Galvanized pipe is more expensive than black iron, but on the other hand it does not corrode so easily, and provides a greater protection against electrolytic corrosion of the lead sheath. This protection appears to be exerted in both "cathodic" as well as "anodic" areas. It would, therefore, appear advantageous to use only galvanized iron pipe, but having regard to the cost aspect, use is made of black iron pipe where experience has shown that corrosion is relatively slight. Generally speaking, it is desirable to use galvanized pipe only in the cases of ⅜ in. and ½ in. sizes, while for pipes larger than 1½ in. black iron pipe will usually be satisfactory, the extra cost of galvanized pipe increasing appreciably with the diameter of the pipe.

Nominal Bore	External Diameter	Thickness		Weight per Foot
Inches	Inches	I.W. Gauge	Inches	lb.
⅜	11/16	13	.092	.582
½	27/32	12	.104	.818
¾	1-1/16	11	.116	1.165
1	1-11/32	10	.128	1.653
1¼	1-11/16	9	.144	2.367
1½	1-29/32	8	.160	2.973
2	2-3/8	8	.160	3.786
2½	3	7	.176	5.338
3	3-1/2	7	.176	6.309
4	4-1/2	7	.176	8.253

Fig. 10.—Dimensions of Iron Pipes.

The larger diameters of iron pipe are more costly than 4 in. earthenware or concrete pipe even when allowance has been made for the lower laying costs of the former. Under average conditions the laid cost of iron pipe under 2½ in. internal diameter is lower than the corresponding cost of earthenware or concrete pipe. On the other hand, for sizes larger than 2½ in., the installed cost of iron pipe is greater. Therefore, the use of iron pipe in sizes larger than 2 in. is normally restricted to those cases in which it is required specially for mechanical or electrolytic protection of the cable or the conditions are such that earthenware or concrete pipes are unsuitable, such as:—

(a) In crossing bridges culverts, etc.

Nominal Bore of Pipe	MAXIMUM SIZE OF CABLE											
	Black Iron Pipe						Galvanised Iron Pipe					
	Diam. of Cable	6½ lb. Q.L.	10 lb. Twin	10 lb. Q.L.	20 lb. Q.T. or Q.L.	40 lb. Q.T. or Q.L.	Diam. of Cable	6½ lb. Q.L.	10 lb. Twin	10 lb. Q.L.	20 lb. Q.T.	40 lb. Q.T.
⅜"	—	—	—	—	—	—	.30"	—	2 pr.	—	—	—
½"	.38"	—	7 pr.	—	—	—	.44"	—	10 pr.	—	—	—
¾"	.55"	—	15 pr.	28 pr.	—	—	.62"	—	25 pr.	38 pr.	14 pr.	8 pr.
1"	.72"	—	35 pr.	54 pr.	28 pr.	14 pr.	.82"	—	50 pr.	74 pr.	38 pr.	14 pr.
1-1/4"	.95"	150 pr.	75 pr.	100 pr.	54 pr.	24 pr.	1.00"	150 pr.	75 pr.	100 pr.	60 pr.	28 pr.
1-1/2"	1.19"	250 pr.	150 pr.	150 pr.	74 pr.	38 pr.	1.29"	300 pr.	150 pr.	200 pr.	104 pr.	54 pr.
2"	1.51"	400 pr.	200 pr.	300 pr.	150 pr.	74 pr.	1.63"	500 pr.	250 pr.	300 pr.	160 pr.	74 pr.
2-1/2"	1.91"	600 pr.	300 pr.	500 pr.	228 pr.	122 pr.	2.03"	800 pr.	400 pr.	500 pr.	254 pr.	122 pr.
3"	2.42"	1000 pr.	600 pr.	800 pr.	400 pr.	182 pr.	2.48"	1200 pr.	600 pr.	800 pr.	400 pr.	216 pr.
3-1/2"	2.75"	1400 pr.	800 pr.	1100 pr.	542 pr.	254 pr.	2.85"	1400 pr.	800 pr.	1100 pr.	542 pr.	254 pr.

Fig. 11.—Maximum Size of Cable for Black Iron and Galvanized Iron Pipe.

(b) In hard ground across open channels.
(c) In positions where sufficient cover for other classes of ducts is unobtainable.
(d) Where pipes are required to be laid under roadways, etc., by pipe pushing machines or similar devices, and thus avoid opening up expensive pavements.

The small sized iron pipes can be laid at considerably lower cost than earthenware or concrete pipes, and their use where small cables only are necessary has materially reduced the cost of underground construction and extended the economic use of underground cable distribution systems.

Fig. 11 shows the maximum size of cable which can be safely drawn into various sizes of black and galvanized iron pipe. The table is based on the assumption that the pipes will be laid in straight lengths. If it is necessary to introduce a bend in the run due allowance must be made, and possibly a larger pipe used. The permissible diameter of cable for black iron pipe is somewhat less than for galvanized pipe. Although the nominal bores are the same, black iron pipe shows a marked tendency to form a scale which reduces the effective diameter, whereas galvanized pipe exhibits a smoother and more uniform surface. Where a single pipe is laid under a permanently paved roadway or footway, it is advisable to lay a pipe one or two sizes larger than would ordinarily be required, and thereby avoid the heavy cost of laying new pipe where variation from forecasted development necessitates the replacement of cable with one of larger size.

Nest Arrangements for Multi-Ducts: Fig. 12 shows typical nest arrangements for multi-duct conduits which are most suitable for normal conditions. The normal arrangement indicated is that which in general is the most economical in regard to excavation costs, but frequently owing to space limitations it may be desirable to adopt other arrangements such as the alternative shown. Where a large number of ducts is necessary it is inadvisable to use a nest more than 4 ducts wide, as apart from economy in excavation costs the 4-duct wide configuration makes for most convenient arrangement of cables in the manhole, that is, two cables from each level are arranged on each wall of the manhole. The arrangements for 4-way and over are shown for earthenware self-aligning conduits, but the same configuration would generally apply to other types.

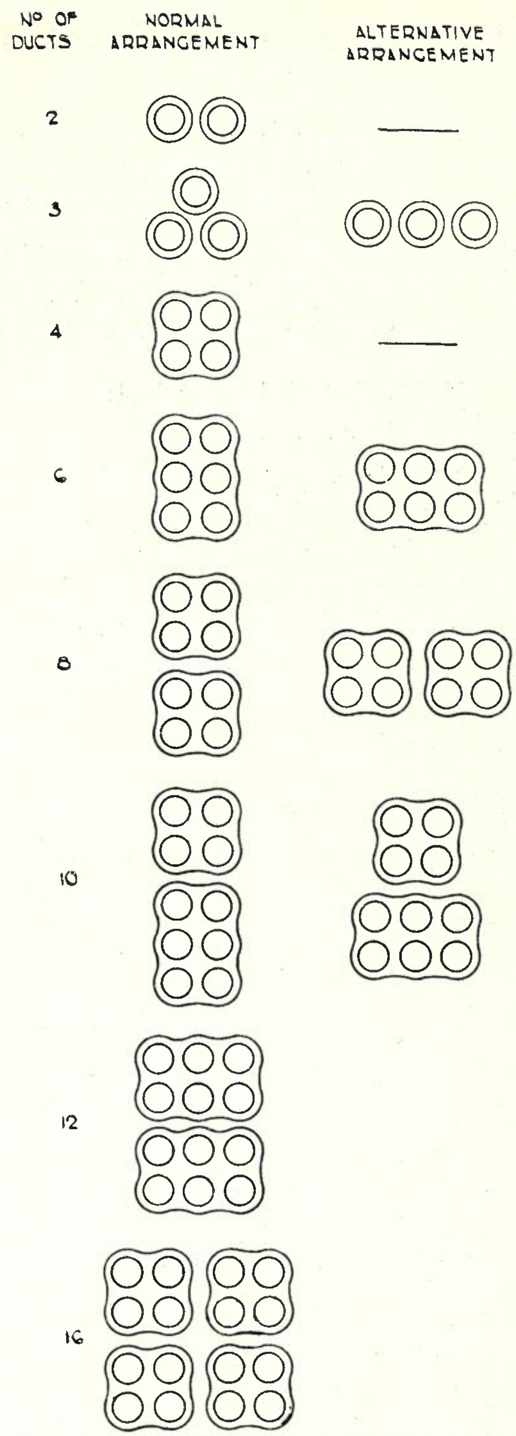


Fig. 12.—Nest Arrangement for Multiple Ducts.

Odd numbers of ducts, such as 5, 7, etc., ways, are not normally installed but if necessary can be provided by adding a single pipe on top of the nest, e.g., one 4-way plus a single pipe to form a 5-way.

(To be continued.)

RECONDITIONING SWITCHBOARD PLUGS

E. J. G. Bowden and A. C. F. Anderson

In view of the marked shortage of switchboard plugs the Adelaide Postal Workshops were requested by the Chief Engineer in December, 1940, to experiment with the reconditioning of large quantities of discarded plugs Nos. 2037 (Magneto), 3357 (C.B. P.B.X.), and 3362 (C.B. No. 1), which had accumulated throughout the Commonwealth. At that time new plugs were unobtainable.

Most of the discarded plugs had:
- worn tip,
- worn insulated ring,
- worn sleeve,

and in addition many had:
- low insulation resistance,
- broken insulating material.

Many, of course, were damaged beyond repair.

After considerable experiment and many failures a series of processes has been evolved enabling thousands of plugs to be reconditioned. The treatment of 3-part plugs No. 3357 is described below and may be of interest as illustrating the processes now in use. The other types of plug may be treated by the same methods, modified as necessary.

Plug 3357—Reconditioning Processes

Preparation: The plug (type shown in Fig. 1d) is held in a lathe chuck and the sleeve portion rubbed down with an abrasive strip held in a special tool (Fig. 2). The tool is held by hand. It should be realised at the outset that switchboard plugs are not sufficiently concentric to permit any practical method of "chucking" for turning down with a cutting tool. Moreover, plugs by different makers have individual characteristics.

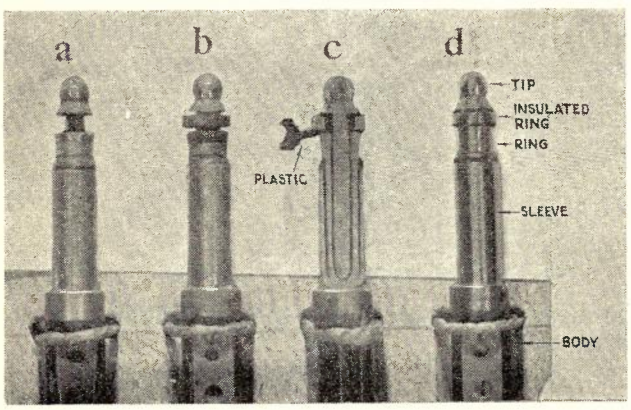


Fig. 1.

After rubbing down, the sleeve is cylindrical and there are no "high spots" to mar the subsequent plating. The tip is rubbed down by the use of a tool constructed on similar lines to that shown in Fig. 2 but modified in shape.

Cleaning: The tip and sleeve portions are then sand-blasted to ensure a good plating surface, and the plug washed in an acid solution, scrubbed with pumice, and dipped in a cyanide solution.

Plating: The plugs are placed in special clips, tip downward, in a copper plating bath so that only the working portion of the plug is in the plating solution. The clip makes electrical connection with the tip and sleeve only, as copper is required to be deposited only on these portions. A plating current of approximately 30 mA per plug is maintained for 30 minutes. The plugs are then removed from the bath, lightly brushed with a brass wire brush, dipped in a cyanide solution, and transferred to a brass-plating tank with the least possible delay. It is found that "scaling" of the brass plating and other defects develop if the preliminary copper plating is omitted. A current density of 30 mA per plug is maintained for brass plating for a period up to seven hours. During this period the plugs are turned round by hand several times to ensure an even coating of brass. It is found impracticable to deposit more than 0.003in. thickness of brass at one plating—consistent deposits of 0.0025in. (finished) are considered good. Heavy plating is uneven and liable to scale. If more than 0.0025-0.003in. is required the plug must be dressed down again and replated. Plugs are then removed from the bath, washed in cold water, then in hot water, and again scrubbed in cold water to remove all traces of cyanide, and are dried in an oven at a temperature of 180deg. F.

