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AN OUTLINE OF THE DEVELOPMENT OF TELECOMMUNICATION SERVICES BETWEEN AUSTRALIA AND PLACES OVERSEAS—PART 1

J. C. Harrison

Introductory: The possibility of arranging for Australia to be connected with Europe by a submarine telegraph cable was discussed in this country as early as 1857, that is, three years after the first telegraph line had been erected in Australia, between Melbourne and Williamstown. Definite action to secure the benefits associated with such a system was not taken, however, until 1869.

In 1859, only five years after the erection of the first overhead land line in Australia, communication was established between Victoria and Tasmania by means of a submarine cable across Bass Strait. This cable was laid by the Governments of Victoria and Tasmania, from Cape Otway to King Island, land line across that island, submarine cable from King Island to Three Hummocks Island, thence to Circular Head, and from Circular Head to Low Head. The cable was composed of a single conductor of No. 16 gauge, and armouring of No. 8 gauge iron wires; its weight represented slightly more than two tons per mile, and it cost approximately £53,000. Within a few weeks of it being laid a break occurred, and thereafter frequent interruptions were experienced. Communication was completely interrupted on April 28, 1860, as a result of a fault in the King Island-Circular Head section, and as attempts to effect repairs were not successful, the cable was abandoned.

Ten years later another submarine link was laid between Victoria and Tasmania over a different route, namely, from Flinders (Victoria) to Low Head, near the mouth of the River Tamar, by the Telegraph Construction and Maintenance Company, at a cost of £70,000, in accordance with an agreement between that company and the Tasmanian Government, the latter undertaking to pay the company a subsidy of £4,200 annually. The rights of the company were subsequently transferred to the Eastern Extension Company, which laid a duplicate cable across Bass Strait in 1885 at a cost of £31,000. An agreement made between the latter company and the Tasmanian Government on 14/3/1889 provided that the subsidy mentioned should be limited to a period of 20 years. The Tasmanian authorities also undertook to guarantee the company revenue from traffic receipts to the extent of £5,600 yearly. The agreement referred to remained in operation until April 30, 1909.

The Commonwealth Government opened negotiations with the company in 1902 for the purchase of these two cables between Tasmania and the mainland, but as the price asked by the company was deemed excessive, tenders were invited for the laying of two new cables between Flinders and Low Head, a contract being placed eventually with Siemens Bros. and Company Ltd., London, for £52,447. The new cables were opened to the public on May 1, 1909, the day after the expiration of the agreement with the company, adoption of this arrangement resulting in the Commonwealth effecting substantial economies, as well as providing an improved grade of service to the public. The company subsequently picked up its old cables from Bass Strait.

It is of interest to review briefly the progress of submarine cable communications outgoing from England towards Australia in this early period. Cable communication between the United Kingdom and America was first established in 1858.

The first attempt to establish telegraphic communication between Great Britain and the Far East was made in 1858, by means of a submarine cable from Suez, through the Red Sea, and round the coast of Arabia to Karachi. The enterprise proved to be a most unfortunate one, the cable being soon injured by chafing on reefs, resulting in its early abandonment. In 1868-69, seven companies entered into an undertaking to provide submarine cable connections with the Far East, and communication was established between Great Britain and Bombay on 11/6/1870, thus enabling telegraphic communications to be exchanged between those points without being dependent on long landline routes via Turkey or Russia. Prior to this date an unsatisfactory and unreliable telegraph connection had been in use between Europe and India, via overland lines through Turkey and Persia, working in conjunction with an Indian Government cable through the Persian Gulf, established in 1864. Communication was extended to Singapore and Java in 1870, and to Penang, Hong Kong, and Saigon in 1871.