Precautions to Ensure Satisfactory Insulation Resistance

The plugs, still at 180deg. F., are placed in a dehydrator. This consists of two cylinders connected together at their bases by a valve, both cylinders being partly immersed in boiling water. One of the cylinders (in which the heated plugs are first placed) contains only a loose sieve for holding the plugs; the other contains beeswax at approximately 200deg. F. The cylinder containing the plugs is then exhausted of air (25in. mercury) and maintained thus for one hour. The beeswax is admitted, via the valve, to the cylinder in which are the plugs, and the vacuum released after a few minutes. The beeswax is then drawn off by applying the vacuum to the other cylinder. The plugs are allowed to drain (still at 200deg. F.) for approximately 10 minutes, and then wiped with a cloth. This process ensures that the insulation resistance of the plugs is maintained. Before its introduction the only method practicable was slow drying in an oven for several weeks, and even then it was found that the early application of any testing voltage to the plugs permanently broke down their insulation resistance, probably because the plating solution had entered the pores of the insulation. Furthermore, some plugs, apparently satisfactory on test, were found to break down in insulation after varying periods, many even without being used. The dehydration and beeswaxing processes have overcome this very serious defect.

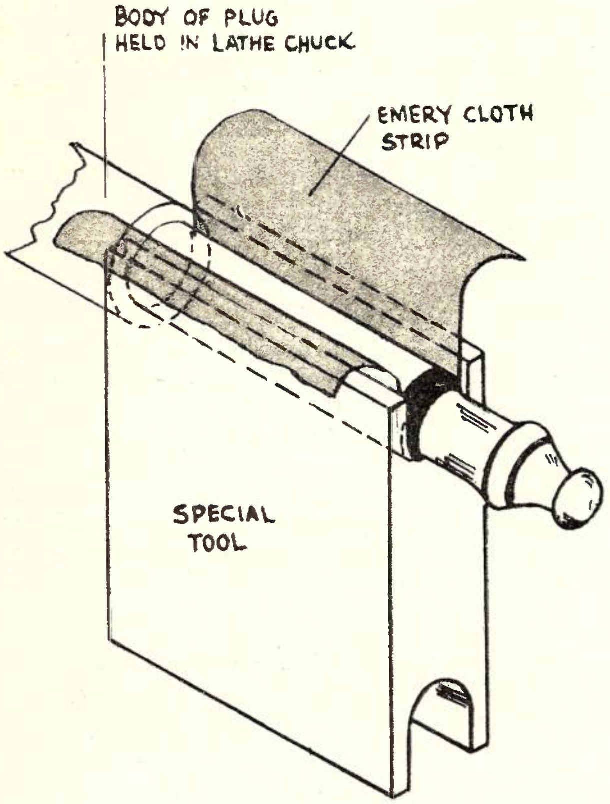


Fig. 2.

Treatment of Sleeve and Tip: The sleeve and tip are again rubbed down to a true surface with the tool shown in Fig. 2 and gauged. If insufficient brass has been added the plug is returned for further plating.

Ring Contact: This is never sufficiently worn to warrant attention. No electrical connection is made to it in the plating baths, and no metal is therefore deposited.

Treatment of Insulated Ring: This ring cannot be satisfactorily plated on account of its shape and the difficulty of providing an electrical contact for it while in the plating bath. Moreover, it is generally worn to a considerable extent (up to 0.015in.), and it was early realised that its complete replacement would be necessary. The worn ring and associated insulation are therefore removed in a small hand press, the plug resting in a cradle of the correct shape with a chisel point descending a limited distance (Fig. 1a). This prevents injury to the other parts of the plug. New rings of ample exterior diameter are made with a centre hole just large enough to slip over the tip of the plug. One side of the new ring is knurled to assist in keying the ring to the insulating material. The ring is fitted in a hand press by the insertion of the plug upwards in a tapering steel die. The ring, which is annealed, is slipped over the tip and a descending collar ram forces the ring and plug down the tapering die, shrinking the ring so that it cannot leave its slot (Fig. 1b).

Injection of Insulating Material: An electrically heated injection press has been designed and built in the workshops for this purpose. The mould is in two parts, each part being mounted on one jaw of a quick-acting toggle vice. Heating elements are fitted immediately behind, and in contact with, the mould parts. The mould conforms, of course, to the plug shape, but has a groove to hold the insulated ring in position.

With the plug in position and the mould closed a loading tool is introduced between the mould and the injector ram which, moving down under hand pressure through the loading tool, forces a charge of thermo-setting moulding powder into the pre-heating chamber. The ram is then lifted free of the loading tool (which is removed) and again pressed down. This forces the charge, now in a plastic state, through a very small gate into the plug chamber. The ram is only 1/8in. in diameter, and so arranged that a downward pressure by the operator on the injector handle of 10-20 lb. gives an injection pressure of some 4 to 8 tons per square inch. As the quantity of powder is very small (one ounce will inject approximately 80 plugs) and is very intimately heated, the curing period is very short, about 30 seconds at 250deg. F. At this stage one of the advantages of the particular powder used is apparent as, at the moment of hardening, a small volume of gas is evolved, and an experienced operator can detect the moment when the plug will lift readily from the mould without the use of force or ejector pins. This quality is improved by mixing "Brown" and "Black" powders in equal quantities. Fig. 1c shows a cut-away view of the plug immediately after its removal from the mould. If the insulating material between the ring and the sleeve (see Fig. 1d) is broken, it is replaced by the use of a suitable mould.

The ring, now firmly held in place by the plastic, is turned to correct diameter by placing the plug in a special chuck of a precision lathe, the slide-rest of which is fitted with a micro-indicator, which is capable of indicating differences of 0.001in. in the diameter of the insulated ring as it is turned down and ensures far more accuracy than does the usual "dead" stop fitted to a lathe slide-rest. Rounding the edges of the insulated ring is done very simply with a hand tool in another lathe. Fig. 1d shows the plug after completion of all processes.

Final Treatment and Tests: All the foregoing processes are gauged with "go" and "no go" gauges at appropriate times. Plugs on completion are rapidly tested for insulation resistance by means of a power-driven Megger wired to a series of jacks. By inserting the plug in the various jacks the insulation resistance between the several components of the plug is rapidly measured. The bodies of satisfactory plugs are sand-blasted inside and well cleaned and polished outside. The whole of the plug is then lightly brushed over with a spirit lacquer to prevent tarnishing. Tag screws and plug cover are added, and the plugs returned to store in packets of 50.

General: It is fully realised that the somewhat complicated processes described above are carried out as a war measure only, and that when new plugs become obtainable at prices approaching pre-war levels the reconditioning of plugs will not be necessary or economical. It is interesting to note, however, that almost all the processes, which are, of course, repetitive, can be carried out by junior members of the staff, i.e., lads and girls from 16-18 years of age. Completed plugs are, however, individually subjected to careful examination and check by the normal Workshops testing staff. Many of the processes described herein have been the result of "trial and error," and possibly still further variations will be made before the necessity for plug reconditioning ceases.

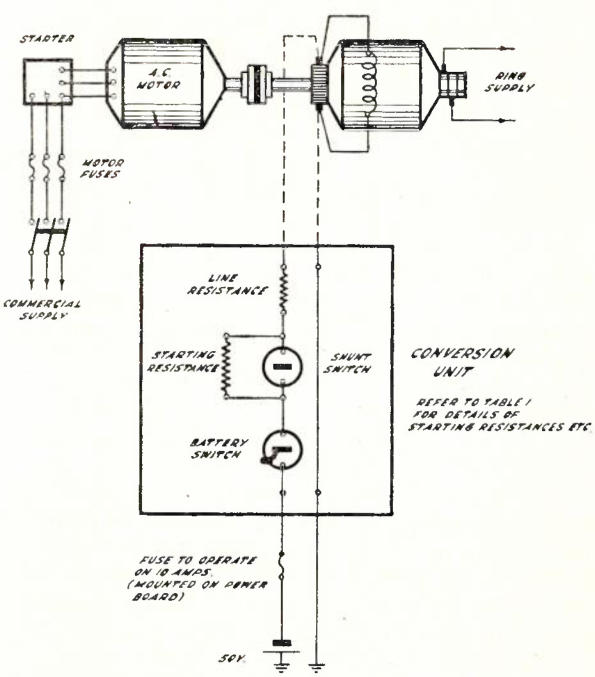
CONVERSION OF MAINS OPERATED RINGERS FOR 50-VOLT D.C. OPERATION

A. H. Pilgrim

With the outbreak of war in the Pacific area it became necessary to make plans to maintain telephone service under various emergency conditions. One such emergency would have been failure of the commercial power supply, and one item of telephone plant affected would have been the mains driven ringer. There is always a chance that this emergency may arise in peacetime, so that most exchanges are equipped with alternative battery driven ringing machines; however, in view of the possibility that an interruption in power supply occurring in wartime may be of prolonged duration, it was considered wise to have on hand also an alternative to the battery ringer.

One method of arranging this would be to mount a D.C. motor so that it could belt-drive the mains operated ringer if necessary. This would involve mounting a belt pulley on the ringer shaft between the A.C. motor and the self-exciting ringing alternator. A much simpler method was, however, eventually adopted by taking advantage of the fact that the electrical characteristics of the self-exciting ringing alternators used are similar to those of the battery driven ringing dynamotors, thus permitting them, with minor alterations, to be driven from the D.C. supply. The following notes indicate the methods adopted with various classes of ringers to achieve this.

The first mains operated ringer selected for conversion was an inductor type machine manufactured by Walter Jones & Co., London, and installed at Redfern Exchange, New South Wales. Redfern is an exchange of some 2,300 lines, of which 38 per cent. are P.B.X. lines and carrying very heavy traffic and supplying ring to 50 P.B.X. switchboards. It was found that the excitation voltage when the machine was running as a mains driven ringer was 64 volts. The A.C. motor was uncoupled from the ringing alternator by loosening the grub screws on the motor side of the coupling and sliding the half coupling back on the motor shaft. A 50-volt supply was then connected to the commutator brushes of the ringing alternator via a conversion unit consisting of two switches and a starting resistance (see diagram). The starting resistance used consisted of two ordinary 50-volt 60-watt lamps



METHOD OF CONNECTING CONVERSION UNIT

Fig. 1.

in parallel. Once the machine (now acting as a ringing dynamotor) had run up to speed the starting resistance was short-circuited and the commutator brushes advanced to achieve maximum speed and sparkless commutation. When taking the exchange load the speed of the machine was the same as when driven by the A.C. motor, and the voltage of the ringing current was only slightly lower. The machine was run in this way for 48 hours and a record kept of the temperature of the field and armature, but no abnormal rise was detected.

Comparative figures of the performance of the Redfern ringer are given in Table 1, together with details of the ringers at East Exchange (Newton Bros. machines), where the excitation voltage is 49.5 volts. All ringing machines in the Sydney metropolitan area were subsequently provided with conversion units. In some instances their use has caused small changes in speed and ring voltage, but these have not been important. Table 2 indicates for various types of ringing machines in use in Sydney the type of starting resistance that has been used and other conversion details. With machines manufactured by Newton Bros. and with the direct-drive Crompton Parkinson machine, it is difficult to uncouple the A.C. motor from the ringing alternator, so that in such cases the rotor is an additional torque load on the ringer when it is operating as a ringing dynamotor. This is doubtless the main reason why the speed of the ringer in such cases is slightly reduced (see Table 1—Newton Bros. ringer). As a precaution in these cases the A.C. motor fuses should be removed when the conversion is carried out. With some ringers supplied by Newton Bros. the excitation voltage is very low (20 to 22 volts), and in these circumstances a series resistance of approximately 5 ohms has been inserted in the battery lead when the machine is operating from the exchange battery. On all machines marks have been made on the frame and on the brush rocker so as to facilitate the work of altering the position of the brushes when the mains driven ringer is converted to 50-volt working, or vice versa.