The promoters of one English company in 1859 despatched to Australia two representatives (Messrs. Lionel and Francis Gisborne), with a proposal to lay a light cable from the east end of Java, in five sections, to Moreton Bay (Brisbane), involving a distance of approximately 3,780 nautical miles, at an estimated cost of £800,000, subject to the Australian Colonial Governments either taking over and working the cables themselves, or guaranteeing net receipts up to 6 per cent. on the capital outlay. After extended negotiations, the Victorian Legislature in 1860 passed resolutions approving of a subsidy limited to £13,000, subject to certain conditions, and the New South Wales Government also agreed to a subsidy of £9,625. The cable proposed was of the same type, but rather heavier, than the first submarine link laid between Suez and Bombay in 1858, but that cable had soon failed, like the first Atlantic link. The negotiations between the promoters and the State Governments continued for several years, without finality being reached. In reporting on this scheme in 1859, Sir Charles Todd, then Superintendent of Telegraphs and Government Astronomer for South Australia, stated that he thought it probable that an overland route from Adelaide to Darwin would ultimately be found practicable, and Mr. John McDowell Stuart's return to Adelaide after having crossed the northern boundary of the colony on his explorations confirmed his opinion in that respect. Sir Charles opposed all schemes which involved any length of cable where land lines, which would tend to develop the country, were practicable. He urged that the erection of an overland telegraph line to the northern coast should be regarded as a national work, in which all the Australian colonies should participate.

In 1862, a proposal was put forward by the promoters of another British company for the laying of a network of cables to connect Rangoon, Singapore, Hong Kong, Java, and Moreton Bay, at an estimated cost of £2,080,000, the Australian colonies being asked to guarantee a subsidy of £50,000 per annum for 30 years. Sir Charles Todd vigorously opposed this scheme for terminating the cable at Brisbane, and advocated a scheme to bring a cable to Darwin, as Stuart's overland route was the best for a transcontinental line. His preference for that route to one round the head of the Gulf of Carpentaria was based on the fact that the north-west monsoons would be felt less on the overland track, and that almost perfect insulation conditions would be experienced in the dry interior. The proposition was not adopted. The fact that up to the end of 1866, out of approximately 20,000 miles of cable laid, about 50 per cent. of the whole had proved unsuccessful, gave rise to some natural hesitancy on the part of the Australian authorities towards this scheme.

The British Australian Telegraph Company put forward a plan in 1870 for the installation of a cable from Java to a point in the Gulf of Carpentaria, to connect with the telegraph system of the State of Queensland, then being extended to Normanton. The agent of this company, Captain Noel Osborne, however, on arrival in Adelaide, entered into an arrangement with the South Australian authorities for the proposed cable to be terminated at Darwin, subject to the South Australian Government undertaking to construct, at its own cost and risk, a land line connection across the continent from Darwin to Adelaide. By this time communication had already been established between London and Singapore, via Bombay and Madras, and also between Singapore and Java.

The South Australian Parliament decided, by Act No. 11 of 1870, to authorise the construction of the line, over a route 2,000 miles long, notwithstanding the difficult and arid nature of the country, and the fact that for a distance of over 1,400 miles it was not populated by white men.

An agreement was made between the company and the Governor of South Australia on August 29, 1871, under which the company undertook to lay a cable between Java or Singapore and Darwin, to be used for the purpose of telegraphic communication with Europe, the work to be completed by 31/12/1871. On its part, the Government of South Australia agreed to erect a telegraph line between Darwin and Adelaide. The engrossment included a stipulation that if the land line were not completed by 31/12/71, the company might lay down and complete and thenceforth maintain and use a telegraph line between its cable at Darwin and Burketown, either wholly overland or wholly in the sea, or partly overland and partly in the sea.

The agreement referred to provided that the company should charge for telegrams transiting the cable, rates not in excess of the ordinary current charges of the respective company for the like service, without preference or favour to any messages. The Government undertook to transmit promptly all messages that were delivered at either terminus of the overland telegraph line at such rates as were agreed upon between the Superintendent of Telegraphs and the company's manager. The overall rate agreed upon was £9/7/6 for 20 words.

The work of laying the submarine cable between Banjoewangie and Darwin was completed and communication established between Darwin and London on November 17, 1871.

In 1873, the British Australian Telegraph Company was amalgamated with the British Indian

Extension Telegraph Company and the China Submarine Telegraph Company, to constitute the Eastern Extension Australasia and China Telegraph Company Limited. In an agreement dated May 26, 1874, between the new company and the Governor of South Australia, the rights which had been conferred on the original company regarding the grant of free land for cable purposes at Darwin were transferred to the new company, which is referred to hereunder as the "Eastern Extension Company," that being the name by which it has been generally known throughout Australia for a period of 68 years.