The conversion units were made up very quickly, and the lamp batten holders and switches were mounted on standard commercial 6in. x

TABLE 1

Exchange	Make of Ringer	Ringer	Voltage—(normal load)			D.C. Current Input in Amp.			R.P.M.—(normal load)	
			Excitation	Exchange Battery	Ringing Current Output	No Load	Normal Load	Rating	Rating	Actual
Redfern	Jones	No. 1 Mains Operated	64	—	85	—	—	—	975	970
		No. 1 Battery Operated	—	52	83	2	2.25	—	—	970
		No. 2 Battery Operated	—	52	83	1.5	2	3.5	1000	975
East	Newton Bros.	No. 1 Mains Operated	49.5	—	92	—	—	—	940/1000	920
		No. 1 Battery Operated	—	48	82	2.7	3.9	—	—	880
		No. 2 Battery Operated	—	48	82	2.7	3.8	3.85	1000	920

TABLE 2

Type of Mains Operated Ringing Machines	Excitation Voltage	Conversion Unit Details		Treatment of A.C. Motor	Treatment of Alternator
		Start Resistance	Line Resistance		
W. Jones & Co.	64	Two 50-Volt 60-W. Lamps in parallel	—	Uncouple A.C. Motor	Connect conversion unit to brushes and advance brushes on commutator to position marked "DC" on motor frame
Crompton Parkinson Ltd. (belt drive)	38–40	Approx. 10 ohms	—	Remove belt	ditto
Crompton Parkinson Ltd. (direct drive)	38–40	Approx. 8 ohms	—	Remove commercial supply fuses (motor cannot be uncoupled)	ditto
Newton Bros.	49–50	Three 50-V. 60-W. Lamps in parallel	—	ditto	ditto
Newton Bros.	20–22	Approx. 3 ohms	Approx. 5 ohms	ditto	ditto

6in. base blocks or 9in. x 6in. base blocks when three lamps were necessary. The equipment on the base blocks was wired to two pairs of terminals to which were connected two leads of suitable length. When wire resistors were used, the resistance wire was wound on a piece of fibrocement sheet. Two other sheets of the same size were mounted one on either side of the resistor sheet and separated from it, and the switches and terminals were mounted on one of these sheets. When in use in an emergency the conversion unit could conveniently be placed on the ringer pier.

STAFF LOCATOR SYSTEM—PERTH PUBLIC HOSPITAL

P. Carroll, B.A., B.Sc.

Introduction: Towards the end of 1941 a large new building for the Perth Public Hospital was nearing completion. The building is in the form of a "U" and consists of eleven storeys. A P.A.B.X. was to be installed, and on account of the size of the building, the Hospital Authorities wished to have a staff locator system installed in conjunction with the P.A.B.X. in order to save time in the finding of members of the staff for incoming telephone calls or other matters. The staff locator system which is to be described was designed for installation at the Hospital. Owing to war-time difficulties, the building was not completed, and the system has not yet been installed.

Facilities Provided:

(1) 49 members of the staff are allocated numbers on a two-figure basis 11-17, 21-27, —, 71-77.

(2) At the locator points, which are distributed at the most suitable positions throughout the building, indicator boxes as shown in figure 1 are situated. In the indicator boxes, lamps in pigeon holes behind frosted glass numbers on a blackened glass background, are provided. The lamps are in two columns, the left-hand side representing the tens digit of the called number, and the right-hand side column representing the units digit. The numbers may be on 2 or 3 sides of the box in order that the number called may be seen from more than one direction. In the photo an indicator box with the number "23" flashing is shown.

(3) When the telephonist wishes to locate a member of the staff she plugs into the appropriate jack on the switchboard. This causes the number of the person required to flash at all indicator boxes in the building. When the person called notices his number flashing, he proceeds to the nearest extension telephone and contacts the telephonist. When the telephonist unplugs, the number ceases to flash.

(4) Two members of the staff may be located simultaneously, by the alternate flashing of the numbers of the two persons required.

(5) Flashing is provided in order to readily draw attention to the fact that the indicator boxes have been brought into operation and a member of the staff is wanted by the telephonist.

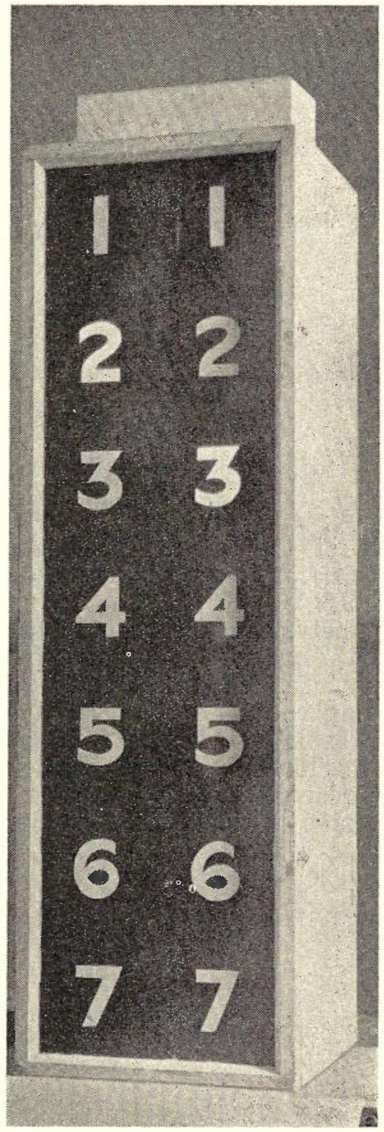


Fig. 1.

Circuit Operation: The circuit of the staff locator system is shown in figure 2.

On the switchboard a jack strip designated 11-17, 21-27, —, 71-77 is mounted. Associated with this jack strip are two calling plugs, one of which is to be used when a single member of the staff is to be located. Should it be required to locate simultaneously a second member of the staff, the second calling plug is inserted into the appropriate jack. The insertion of the first calling plug into any jack will produce the operation of the relay A from the sleeve of the calling plug. Contact A1 operates relay X. Contact X1 operates relay Y, and contact X2 operates the mercury tilt relay Z. The making of contact Z1 puts earth on the tip and ring of the calling plug. Earth on the tip of the jack of the number plugged into causes the light corresponding to the tens digit of the number called to glow at all indicator boxes. Earth on the ring causes the units light to glow at all the indicator boxes. The interaction of relays X and Y produces a make and break cycle of contact Z1, the make and break portion of the cycle each being of several seconds' duration. As the lights associated with the first calling plug only glow during the make of contact Z1, a flashing of the number required is produced. Should it be desired to locate simultaneously a second person, the second calling plug is inserted into the appropriate jack. The two lights associated with this jack will glow during the break period of contact Z1. Alternate flashing of the numbers of the two persons to be located will, therefore, take place at all indicator boxes. On unplugging, the circuit is restored to normal by the release of relay A.

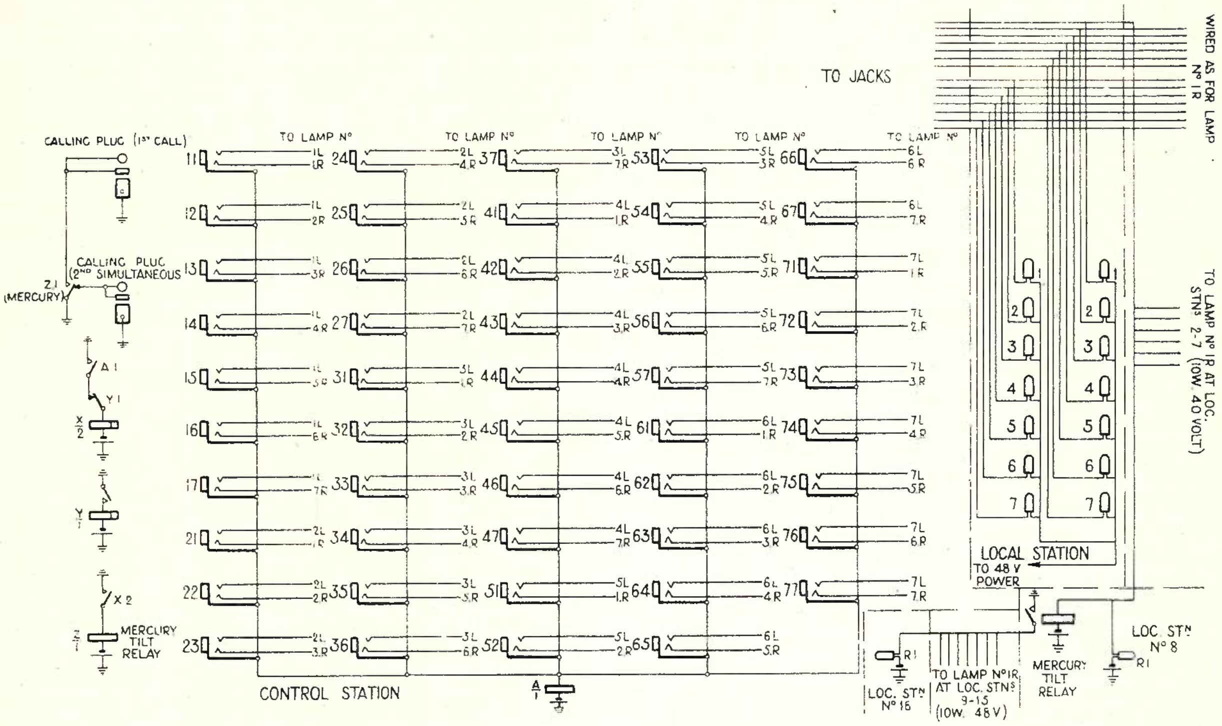


Fig. 2.

At the Perth Hospital, 16 indicator boxes are to be installed. These indicators will be divided into two groups of 8 with corresponding lamps in each group of 8 wired in parallel. Separate battery feeds will be provided for each group of 8 indicators as shown in figure 1. It is necessary to provide a 10-pair cable between the switchboard and indicator boxes.

THE MURRAY MULTIPLEX "RUN IN"

R. C. Henry

General: The purpose of "running in" is to synchronise the speed phase relationship between the "correcting" and the "corrected" distributors. In this respect the former runs at a constant speed, which, under standard conditions, is 270 revolutions per minute. The latter or "corrected" distributor rotates at a speed which is slightly in excess of that of the former, but as soon as the two distributors are in phase the brushes of the corrected station are automatically retarded once in every second or third revolution.

"Run In" Procedure: Suppose that a Quadruple Multiplex system operating over a Type B carrier wave telegraph channel is to be run in and handed to Traffic for the day's run. It will be assumed that the necessary preparatory work of cleaning, oiling, and inspection of the Multiplex equipment is completed and that a satisfactory local run back has also been carried out. Also, the send plug of the Murray terminal box at the corrected station has been adjusted, anti-clockwise, to its predetermined position, to compensate for line lag. Therefore, the corrected station is in readiness to receive the correction signal from the distant distributor.

Transmission of the Correction Signal: Before the run in is commenced both stations will set their respective Murray transmitters to space by operating their associated start-stop levers to the "down" position. Segments 21 and 22 of the send ring at the correcting station are permanently connected to mark and space battery respectively, so that for each revolution of its brushes, a mark and space impulse is transmitted to the carrier channel. As a consequence, the receive relay at the corrected station will mark and space in accordance with the received correction signal.

Reception of the Correction Signal: Assume that the corrected distributor is running fast, i.e., gaining on the correcting station. In this case, considering the marking element only, the printer magnets will be operated in a forward direction. Thus, a possible sequence in the operation of the printer magnets for, say, four revolutions of the "corrected" distributors would be as follow:

1. Fourth magnet of the third arm printer.
2. Fifth magnet of the third arm printer.
3. First magnet of the fourth arm printer.
4. Second magnet of the fourth arm printer.

On the other hand, should the speed of corrected distributor be slow, the printer magnets are operated in a backward direction.

Since the length of a receive segment is one-half that of a send segment, consideration will show that the number of times each particular printer magnet is successively operated before its neighbour is energised affords a means of determining the working speed difference between the correcting and corrected stations.

In the four-channel Multiplex System being considered, correct speed adjustment is such that each printer magnet is operated from 18 to 20 times in succession as the correcting mark impulse moves slowly forward to eventually operate adjacent printer magnets. Suppose a particular printer magnet to be operated 14 times in succession before the correction mark impulse moves forward, then the speed of the corrected distributor would be too fast, and the vibrator would require adjusting to slow down the phonic motor. Again, if the magnet were operated, say, 25 times, the speed is obviously too slow and the vibrator would again require attention in order to speed up the phonic motor.

Operation of the Correction Magnet: If the corrected station distributor has been adjusted to meet the above requirements the marking element of the correction signal will continue to operate each printer magnet in turn until it eventually reaches segment 21, to which is connected the correction magnet. As a result the correction magnet operates, thereby causing the distributor brushes to be stepped back $1\frac{1}{2}$ degrees with respect to the phonic motor. The corrected distributor will again pick up speed only to be again stepped back, which, in practice, is once every second or third revolution.

Repere or Action Point: This is referred to as that precise part of the correction segment at which the correction magnet operates as the receiving brush sweeps across it. If receiving conditions are normal the receive brush at the corrected station is just passing over the repere point simultaneously with the cessation of the marking element of the correction signal; i.e., as the sending brush at the correcting station just leaves send segment 21. In considering the action of the correction signal, no mention has been made of its space element. The space contact of the receive relay is left open circuited, but, notwithstanding this feature, the reception of the space element of the correction signal is of great importance.

Consider the case in which the space element is not received by the receive relay at the corrected station. Suppose that the first code impulse transmitted by segment 1 at the correcting station is a marking impulse. Therefore, the receive relay at the corrected station will remain on its mark contact for an abnormal period, prolonging the operation of the correction magnet, and hence destroying the state of synchronism between the two stations. However, should the space element of the correction signal be received, then the receive relay is restored to its space contact immediately after correction has taken place, thereby permitting normal operation to ensue.

Reversals: Having established synchronism and correct phase relationship between itself and the distant station, the corrected station will signify this state of affairs by throwing the linked switching keys situated on the Murray terminal box to "Reversals," which connects the static modulator of the carrier wave system, via the send carrier loop, to 50 cycle square topped reversal current supplied by a generator situated in the telegraph office, which obviates the use of the send plateau for this purpose. The distant station, on observing the incoming reversal signals, will also transmit reversals in a similar manner. Reversal current is therefore received by the receive relay at the corrected station via the tongue of the carrier receive relay and receive carrier loop.

Two 50-0-50 milliammeters wired in series with the send and receive carrier loops respectively enable both the sent and received reversals to be observed. In this regard, particular attention is paid to any biassed condition of the reversal signals, which must be removed before further tests are carried out.

Orientation: From what has been said regarding the reception of the correction signal, it will be understood that the reason for the receiving segments being half the length of a send segment is to prevent any overlapping of received signals. Further, the receive ring which carries the channel receive segments is capable of being adjusted as a whole.

The method of adjusting the receive ring to the best position for the reception of signals is called "orientation," and is accomplished at the corrected station in the following manner:

After reversals have been checked and any necessary adjustments effected, the corrected station operates the reversal switch three times, thereby indicating to the distant station to transmit "thirds." A "third" is, of course, the centre element of the five-unit code, and corresponds to the function, "letter space." Both stations, therefore, restore their reversal switching keys to normal, then the distant station will operate the third lever of the first arm transmitter to its mark contact. The corrected station printer of the first arm, therefore, receives a series of letter spaces.

The receive ring is now rotated until the third and fourth printer magnets are operated; i.e., the letter N is printed. The position of the receive ring is now marked, and again rotated, but in an opposite direction, until third and second printer magnets are operated, which results in the printing of the letter I. This position of the receive ring is again marked, and finally the receive ring is set midway between the two markings. Thus orientation of the corrected station has been effected.

Corrected Station Transmits "Thirds": The home station will now transmit thirds to the distant station, who will take an orient of the receive ring in a similar manner as discussed above.

Webster Correction Segment: Quadruple Multiplex Systems operating over Type B carrier wave channels are affected by a type of distortion which causes the mark element of the correction signal to be foreshortened when the transmitted code impulse from segment 20 of the send ring of the correcting station is a mark element.

By making use of the Webster correction segment a means is provided by which the adverse effects of correction signal distortion is overcome. A complete discussion regarding the theory and application of the Webster segment cannot be undertaken at present, but the method of taking an orient, when it is switched in for use at a corrected station, will be briefly described.

When the distant correcting station has completed the adjustment of the receive ring of his plateau to incoming thirds from the corrected station he will restore the fourth arm start-stop transmitter lever to its "up" position, thereby causing the transmission of "erasures" to the fourth arm printer at the corrected station. Clearly this is a condition which will cause correction signal distortion.

In addition, the correcting station will also send "thirds" from the first arm transmitter.

The corrected station having switched in the Webster segment now takes a second orient, the position of which will depart from that of the former. A final setting of the receive ring is, therefore, made midway between the normal and the orient taken with the Webster segment switched into Service.

Transmission of Trial Tapes: The "run in" is now completed, and trial tapes are transmitted and received by both stations on a duplex basis, and, if satisfactory, the system is handed to Traffic for service.

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. 2377.—ENGINEER—TELEPHONE EQUIPMENT

E. J. Bulte, B.Sc.

Q. 4.—Describe the B.P.O. 3,000 type relay under the following headings:—

(a) Fundamental design.
(b) Magnetic circuit.
(c) Buffer blocks.
(d) Springs and contacts.
(e) Residuals.
(f) Design of windings—factors of safety in ampere turns, permissible tolerances in resistance and turns, permissible heat loss.
(g) Types of relays—straight, slow, fast and impulsing.
(h) Adjusting tools and adjustments.

A.—(a) See Q. 8, Fig. 1, Page 315, Vol. 4, No. 5. The yoke is secured to one end of the coil assembly by the circular nut to form a low reluctance magnetic joint. The yoke is machined at the other end to form a knife edge on which the V-shaped armature is pivoted. The armature is prevented from sliding off the knife edge by being held against the yoke with a spring-loaded screw.

(b) The magnetic circuit is very efficient. The points of highest reluctance are the knife edge and the air gaps between the armature and the core. The area of these sections is increased in order to maintain the efficiency of the magnetic circuit. The knife edge fulcrum is specially designed to give low reluctance.

(c) The buffer blocks are stepped mouldings made of white "beetle" and are provided so that the springs may be readily placed at the required spacings from each other, at the same time serving as a buffer surface to tension the springs against.

(d) The springs are of nickel silver, either 12 or 14 mils thick, according to the operating requirements. The "fixed" springs are provided with a small side projection near the contact end which rests on one of the steps of the buffer block. At the contact end they are split for a short distance, each half of the tip being fitted with either silver or platinum-domed contacts according to the circuit requirements.

(e) Phosphor-bronze residual studs are fitted into the armature and are of varying lengths according to requirements. When necessary, an adjustable residual in the form of a brass screw is screwed into the armature and secured by a locknut.

(f) A factor of safety of 2 is usual in selecting a relay coil for a particular spring load. The permissible tolerances specified for resistance and turns are 5% and 3% respectively. The maximum permissible heat loss is 6 watts.

(g) A straight relay has a soft iron core and an armature fitted with a residual stud or screw. A slow-acting relay is provided with a copper slug at either the armature or heel end of the core, depending respectively as to whether a slow-operating or slow-releasing relay is required. A fast-operating relay is provided with a nickel-iron core with a reduced section pole piece and, in order to reduce the inductance, is usually of low resistance with a minimum number of turns. An impulsing relay is provided with an isthmus type armature and an adjustable residual screw.

(h) The following are the main adjustments necessary:—

1. Adjust residual (if adjustable) or check residual stud using feeler gauges.
2. Check and adjust armature travel using the armature bending tool.
3. Straighten springs and align the twin contact points to make or break simultaneously, using a spring tongue adjusting tool.
4. Adjust the tension of the buffer springs against the buffer block steps, using a spring adjuster and tension gauge.
5. Adjust each lever spring in turn using the spring adjuster and tension gauge.

Q. 5.—Describe the supervisory alarm equipment provided in a 2,000 type line finder exchange or in any other type of automatic main exchange with which you are familiar.

A.—The supervisory alarm equipment in a 2,000 type line finder exchange consists of equipment to detect faults or non-standard conditions in the exchange and to furnish an indication in the form of a lamp display and ringing bell in order that steps may be taken to restore the conditions to normal. Alarm signals are classified into two groups, prompt and deferred. The former indicates that a failure of an urgent nature has occurred and requires prompt attention, whilst the latter is used for faults which may be temporarily neglected without affecting the service. Types of fault, their classification and the period of delay is given below:

The various delay periods are produced by uniselectors stepping under the control of impulses at regular intervals, these impulses being derived from either the ringing machine auxiliary cams, the exchange clock or auxiliary relay equipment. One delay equipment as above is provided for each relay period required, this equipment being mounted on the alarm equipment rack.

For alarm indication purposes, each floor of the exchange is divided into sections and each section is further divided into sub-sections. Each sub-section is equipped with a terminal block to which all the alarm leads in that section are taken. Associated with this terminal block (usually referred to as a classification block) are two lamps indicating respectively the prompt (red) and deferred (white) alarms. Cables are taken from each sub-section classification block to the alarm equipment rack, where they are grouped and connected to the operating coils of the section relays. Each section is provided with a prompt and a deferred relay, the contacts of which are commoned and control the floor lamps and bells.

Groups of floor and section lamps are provided on each floor in as many positions as are necessary to allow easy observation. In order to call attention to a lamp indication, floor bells are provided. A fault in a particular section will operate the floor bell on all floors. During hours of continuous attendance on each floor the floor bells may be isolated so that they will only operate when an alarm occurs on their own particular floor. Localisation within the sub-section is obtained by observing the rack lamps. In some cases, shelf lamps are equipped on the racks in order to facilitate protection of the faulty circuit. In the case of PG's on bimotional switches a lamp is provided in each switch to facilitate location of the particular switch which is being held. The alarm lamps are extinguished and the alarm bells silenced after the faults are cleared. In some cases an alarm cut-off key is provided in order to disconnect a deferred alarm from the main exchange alarm, i.e., the lamp would still glow, but the bell would not ring.

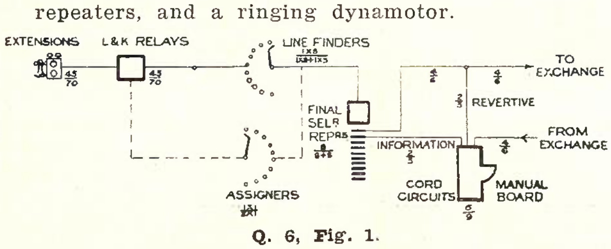
Alarm	Cause of Alarm	Prompt or Deferred	Delay Period
Fuse	Operation of a fuse	Prompt	Nil
Release	Switch failing to restore to normal when its release circuit is energised	Prompt	9 secs.
Ring Fail	Failure of ringing current, not due to a fuse	Prompt	Nil
Voltage	Voltage at bus-bars outside prescribed limits	Prompt	Nil
Charge Fail	Operation of circuit breaker through overload or reverse current	Prompt	Nil
Line Finder Supervisory	Line Finder fails to find calling line	Prompt	6 secs.
P.G.	First selector held for excessive period before receiving impulses	Deferred	6 mins.
C.S.H. (called sub. held)	Calling or called sub. holding the connection for an excessive period after the other party has cleared	Deferred	6 mins.
N.U. Tone Supervisory	Sub. maintaining a connection to a line connected to N.U. Tone	Deferred	3 mins.
N.U. Tone Overload	A low resistance earth fault on a line temporarily connected to N.U. Tone	Deferred	Nil
Failure of Ringing Machine No. 1	Failure of power supply to ringing machine. (This does not indicate a failure of ringing current since Machine No. 2 will start.)	Deferred	Nil

Q. 6.—(a) A subscriber whose present requirements are 45 extensions and 8 exchange lines, and five-year requirements 70 extensions and 12 exchange lines, is to be provided with a P.A.B.X. Draw a typical trunking scheme and layout for the system you consider suitable and list the main items of equipment required.

(b) Describe a method of preventing direct access for outgoing calls from P.A.B.X. extensions and draw a schematic circuit showing details of the method described.