Erection of the Adelaide-Darwin Overland Line: The construction of the Adelaide-Darwin line, over unfamiliar broad stony deserts, long stretches of sand hills, with long stages without water, and so sparsely timbered that it was necessary to transport iron poles and all supplies over greater distances, was a notable achievement. Moreover, all these difficulties had to be overcome within the relatively short period of eighteen months. The work was planned by Sir Charles Todd, who also directed the operations connected with the construction of the line.

The southern and central sections were constructed before the cable connection between Banjoewangie and Darwin was completed on November 17, 1871, but the northern section was not finished until nine months later.

During that period a horse express service was used, therefore, to convey messages across the gap in the land line sections until the electrical junction was effected on 22/8/1872, and the long overland telegraph line completed. On that day Sir Charles, while camped near Central Mount Stuart, and seated on the ground with a small pocket relay in his hand, received and acknowledged congratulatory messages from the Governor and Government of South Australia.

At the time the land line was completed, however, the submarine cable had become interrupted, and the fault was not removed until October 21, 1872. Since that date all the settled parts of Australia have enjoyed telegraphic communication with other parts of the world. Prior to 1900 there were, however, occasional breakages of the cables, and there have also been failures of the lines through meteorological and other causes.

During the 17-year period from 1872 to 1889, the earnings derived by the South Australian Government from the overland line represented £476,000. While this amount exceeded the working expenses for the period, £409,000, it was not adequate to cover the interest charges also, and the loss, exclusive of interest on the cumulative annual deficits, represented £282,000, while, after taking into account the interest on the annual deficits over the period, the total loss was equivalent to £398,000. Although the construction of the line did not produce dividends during this period, it conferred not only on South Australia, but the whole of Australia, the benefit of telegraphic communication with other parts of the world. Subsequently the financial position of the line improved with the development in the traffic load, following on the reduction in tariffs.

Duplication of the Darwin-Banjoewangie Submarine Cable: A duplicate cable was brought into use between Darwin and Banjoewangie on November 1, 1879, extended by a further submarine link direct to Singapore. This duplicate connection was established not because the single cable was inadequate for the transmission of the volume of telegraph traffic then offering, but in order to provide a greater measure of freedom from interruption to cable communication between Australia and Great Britain. The Governments of New South Wales and Victoria, by a covenant dated 6/5/1879, undertook to pay the Eastern Extension Company an annual subsidy of £32,400 for a period of 20 years, subject to the company laying the second cable between the points mentioned. Subsequently, the Governments of South Australia, Western Australia, and Tasmania became parties to the subsidy, the amount being divided between the States on a population basis. The Government of New Zealand was a signatory to this contract, but as the Parliament of that country refused to ratify the agreement, it did not actually pay any portion of the subsidy.

The installation of the Darwin-Banjoewangie-Singapore link obviated the need for the use of the Batavia-Banjoewangie land line, which had been subject to interruption, and, moreover, the repetition in this section gave rise to numerous mistakes in the transmission of the Anglo-Australian traffic, and particularly in telegrams containing code. In 1894 the Eastern Extension Company obtained a special wire between Batavia and Banjoewangie for transmission of international traffic by its own staff, when it was necessary to divert traffic to this route, and this innovation resulted in more efficient service.

The whole of the additional submarine link was completed by January, 1880, the cost being £537,000, as compared with £572,000 for the original cable. The subsidy continued from 1879 to 1899.

Between October 21, 1872, when through communication between all ports of Australia and London first became available, and November 1, 1879, when the duplicate cable was laid, only two major interruptions were experienced, namely, 38 days in 1877, and 18 days during 1879, making

EDITOR'S NOTE

Space does not permit a full description of the trials and difficulties which were met and surmounted during the erection of the overland telegraph line. It is intended, however, to publish a description of this notable feat in a subsequent issue of the Journal.

a total of 56 days, or an average of 7 days per annum. The interruption of 38 days in 1877, however, gave rise to a strong demand for the duplication of the system throughout its entire length, from Darwin to Penang. From the date of the duplication to the middle of 1900, communication was totally interrupted for a period of only 41 days in 20 years. The number of outlets now available for the transmission of telegrams to destinations overseas has so greatly expanded that complete interruption is nigh impracticable.

Unfortunately, an earthquake near Java buried the duplicate cable some time after it was laid, and although repairs were effected, the hopes that its installation would ensure continuity of communication were wrecked.