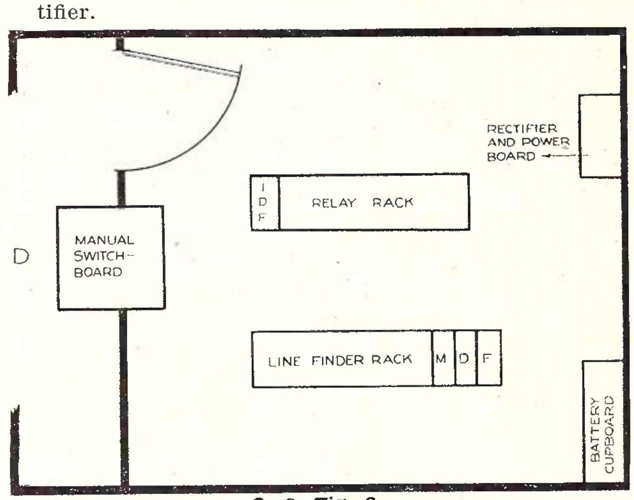
A.—(a) See Figs. 1 and 2. The P.A.B.X. equipment used is of the line finder type. The main items of equipment required are:—

1. Line finder rack equipped with 90 L and K relays, 20 uniselectors, 50 outlet, used as line finders, 2 shelves and banks sets of 10 for 20 final selector repeaters, and a ringing dynamotor.



Q. 6, Fig. 1.

2. A relay rack fitted with 2 shelves for 10 relay sets each for cord circuit, information revertive call trunk offering and miscellaneous relay sets.
3. A single position manual switchboard.
4. A power board.
5. An automatically controlled 10 amp floating rectifier.

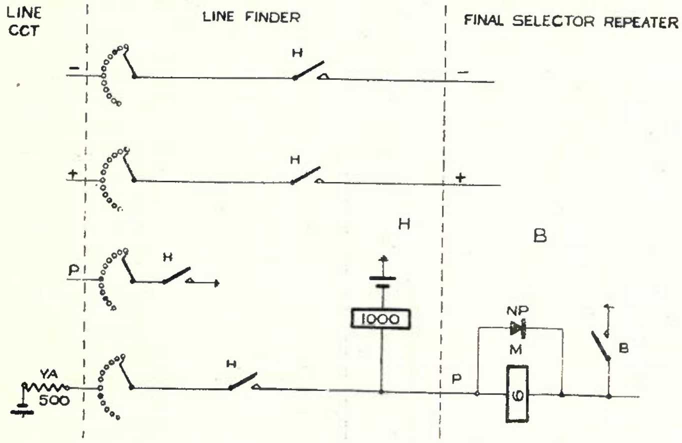


Q. 6, Fig. 2.

6. Eight 6-volt motor vehicle type batteries of approximately 80 ampere hours' capacity mounted in a battery cupboard.
7. A single-sided M.D.F.
8. An I.D.F.

(b) There are several methods of preventing direct exchange access. The following applies to the fine finder equipment listed above:—

A 500 ohm non-inductive resistance is connected to battery in the line circuit of the extension as indicated in Fig. 3. If this extension calls the exchange the current in the P wire from the line finder is increased as a 500 ohm resistance is connected across the hold relay H in the latter switch. When the switch steps to the O level, relay M, which is marginal in adjustment, will operate owing to this increased current. In the final selector repeater, contacts of M relay apply busy tone to the calling line and prevent rotary action of the switch. Extension to extension calls are not affected as M relay is short circuited, except when the normal post springs are operated on the 10th level.



Q. 6, Fig. 3.

Q. 7.—List the chief routine tests you would specify for the efficient maintenance of the automatic switching equipment in a 1,000-line automatic main exchange with junctions to another main exchange. The approximate frequencies of the tests should be stated and the necessity for their performance described briefly.

A.—See table hereunder.

The necessity for the performance of the various tests is as follows:—

1. To clear all false off normals and permanent loops.
2. To test urgent alarm signals associated with the exchange equipment, viz., high and low voltage, circuit breaker and ringing failure alarms.
3. To test the operation of the subscribers' uniselectors and associated outgoing trunks.
4. To test the continuity of the trunks outgoing from the banks of the bimotional switches and also certain switch functions.
5. To check the correct operation of the bimotional switches.
6. To test the operating and repeating functions of repeaters and the outgoing junctions.
7. To test the ringing and tone equipment for satisfactory operation.
8. To test the subscribers' meters for correct operation.

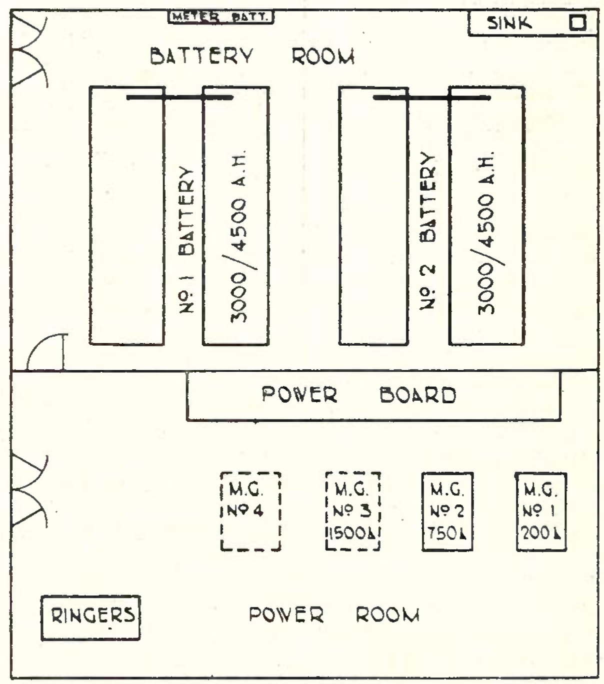
Q. 8.—(a) Draw a schematic power circuit suitable for an automatic main exchange. The plant is required to provide initially for a consumption of 5,000 A.H. per day, and ultimately for 10,000 A.H. per day.

(b) Draw a typical layout of the battery and power rooms for the exchange referred to in (a). List the capacities or ratings of the plant shown in the layout.

(c) Describe the main features of an automatic voltage regulator for controlling the output of a motor-generator.

A.—(a) See Telecommunication Journal, Vol. 3, No. 5, page 273, Fig. 6.

(b)



Q. 8, Fig. 1.

(c) See Telecommunication Journal, Vol. 3, No. 5, page 270.

Routine Test	Performance on Equipment	Frequency
1. Off Normals and permanents	Group Selectors and Final Selectors	Three times daily
2. Urgent Alarm Signals	Exchange Equipment	Daily
3. Switch and Trunk Test	Uniselectors	Trunks every two weeks (a proportion daily)
4. Internal trunk testing	Trunks from all Bi-motional switches	Trunks from all switches every two months (a proportion daily)
5. Operating or performance tests	Group selectors and Final Selectors	Twice weekly (a proportion daily)
6. Junction tests	Repeaters	Daily
7. Ringing and tone performance test	Ringing, busy and tone equipment ..	Daily
8. Register performance test	Subscribers' registers	Half-yearly

EXAMINATION No. 2492—MECHANIC, GRADE 2, TELEPHONE INSTALLATION AND MAINTENANCE.

M. A. Bowden.

Q. 1.—State what tests should be applied to a final selector in order to ensure that the switch functions correctly. How often should these tests be carried out?

A.—(a) Loop Test.—To prove operation of relays A and B and the return of "Earth" to the release trunk to hold the connection.

(b) Impulsing.—To prove the vertical and rotary movements of the switch under both short line and long line conditions.

(c) Test for busy.—And the transmission of the busy signal to the caller.

(d) Ringing test.—Ringing current to the called line and ringing signal to the caller.

(e) Ring Trip and Reversal.—Ring cut off immediately called number answers. Battery reversal to calling line and registration of call.

(f) Wiper Cords.—For correct polarity and freedom from fractures likely to cause noisy speaking conditions.

(g) Continuity of speaking circuit.

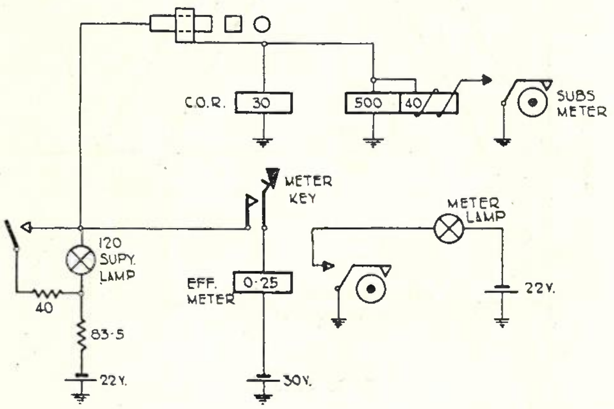
(h) Switch Release.

The tests are required to be made twice weekly and are applied with the aid of Test Set No. 1.

See Telecommunication Journal Vol. 3, No. 3, February 1941, for a description of the Test Set and its operation.

Q. 2.—Describe with the aid of a circuit, the operation of a subscriber's meter in a C.B. manual exchange.

A.—The diagram shows schematically the sleeve circuit connections when a plug is in the jack of a C.B. subscriber's line.



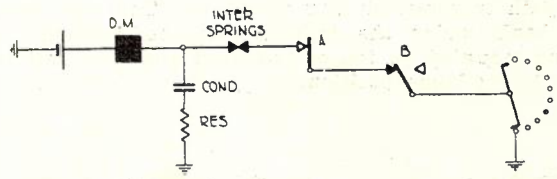
Q. 2, Fig. 1.

The cut off relay, 30 ohms, is in parallel with the 500 ohm winding of the subscriber's meter and the combination is in series with the supervisory lamp and an 83½ ohm resistance. Under this condition the cut-off relay operates, but insufficient current passes through the meter to operate it. During conversation the supervisory lamp is shunted by the 40 ohm resistance and, although the total current in the circuit is thereby increased, the meter does not operate. On completion of the conversation and before the connection is taken down, the telephonist depresses the meter Key. Circuit is completed, + batt. 30 ohm C.O.R. and 500 ohm meter winding in parallel, meter Key operated, 0.25 ohm effective meter, 30V meter battery. The current through the subscriber's meter is considerably increased and it operates. The effective meter does not operate until after the armature of the subscriber's meter has fully operated. At this stage a pair of contacts close to connect the 40 ohm winding of the meter in parallel with the 500 ohm winding. The effective meter now operates because of the increased current through it, and the meter lamp on the "A" position glows to indicate to the telephonist that the subscriber's meter has operated. The meter Key is then released and the connection taken down.

Suggested exercise—Calculate the current through the 500 ohm winding of the subscriber's meter under the various conditions mentioned.

Q. 3.—Why is a spark quench circuit included in the circuit of a subscriber's uniselector? Draw that portion of the circuit which shows the spark quench facility and describe its operation.

A.—A spark quench circuit is included to prevent undue sparking at the Drive Magnet interrupter spring contacts during the operation of the switch. Such sparking, if permitted, would quickly destroy the contacts. The spark quench facility consists of a condenser with a resistance connected as shown.



Q. 3, Fig. 1.

When the A relay is operated and the P wiper of the switch is resting on a busy bank contact, D.M. operates to step the wipers to the next contact. The interrupter springs open towards the end of the D.M. armature stroke. Stepping will continue so long as the P wiper tests "E" potential at a bank contact. The drive magnet D.M. is highly inductive and the back E.M.F. will cause sparking at the interrupter spring contacts unless provision be made to suppress it. When the contacts break, with a condenser and resistance connected as shown, the back E.M.F. of the magnet charges the condenser and the potential across the interrupter springs is reduced to safe limits. When the springs close again the condenser discharges through the contacts. The resistance in series with the condenser regulates the discharge so that there is no heavy rush of current immediately the contacts come together. Excessive current at this stage would tend to weld the contacts.