One of the Darwin-Banjoewangie cables was abandoned some years after the formation of the merger company in 1929, as it was no longer needed in the light of the other routes available.

Broome-Banjoewangie Submarine Cable: A third cable was laid between Java and Australia in 1889, by the Eastern Extension Company, the terminal points being located at Broome and Banjoewangie, the distance between these points representing approximately 970 miles. No subsidy was sought from the Governments for the provision of this additional facility, which was not actually justified from the point of view of the volume of traffic then being dealt with, the two cables in existence at the time possessing a large margin of traffic carrying capacity. It was, however, anticipated that the installation of this additional outlet would reduce the risk of total interruption to cable communication between Australia and places overseas. However, severe volcanic disturbances were experienced in 1890, both the Darwin-Banjoewangie cables being interrupted from June 11 to 20, and the Broome-Banjoewangie service being dislocated from June 11 to August 1. By an agreement made on June 30, 1889, between the Eastern Extension Company and the Governments of South Australia and Western Australia, the Government of the latter colony was guaranteed a minimum revenue of £1000 a year from traffic circulating over the new cable link. The indenture provided, however, that traffic to and from States other than Western Australia would be routed via Broome only when the other channels were interrupted. The cost of this cable represented £120,000. The introduction of this additional cable service not only brought an alternative submarine outlet into operation, but it also enabled an independent Australian land line system to be used via Broome-Perth-Albany-Eucla-Adelaide (total 2000 miles), during interruption to the Adelaide-Darwin route. The Broome-Banjoewangie cable was taken up in 1914, as it was no longer required with the other cables then in use. At the time the Broome-Banjoewangie cable was laid there was an alternative route available to Europe, beyond Singapore, via Hong Kong, Shanghai, and Vladivostock, by submarine circuits, partly belonging to the Eastern Extension Company, thence by land line across Siberia and European Russia to Libau, on the Baltic Coast, and by submarine cable to Newbiggin, in England.

Australia-New Zealand Submarine Cables: In accordance with an indenture made between the Governments of New South Wales and New Zealand and the Eastern Extension Company on June 24, 1875, the latter undertook to lay a cable between La Perouse, near Sydney, and Nelson, New Zealand, in return for a subsidy of £7,500 per annum for a period of ten years, two-thirds being borne by the Government of New Zealand and one-third by New South Wales. The agreement stipulated that the charge for telegrams transmitted over the cable should not exceed 7/6 for a message of 10 words, and ninepence for each additional word (the names and addresses of the addressees and senders being counted), and that the charge should be reduced to 5/ per message of 10 words and 6d. for each additional word when the traffic averaged 200 or more messages daily.

The cable was laid over its route of 1,262 miles, and communication established in May, 1876. When the subsidy expired, the New Zealand Government refused to renew it, and consequently the tariff was increased from 7/6 to 8/6 for a 10-word message. A duplicate cable was laid by the company in 1890 at its own expense, with the object of preserving continuity of service. A little later, the New Zealand Government, in consideration of a reduction of the tariff to 2/ for 10 words, agreed to guarantee the company an annual income of £20,000 from the cable, subject to the Government's subsidy being limited to £9,000 a year, and this arrangement remained in existence until 1900. In 1916 these cables were brought direct into Sydney via underground lines from Bondi. A third cable was laid between Australia and New Zealand by the Pacific Cable Board in 1912, but following on the formation of the merger company, one of the two cables between Sydney and Wellington was recovered and the second abandoned in 1935. The rates for messages between Australia and New Zealand were 4½d. per word in 1902, except as regards messages between the Dominion and Tasmania, in which case the tariff was 5½d. a word. Subsequently the tariff of 4½d. a word was applied to messages between the Island State and New Zealand.

Bundaberg-New Caledonia Submarine Cable: A submarine cable was laid and opened for traffic between Bundaberg and New Caledonia on October 18, 1893, in harmony with an agreement between the Governments of New South Wales and Queensland, and a French company known as the "Societe Francaise des Telegraphes Sousmarine," the name of which was subsequently changed to "Compagnie Francaise des Cables Telegraphiques." This indenture provided that the company should lay a submarine cable for the purpose of establishing telegraphic communication between Queensland and New Caledonia in consideration of the payment by the Governments mentioned of an annual sum for a period of 30 years, at the rate of £2000 a year each, or such smaller sum as would, together with one-sixth of the net sum received by the company for messages transiting the cable during the year, after deducting working expenses (not in excess of £2,400 a year), amount to £2,000 in each case. It stipulated, however, that the Government of each State should have the free use of the cable for Government messages up to a maximum value of £2,000 in each year. The company proposed to extend the service to Hawaii, Samoa, and places beyond, thus providing a second route across the Pacific. The company actually secured authority to land the cable at Hawaii, and the Government of the latter territory agreed to pay the company an annual subsidy of 25,000 dollars for 15 years, provided communication was established not later than 1/1/1894. The plan to extend communication was, however, abandoned. Regarding the section between Australia and New Caledonia, the payment to the company of the subsidy ceased in 1923, and, as the cable had become interrupted, it has since been abandoned, from which time traffic between Australia and New Caledonia has been transmitted radio-telegraphically.

Reduction in Rates for Telegrams between Australia and Great Britain up to 1900: The charge for telegrams between Australia and Great Britain was fixed in 1872 on the basis of £9/7/6 as for 20 words, the word rate thus being equivalent to 9/4½. The minimum charge was abolished in 1876, and the tariff fixed at 10/6 per word. The rate per word was reduced to 9/4 during 1886. The company was obliged to pay to other parties participating in the circulation of the traffic no less than 4/10 of the 9/4, the apportionment of charges being as indicated hereunder:

	s.	d.
Eastern and Indo-European Companies	2	11
Indian Administration		7½
Javanese Administration		1½
Eastern Extension Company	4	6
South Australian Administration	1	2
	9	4

Substantial reductions in the tariffs were effected in 1889, the rate being lowered from 9/4 to 4/ per word for ordinary telegrams, with corresponding modifications in the charges for Government and press telegrams. This outstanding development was brought about by an agreement, dated 31/3/1891, following on discussions at Intercolonial Postal and Telegraph Conferences held in 1890 and 1891, the Governments of New South Wales, Victoria, South Australia, Western Australia and Tasmania undertaking to pay the company a sum equal to half the amount by which the revenue of the latter might be less than the sum of £237,736 in any year after the reduced rates were applied, the sum mentioned representing the total receipts of the company during 1889. The agreement stipulated that the reduced rates should continue in force until the expiration of two months' calendar notice given by the Governments or the company.

The first year's payment by the Governments represented £27,520, and the second year's amounted to £21,778. It became evident that the reduction had been too great to permit the increase in the volume of traffic to offset the loss in revenue. The experiment might have been continued indefinitely but for the great banking and financial crisis which occurred at this time, and which seriously embarrassed the Governments. The latter, moreover, were faced with the possibility of even heavier losses in view of the decline in load.

The matter of the guarantee was, therefore, reconsidered by the Governments and the company, and as a result a modification of the arrangements was agreed upon, providing for a reduction in the guarantee figure to £227,000, a reduction in the Government guarantee to an amount not exceeding £10,000 per annum, and an increase in the tariff by 9d. a word for ordinary telegrams, without any increase in the rates for Government telegrams. On their part, the Governments agreed to exempt the company from taxes and Customs duties and wharfage rates on goods imported by the company in connection with its business.

It is noteworthy that the Queensland Government did not participate in the agreements with the company, on the ground that it was not good policy to do so, the introduction of a new route being favoured.