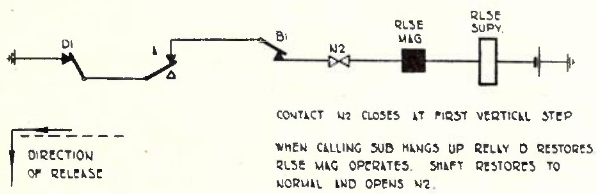
Q. 4.—Dialling takes place over two subscribers' lines, one of which has low insulation resistance and the other high loop resistance. What would be the effect on the impulsing circuit of a group selector in each of the above cases?

A.—Low Insulation Resistance will allow a small current to flow through the A relay continuously. The lower the resistance the greater the current. During impulsing under this condition the relay will operate more quickly when the dial contacts close, because of the initial tendency for the relay to operate and will release more slowly when the dial contacts break because of the residual current due to the low insulation. The effect of each is to increase the time during which the A relay is operated and, as a result, the impulse delivered to the switch magnet during the release period of the relay will be shortened.

High Loop Resistance will reduce the current through the A relay. The building up of the flux in the relay core will be delayed and, therefore, the relay will be slower to operate. Because of the smaller line current the relay core will not be fully fluxed and the release will be more rapid when the circuit is broken. The effect overall is to decrease the operated time of the A relay and, consequently, to increase the length of impulse delivered to the switch magnet. Both Low Insulation Resistance and High Loop Resistance cause distortion of the dialled impulses, and when either is excessive switch failure will result.

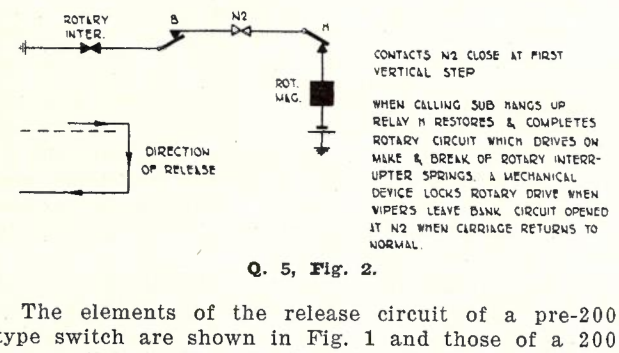
Q. 5.—Compare the release circuits of a 2000 type and a pre-2000 type group selector. Illustrate your answer with diagrams.

A.—The pre-2000 type group selector has a release magnet, the sole function of which is to bring about the release of the switch when the holding circuit is broken. The operation of the magnet armature restores the double dog which holds the shaft in the operated position. The shaft and wipers restore to normal over the path traversed during operation. The wipers leave the bank under the influence of the tensioned cup spring mounted on top of the shaft and the shaft then falls to its home position.



Q. 5, Fig. 1.

The 2000 type switch has no release magnet. Release is effected by the further operation of the rotary magnet when the holding circuit is broken. The wipers are operated to the 12th rotary step free from the bank and the rotary drive is arrested. The shaft is disengaged and is free to fall. When the shaft drops to its lowest position it then rotates the wipers below the bank contacts under the influence of the shaft cup spring to restore the carriage and wipers to the home position.



Q. 5, Fig. 2.

The elements of the release circuit of a pre-2000 type switch are shown in Fig. 1 and those of a 2000 type switch in Fig. 2. For full descriptions of the circuit operations see Course of Technical Instruction, Telephony III, papers 8 and 10.

EXAMINATION No. 2432—MECHANIC, GRADE 2, BROADCASTING

J. F. Ward, B.Sc.

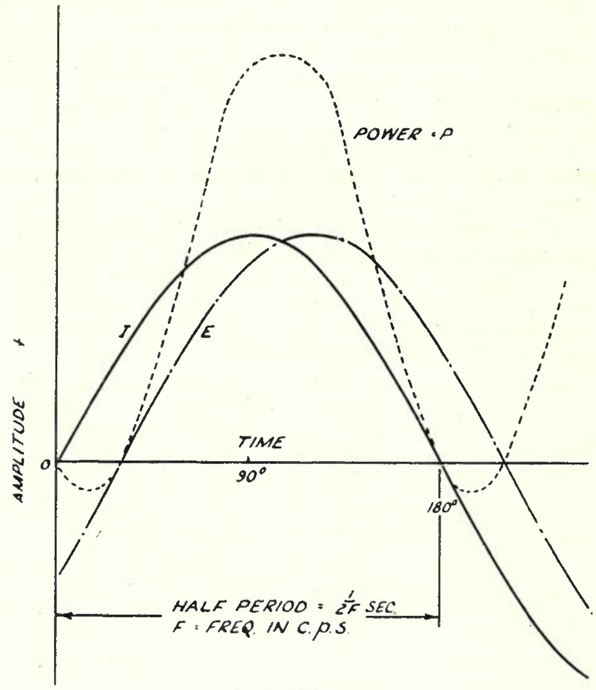
SECTION "A"

Q. 1.—(i.) Explain the term "phase angle" as applied to sine-wave voltages and currents in A.C. circuits.

(ii.) How is this expression used in determining the power in an A.C. circuit?

(iii.) What do you understand by the term "Wattless current," and under what conditions may it occur?

A.—(i.) The magnitude of a sine-wave voltage or current varies from an algebraic minimum to maximum with time. By regarding the period of one complete cycle of these quantities as equivalent to 360 electrical degrees the "electrical angle" of a current or voltage can then be used as a measure of the actual magnitude of the quantity at the instant concerned. The "electrical angle" is referred to as the phase angle of the voltage or current relative to an arbitrary common origin. It occurs most commonly in practice, however, as indicating the difference in phase between voltage and current in an electrical circuit. This is illustrated in Fig. 1, where the current is leading in phase by 30deg. on the voltage.

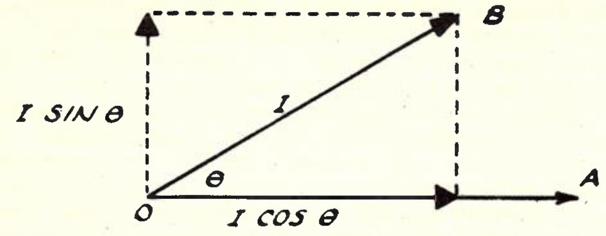


Q. 1, Fig. 1.

The power at any instant is the product of the voltage and current at that instant, and has been drawn also. By a consideration of Fig. 1 it is also clear that the phase difference between voltage and current can be expressed as the angle in degrees equivalent to the time interval between corresponding current and voltage maxima or minima.

(ii.) In any electrical circuit the power expended is the product of the R.M.S. voltage by the R.M.S. current in phase with it. Let OA, Fig. 2, represent the R.M.S. voltage and OB the R.M.S. current leading the voltage by a phase angle θ in the A.C. circuit, then the current in phase with the voltage E is I cos θ and the power expended in the circuit is

$$W = E \times I \cos \theta.$$



Q. 1, Fig. 2.

The term **Cos θ** is known as the power factor. In any A.C. circuit then the power expended is given by the product of the voltage, the current and the cosine of the phase angle between them.

(iii.) Further Fig. 2 indicates that a component of the current of magnitude I sin θ has a phase angle of 90deg. with respect to the voltage. Now if Fig. 1 is redrawn with a phase angle of 90deg. between the voltage and current it will be seen that the resulting power curve is as much positive as negative, i.e., the resultant power in the system is zero. The current I sin θ producing this fictitious power E × I sin θ is called the Wattless Current. Actually, under these conditions, during one half of the cycle energy is stored up in the electro-magnetic field associated with any inductance in the circuit or as electrical charge, if capacity exists, and during the succeeding half cycle is returned to the circuit by the field or from the condenser.

Q. 2.—What do you understand by the terms "Condenser" and "Capacitance"?

A variable condenser having a capacitance of 1,000 micromicrofarads is charged to a P.D. of 100 volts. The plates of the condenser are then separated until the capacitance is reduced to 300 micromicrofarads. Would you expect the P.D. across the condenser to have changed, and, if so, by how much?

A.—Any two electrically conducting surfaces separated by a non-conducting medium, and to which a potential difference can be applied, constitute a simple condenser. The application of the potential difference between the surfaces (or plates) creates an electric field in the medium (or dielectric), electric stress is set up therein, and energy is stored.

The quantity of electricity which is necessary to charge the condenser to a given potential difference depends on the dimensions and the spacing of the plates and on the type of insulating medium. These latter factors, together with the distance between plates, determine the "capacitance" of the condenser. The definition is best given as:

$$C = Q/V \qquad (1)$$

where Q = quantity of electricity taken to charge the condenser.

V = potential difference between its plates.

C = capacitance of the condenser.

For Q and V measured in coulombs and volts respectively the capacitance of a condenser is expressed in farads, and this is the practical unit of capacitance. The unit commonly used is the microfarad, which is $10^{-6} \times$ Farad.

With the system described above it is found that the intensity of the electro-static field established between the plates for a given applied potential difference increases as the distance between the plates is reduced. Further, it depends also on the nature of the dielectric material.

The capacitance of a simple parallel plate condenser is:

$$C = \frac{K \cdot A}{4 \pi \cdot d} \qquad (2)$$

where K = S.I.C. of the dielectric (air = 1).

A = area of the plates.

d = distance between the plates.

Equation (1) indicates that for a given charge the voltage across a condenser increases as the capacitance is decreased.

The charge on the condenser for the values given is

$$Q_1 = C_1V_1$$
$$= 1000 \times 10^{-12} \times 100 \text{ coulomb.}$$

Now the capacitance changes to 300 $\mu\mu$F, but the charge remains the same.

$$\therefore V_2 = Q_1/C_2 = \frac{1000 \times 100 \times 10^{-12}}{300 \times 10^{-12}} \text{ volt}$$
$$= 333 \text{ volts.}$$

∴ The P.D. increases by 233 volts.

Q. 3—Define the term "Decibel."

An Audio Frequency Amplifier having input and output impedance of 600 ohms has a gain of 55 decibels; what will be the output power in milliwatts when a signal at a level of minus 42V.U. (42 decibels below 1 milliwatt) is applied to the input terminals.

Assuming the signal to be of sine-wave form, what would be the peak voltage developed across a 600 ohm load under the above conditions?

(Common log tables to be provided.)

A.—The decibel notation is used to specify the relative magnitudes of two powers. When the common logarithm of the ratio of any two quantities of power is unity, the difference in level between them is defined as one bel. The practical unit, the decibel, is one-tenth of this unit. For two electrical powers, then, P_1 and P_2, the difference in level in decibel is given by:

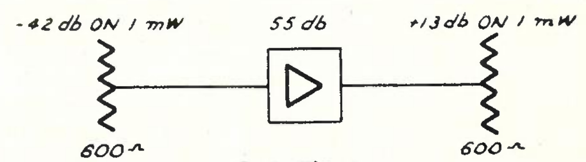
$$10 \log_{10} P_1/P_2.$$

If the impedance at both power levels is the same (both in magnitude and angle), say Z, then the difference in level can be obtained indirectly,

$$= 10 \log_{10} \frac{V_1^2/Z}{V_2^2/Z}$$
$$= 10 \log_{10} \left(\frac{V_1}{V_2}\right)^2$$
$$= 20 \log_{10} \left(\frac{V_1}{V_2}\right) \text{ db}$$

where V_1 and V_2 are the respective voltages. A similar relationship holds when the respective currents are used.

The conditions of the problem are indicated in Fig. 1.



Q. 3, Fig. 1.

Output power = (55 — 42) = + 13 db on 1 mwatt.

Let P_2 = output power in milliwatts

$\therefore 10 \log_{10} P_2 = 13$

$\therefore \log_{10} P_2 = 1.3$

$\therefore P_2 = \text{anti log } 1.3$

$= 19.95$ mwatt.

(**Note:** Alternatively the actual power input in milliwatts could have been calculated and then an output power in level 55 db above this found.)

Further:—

$$P = \frac{V^2}{R}$$

$$V = \sqrt{PR}$$

$$= \sqrt{\frac{19.95 \times 600}{1000}} \text{ R.M.S. Volts}$$

But:—

$$\text{Peak Volts} = \frac{\text{R.M.S. Volts}}{.707}$$

$$= \frac{\sqrt{19.95 \times 600/1000}}{.707}$$

$= 4.90$ volts.

SECTION "B"

Q. 4.—Certain radio frequency amplifiers behave normally at the lower end of the radio frequency spectrum, but break into oscillation at higher frequencies. Explain the probable cause and remedy.

A.—When the energy fed back in any way from the output circuit to the input circuit of an amplifying system exceeds the energy losses in that system, it is possible for oscillations to be set up. This applies both to multi-stage amplifiers and to those using a single stage only. The oscillations can be within or without the audio range. Now as the gain of radio frequency amplifiers is normally high (and is increased by regenerative feed-back) a small voltage from the output reintroduced into the input may rapidly increase in level till a condition of instability is reached. Furthermore, since the amplification of an R.F. amplifier varies with frequency in approximately the same way as does the current in a series-resonant circuit, the degree of stability of such an amplifier varies over the frequency range through which it is operated. The amount of energy fed back from the output to the input depends on the impedance of the feed-back path. If this is reactive it will vary with frequency, hence the stability of the amplifier depends on the frequency at which it is being used. For a capacitive reactance the impedance decreases as the frequency increases, so the liability of oscillation increases at the higher frequency part of the band.

The main source of capacitive feed-back is the inter-electrode capacity of the valve itself, of which the plate to grid capacitance (C_{pg}) is most important. The common method of overcoming this is by the use of screen grid tubes, the extra grid mounted between the normal grid and the plate reducing the capacitance to a negligible value. The other inter-electrode capacitances are reduced by reducing the electrode dimensions. In the case of R.F. amplifiers in transmitters, triode tubes are normally used, in which case the inter-electrode feed-back is overcome by a system of neutralization. This in its simplest form is a method of introducing into the input, portion of the output voltage of equal magnitude but opposite phase to that fed back by the plate-grid capacitance. Other feed-back paths whose impedance will decrease with frequency are stray capacitive couplings between input (grid) and output leads and between components. These are reduced by suitable electrostatic shielding, by the use of earthed screens, or by better layout of components and wiring. As the input and output circuits of R.F. amplifiers will be normally tuned they have considerable associated electro-magnetic fields. The effectiveness of the screening to prevent coupling between input and output due to these fields depends also on the frequency of operation since the eddy currents produced in the conducting material of the shield play an important part here. Minimising oscillation from this cause is a matter of good circuit layout and adequate shielding with suitable conducting metal.

Oscillation due to the R.F. energy feed-back via common impedances, e.g., high tension supply, screen grid dropping resistors, and cathode bias resistors, is reduced by suitable by-pass condensers or networks, which become more effective as the frequency rises and so tend to increase the stability.

Q. 5.—(i.) What is a "Pentode" valve, and in what position in an amplifier is it chiefly used?

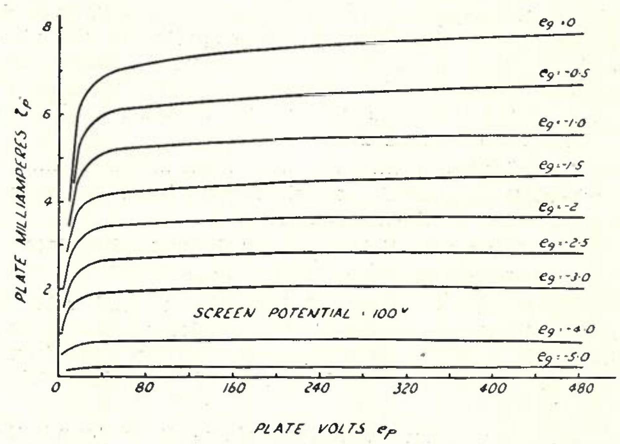
(ii.) Describe the functions of the various electrodes.

(iii.) Draw a typical anode current versus anode voltage curve for a Pentode, and comment on the shape.

A.—(i.) A "Pentode" valve is one containing five electrodes. Normally it is A.C. operated, in which case an indirectly heated cathode is used. The electrodes are then the cathode, control grid, screen grid, suppressor grid, and plate. Pentode valves can be used as voltage or power amplifiers in audio or radio frequency circuits. In a multi-stage amplifier they would normally be used in the initial and early stages to give sufficient voltage amplification to drive the power amplifier output stage. Pentodes are commonly used as intermediate frequency amplifier tubes in radio receivers, and are suitable also for audio output tubes. The output impedance of a pentode is, generally speaking, high.

(ii.) Refer to Telecommunication Journal of Australia, Volume 4, No. 1, page 57.

(iii.) The plate current plate voltage characteristic of a typical pentode used as a voltage amplifier with a given screen voltage of 100 volts is shown in Fig. 1.



Q. 5, Fig. 1.

Clearly from these curves, if the plate potential is greater than the screen potential, the plate current is practically independent of plate potential, and this is especially so for the greater negative values of grid bias. Further, the addition of the suppressor grid has eliminated the kink in the plate characteristic which is present in the corresponding characteristic of the screen grid tube owing to secondary emission from the plate. This allows the grid voltage variation to be greater and thus the resulting plate voltage variation to take place over a greater portion of the plate characteristic curve, thereby giving greater power output and allowing the pentode to be used as a power amplifier.

Since the changes in plate voltage have comparatively little effect on the plate current, the A.C. resistance r_p of the tube which is given by $\Delta e_p / \Delta i_p$ is effectively very high. But $\mu = g_m \times r_p$ where μ is the amplification factor and g_m the mutual conductance of the tube, hence the higher r_p becomes the higher is the amplification possible from the tube. This is the feature of the pentode which makes it possible to obtain much greater amplification than with a triode for equal plate voltage.

Q. 6.—Explain why some types of electrical machinery are liable to produce interference with radio reception.

How is such interference transmitted?

Indicate any method or methods of suppressing interference from small direct current motors.

A.—Any electrical machinery which generates by any means electro-magnetic waves of sufficient intensity within the tunable frequency range of a receiver will produce interference. Further, if any interfering field thus produced is of the same frequency and of comparable intensity to a desired signal, it is impossible to separate the two by any tuning, filtering, or other circuit arrangement within the receiver.

The two most common origins of spurious unwanted electro-magnetic waves are:

(i) The rapid change of current direction which takes place in armature coils of D.C. motors during commutation. This current change produces a magnetic field variation corresponding to a source of high frequency electro-magnetic radiation.

(ii.) Sparking or arcing associated with ignition systems, arc-welding plants, diathermy equipment and between brushes and commutator of D.C. motors.

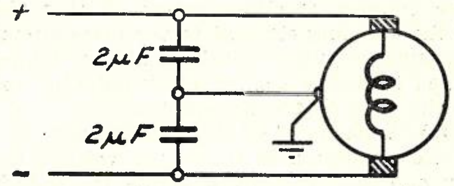
Once produced, this radiation is transmitted to the point of reception by one or more of four alternative paths:—

(i.) Direct radiation from the source to the aerial of the receiving equipment. This method is important only over short distances.

(ii.) Direct conduction via the mains. This is applicable only in mains operated equipment. The input to a receiver is often unbalanced using the power earth as the low potential point. If the mains themselves are acting as an aerial system so far as the interference is concerned it is therefore possible for an interfering potential to be injected directly into the receiver input. Generally speaking, this is not of great importance in comparison to mains radiation.

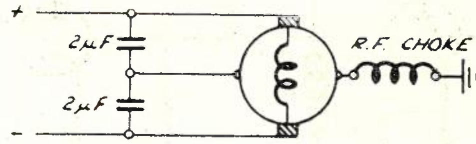
(iii.) Mains Radiation: In this case, the radio frequency energy is conducted via the mains and then radiated from the house wiring which acts as a reasonably good transmitting aerial. This interference is then picked up directly in the receiver aerial by capacitive coupling.

(iv.) Re-radiation: This is the general case of (iii.) and can take various forms. Often re-radiation and mains conduction are both necessary to produce an eventual interference in a particular region.



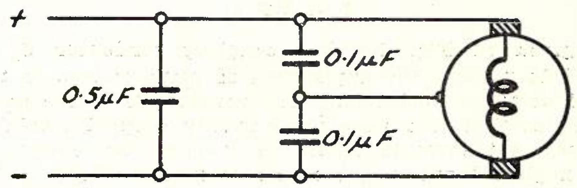
(a)

Q. 6, Fig. 1a.



(b)

Q. 6, Fig. 1b.



(c)

Q. 6, Fig. 1c.

Interference from a small D.C. motor could be due to either the rapid change in current direction in the armature windings due to commutation or to excessive sparking at the brushes. The remedy is primarily to prevent the radio frequency voltages from reaching the mains, and to a lesser extent to reduce the production of radiation in space by suppression of the sparking. This is done most effectively by providing close to the motor low-impedance by-paths for the radio frequencies by using condensers connected across the brushes as shown in Fig. 1.

The radio frequency choke in the lead for earthing the frame of the machine, see (b), is helpful when assymmetrical r.f. voltages exist. When the frame of the motor is not earthed the arrangement of (c) is used to prevent large currents flowing from frame to earth under certain circumstances, since under the above conditions the frame potential w.r.t. earth can be equal to half the mains voltage, assuming, as is usually the case, that one side of the mains is earthed.

Other preventatives which might be employed in certain cases, but which are, generally speaking, not as efficacious as the above method, are:

(a) Fitting suppressor chokes in the mains.

(b) Shielding the receiver input and using a screened aerial feeder.

SECTION "C"

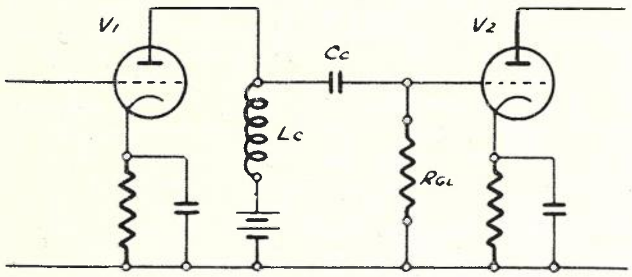
Q. 7.—Describe with circuit diagrams the principles of operation of choke-capacity coupled, transformer coupled, and resistance-capacity coupled audio frequency

amplifiers. How do the characteristics of each type vary with frequency?

A.—A requirement which is common to all types of impedance coupled amplifier stages is that the impedance of the coupling element in the plate circuit of the first tube must be sufficiently high at the frequencies to be amplified to derive a satisfactory potential to ground to drive the grid of the second tube.

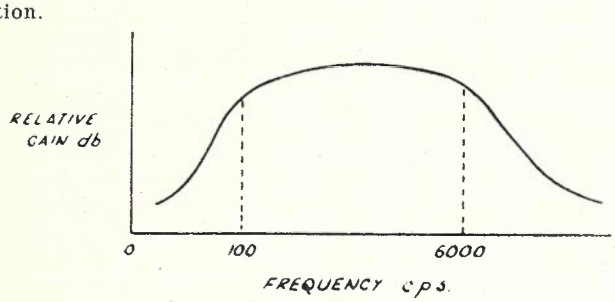
(a) **Choke-capacity Coupled Amplifiers.**

These are amplifiers in which the voltage to be amplified by one tube is derived across the inductive impedance of a choke in the plate circuit of the preceding tube. The essentials of the arrangement are shown in the schematic circuit Fig. 1, whilst a typical response



Q. 7, Fig. 1.

is given in Fig. 2. The coupling condenser C_c is used to prevent the application of plate voltage to the grid of the second tube. The response is of the same form as that of a resistance-capacity coupled amplifier in which the reactance of the coupling condenser can be neglected within the range of amplification. The low frequency response depends on the reactance of L_c in relation to the parallel equivalent resistance of the plate resistance of V_1 and grid leak resistance R_{GL} of V_2 in parallel. The upper frequency at which the response begins to fall off depends on the ratio of the total reactance of the stray capacities to this same equivalent resistance. The fact that the plate circuit choke carries the D.C. plate current is an undesirable feature, due to possible distortion produced by saturation.