DEVELOPMENTS IN EXTERNAL TELECOMMUNICATION SERVICES SINCE 1900

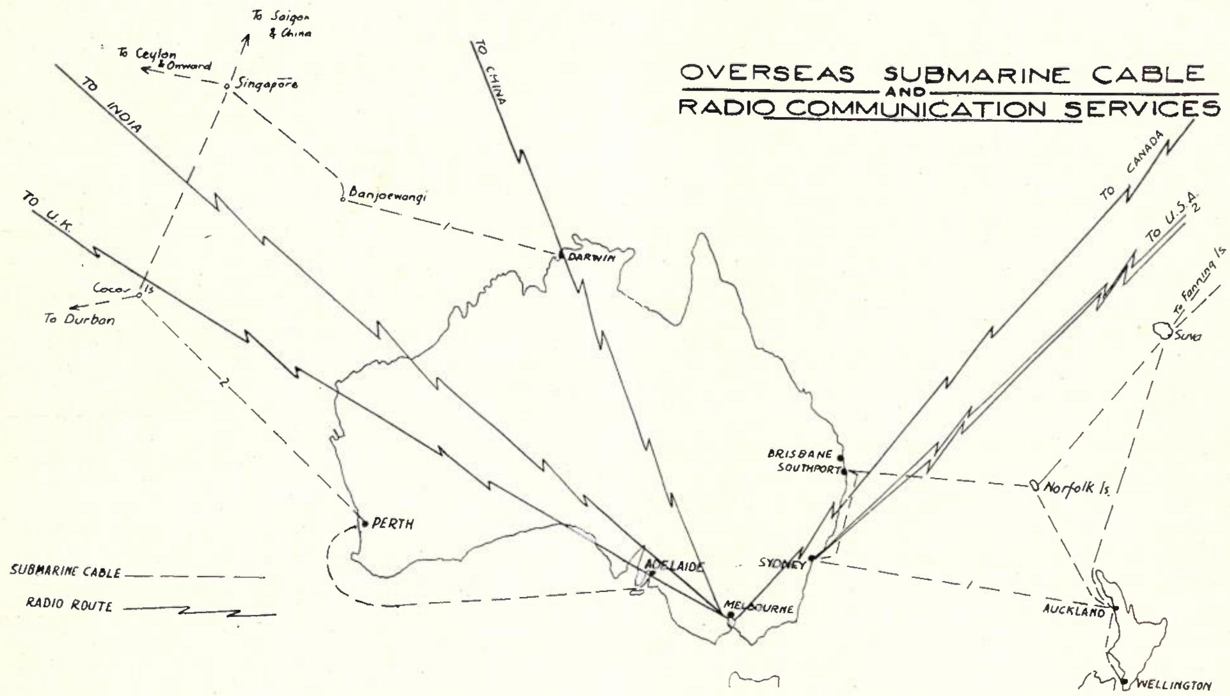
The developments in telecommunication services between Australia and countries overseas since 1900 have been phenomenal, and may be summarised briefly as follow:

(a) A number of alternative submarine outlets has been brought into operation.

(b) Revolutionary changes have been made in the design and method of operation of submarine cables, with consequential improvement in the speed of service.

(c) Great advances have taken place in radiocommunication technique, thus permitting the establishment of direct radio-telegraph services between Australia, the United Kingdom, Canada, the United States of America, India, China, and Fiji.

(d) Progressive reductions have been effected in the tariffs for telegrams between Australia and the United Kingdom from 4/9 to 1/3 per word for ordinary telegrams, together with the introduction of lower rates for telegrams expressed in plain language (deferred, and letter telegrams), notwithstanding that since 1900 there have been substantial increases in the costs for goods, services, and labour.



(e) Facsimile radiocommunication systems have been brought into use between Australia, Great Britain, and the United States of America, permitting reproductions of pictures to be effected within about 12 minutes.

(f) The substantial increase of 1,356 per cent. in the overseas telegraph load from 170,000 telegrams in 1900 to 2,475,000 messages in the year ended 30/6/1942.

(g) Telephonic communication has also been established over radioelectric links between Australia, Great Britain, the United States of America, and certain other places.

Each of these developments is discussed hereunder.

Adelaide-Cottesloe-Cocos Cables: In July, 1899, the Eastern Extension Company offered to lay an additional cable between Australia and South Africa as a strategic link, with a scheme of tariff reductions, commencing at 4/, and falling by steps of 6d. per word to 2/6 a word for ordinary rate telegrams, when the revenues from the Australasian traffic—less outpayments—averaged £330,000 annually for three consecutive years. Progressive reductions in the charges for Government and press messages were also proposed. In return, the company sought the right, on and after the opening for traffic of the Pacific cable—which was then projected—or any other competing cable, to open local offices and to collect direct from and deliver direct to the public in the capital cities; exemption from taxation; and the provision of a free line between Adelaide and Sydney as well as between Adelaide and Melbourne for the use of the company.

The Governments of South Australia, Western Australia and Tasmania accepted the company's offer, and entered into an agreement with the company on April 14, 1900. The Government of New South Wales executed a similar contract on January 16, 1901, notwithstanding the Queensland Government's strong protests that the arrangement would have the effect of postponing the construction of the Pacific cable, because of the competition which would be permitted under the agreements. The Victorian and Queensland Governments declined to become parties to the arrangement, and, therefore, telegrams originating in those States did not enjoy the benefit of the reductions in rates until some time after the creation of the Commonwealth.