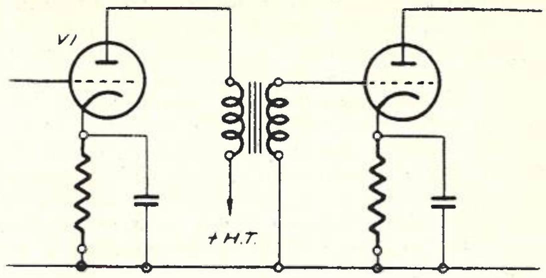


Q. 7, Fig. 2.

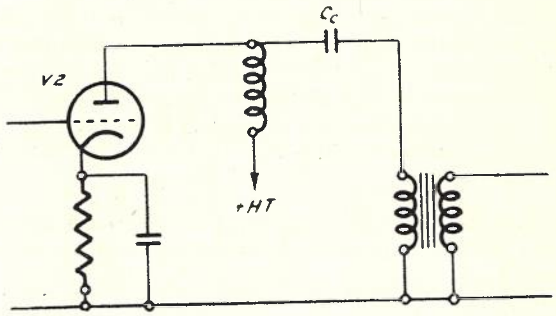
(b) **Transformer-coupled Amplifiers.**

Here the load impedance across which the amplified voltage is developed is a step-up transformer which delivers its secondary voltage to the grid of the succeeding tube. The circuit schematic is indicated in Fig. 3. In (a) and (b) of this figure both direct and shunt feed arrangements are shown.

In this method there is a falling off in amplification at low frequencies because of the insufficient primary inductive reactance. At high frequencies the gain is controlled by the action of the stray capacity in the second stage series resonating with the leakage inductance of the transformer. The Q of this resonant

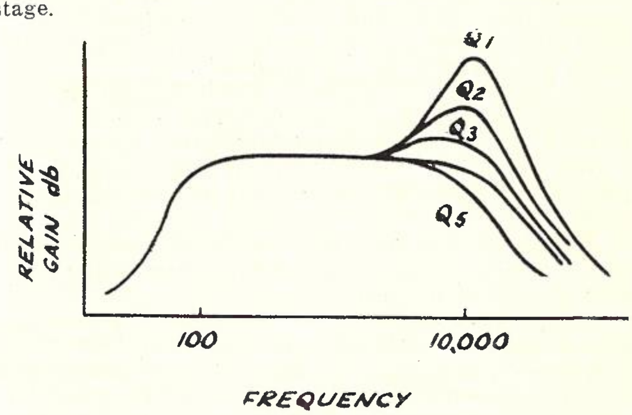


Q. 7, Fig. 3a.



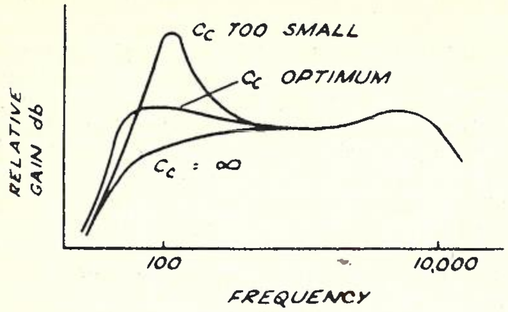
Q. 7, Fig. 3b.

circuit determines the shape of the high frequency response. The desirable characteristics of the transformer are thus high primary inductance to give good low-frequency response, high step-up ratio to give large amplification, and low leakage inductance and low distributed capacity to extend the response to high frequencies. Typical response characteristics for various values of secondary circuit Q are indicated in Fig. 4. The most common use of transformer coupling is in driving a push-pull stage from an unbalanced amplifier stage.



Q. 7, Fig. 4.

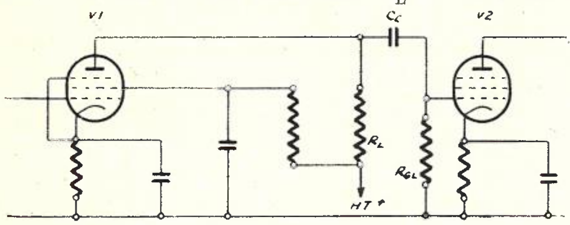
The shunt-fed modification of Fig. 3b, in which the plate current is prevented from flowing in the primary of the transformer, is capable of yielding a superior response characteristic. Resonating the coupling condenser with the transformer primary inductance whilst controlling the value of the load inductance enables the low frequency response to be adjusted independently of the high frequency response in a manner indicated in Fig. 5.



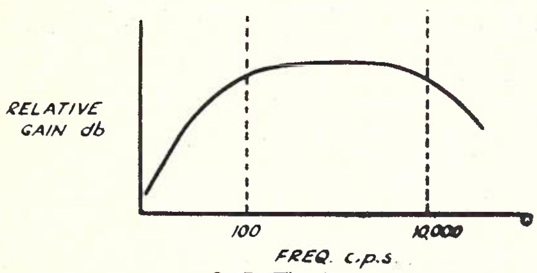
Q. 7, Fig. 5.

(c) **Resistance-capacity Coupled Amplifier.**

This is the most commonly used form of audio voltage amplifier. The basic circuit is shown in Fig. 6. In this method the amplified voltage of the first tube developed across a load resistance R_L in its plate circuit is applied through a coupling condenser C_c to the grid of the succeeding tube. The value of the grid leak resistance R_{GL} must be of the same order as R_L to ensure that the equivalent load in the plate circuit of V_1 is kept high.



Q. 7, Fig. 6.



Q. 7, Fig. 7.

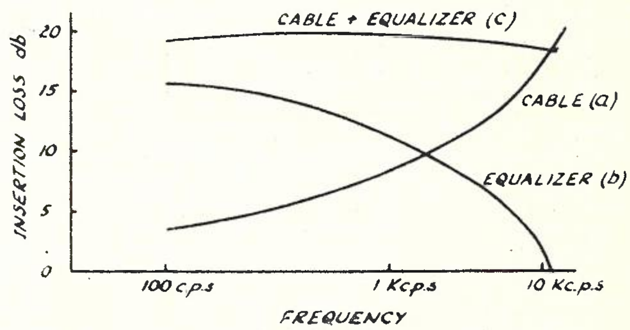
The screen and cathode by-pass condensers are normally made large enough to allow the impedance of the screen and cathode circuits to be neglected. Under these conditions the amplification varies with frequency as in Fig. 7.

The amplification at the high frequencies falls off because of the shunting capacity represented by the plate-cathode capacity of the first tube plus the input capacity of the tube to which the voltage is applied, plus incidental capacity from the wiring. The falling off at low frequencies is caused by the loss of voltage due to the rising impedance of the coupling condenser C_c.

The variation to the shape of the response characteristic with variation of R_L, R_{GL}, and C_c, is indicated in Fig. 8.

Q. 8.—Why is it necessary to insert an equaliser in a telephone line which is to be used for the transmission of broadcast programmes between a broadcasting studio and the transmitting station? State at which end of the line the equaliser should be located, and give your reasons for this preference.

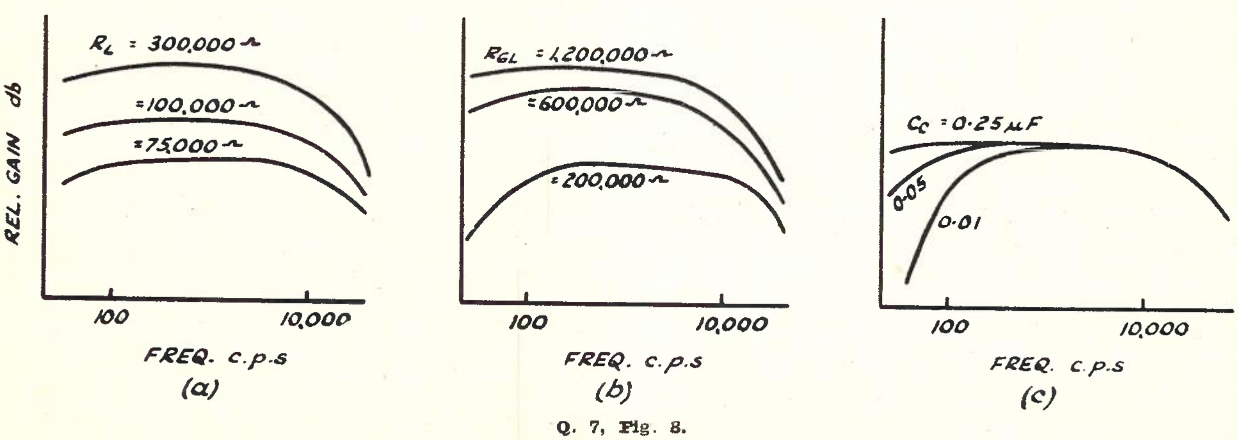
A.—One object of high fidelity broadcasting is to produce the same ratio between the amplitudes of the high and low frequencies of a programme at the receiver output as exists at the microphone input. As all studio and station equipment is designed to have a flat frequency response over the desired range the characteristic of the programme line and associated line equipment, if not flat, must be corrected or "equalised" (by an appropriate network) to become so.



Q. 8, Fig. 1.

In Fig. 1 a typical response curve for a cable programme channel is given.

The cable has a capacitive reactance, therefore attenuating the higher much more than the lower frequencies. The equaliser would then be a network designed to have an inverse response to this as shown in curve (b) of Fig. 1, making the overall response

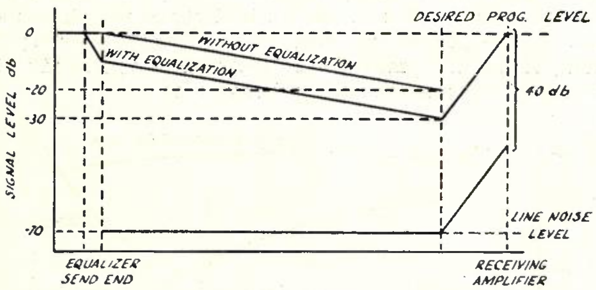


Q. 7, Fig. 8.

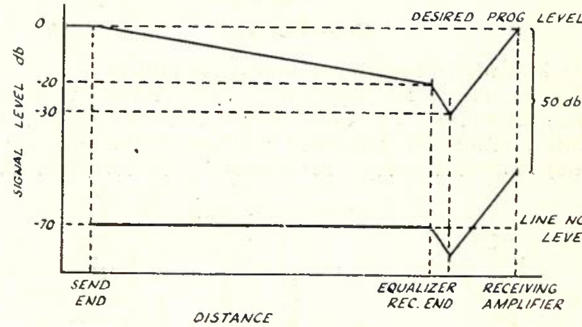
of the cable with its equaliser in series appreciably flat as shown in curve (c) of this figure.

The equaliser would be inserted in the receiving end of the programme line to enable the highest ratio of useful signal to programme line noise to be maintained. The reason for this becomes clear from a consideration of the power level diagrams of Fig. 2, in which (a) relates to the case of the equaliser at the sending end of the line, and (b) to that of the equaliser at the receiving end. For simplicity, these diagrams apply to one particular frequency of transmission only, and assume the equaliser has an insertion loss of 10db at that frequency.

In the first case the signal to noise ratio at the sending end is reduced from 70db. to 60db, because the introduction of the equaliser results in a 10db. lower level input to the line. With the programme line insertion loss of 20db. this leaves a signal to noise ratio of only 40db. at the receiving end since the line noise level at the receiving end of the line has been unaffected by the insertion loss of the equaliser at the sending end. For the second case the signal to noise ratio at the receiving point is now 50db, and this is retained when the equaliser is inserted since both the noise and the signal suffer an equal further attenuation of 10db each. Of course, since the insertion loss of the equaliser is less at the higher frequencies the amount by which the signal to noise ratio is preserved, in using the equaliser at the receiving or low level end, decreases as the frequency rises in the same way, but at all frequencies the improvement justifies introduction at the receiving end. A further factor is that if the equaliser is inserted at the sending end of the circuit any response measurements must be made, including the equaliser, and as the levels are then not directly related to the amplifier output the possibility of unknowingly overloading the amplifier exists.



Q. 8, Fig. 2a.



Q. 8, Fig. 2b.

Q. 9.—What steps would you take to ensure that a secondary battery is maintained in good working order? Give brief reasons for the precautions which you would observe.

A.—Question completely covered by reference to the following sources:

(1) Course of Technical Instruction. P.M.G. Dept. Applied Electricity 11, Paper No. 1.

(2) Maintenance Circular No. 33.

(3) Telecommunication Journal of Australia, Vol. 4, No. 1, page 55.

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