By these agreements the company undertook to procure and lay a submarine telegraph cable between Durban and Australia in five sections: (i) Durban-Mauritius; (ii) Mauritius-Rodrigues; (iii) Rodrigues-Cocos; (iv) Cocos-Cottesloe, W.A.; (v) Cottesloe-Glenelg, S.A. The Durban-Cocos-Cottesloe sections were opened to traffic on November 1, 1901, and the Cottesloe-Glenelg link on March 1, 1902. The length of the Durban-Cocos-Cottesloe-Adelaide cable represents approximately 7,600 miles, and cost £1,750,000. In places it is located at a depth of 3,400 fathoms, which is 700 fathoms deeper than the waters in which the Atlantic cables are submerged, but this depth is moderate in comparison with parts of the Pacific. This project linked up with an additional cable between South Africa and Porthcurno, via St. Helena, Ascension, St. Vincent, and Madeira. The total length of the cable between Great Britain and Adelaide, via the Cape, represents approximately 15,000 miles. The new route, besides providing greater security of telegraph communication to both South Africa and Australia, also enabled telegraphic connections to be extended to certain British possessions which previously lacked telecommunication facilities, including Ascension, St. Helena, Rodrigues, and Cocos.

In 1909 a submarine cable was laid from Java to Cocos Island, thus affording another route from Australia to South Africa. The Cottesloe-Cocos Island cable was duplicated in 1926, when a modern high-speed cable was laid between these points.

Relations between the Eastern Extension Company and the Commonwealth: On the establishment of the Commonwealth, the current obligations and rights of the States with respect to the Department of the Posts and Telegraphs devolved on the Commonwealth, under Section 85 of the Constitution of the Commonwealth, and therefore the Federal Government assumed the obligations which the States had entered into in regard to cable communication with places overseas.

As mentioned earlier, the States of Victoria and Queensland were not parties to the agreements of 1900 and 1901, and consequently were not entitled to the benefit of the reduced rates provided for in those agreements. It was therefore arranged between the Prime Minister of the Commonwealth and the Eastern Extension Company in 1902 that, pending ratification by the Commonwealth Parliament of a proposed agreement with the Federal Government in substitution for those entered into by all States except Victoria and Queensland, telegrams originating in those States which were not parties thereto should receive the benefit of the reduced rates as from June 1, 1902; that the company should be permitted to open its own office in Melbourne as well as in Sydney, Adelaide, Perth, and Hobart, and that it should be given the exclusive use of a telegraph land line between Melbourne and Adelaide, as well as one between Sydney and Adelaide.

From June 1, 1902, therefore, the rate of 3/ per word was applied uniformly to messages between all offices throughout Australia and places in Europe.

In July, 1903, the House of Representatives ratified the agreement, which embodied a stipulation that it should remain in force until 1913, and thereafter until terminated by two years' notice by either party, but the Senate ordered the matter to stand over, pending the result of a conference of representatives of the Imperial, Canadian, New Zealand, and Commonwealth Governments, respecting the effect of existing and proposed agreements on the Pacific Cable undertaking. This conference, which met in London during June and July of 1905, expressed the hope that the Commonwealth Parliament would not ratify the agreement as it stood, and suggested several amendments. In December, 1905, the agreement was ratified by both Houses of the Commonwealth Parliament, subject to certain conditions, which, however, were rejected by the company. The chief objection raised by the latter related to the inclusion of a clause by the Senate providing for the definite termination of the agreement on December 31, 1913. The rejection by the company of the modifications suggested by Parliament resulted in the withdrawal of certain tentative concessions, which had been granted to it, pending the execution of the proposed agreement, including the privilege of collecting messages direct from the public in Melbourne, and consequently its office in that city was closed on April 3, 1903. The 1900 and 1901 agreements have therefore remained in force, subject, however, to further developments as outlined hereunder.

By an agreement dated 14/1/1916, between the company and the Postmaster-General of the Commonwealth, the company was permitted to open a local office in Melbourne, and to collect directly from and deliver directly to the public in Melbourne telegrams between Australia and places overseas. The Postmaster-General also agreed to provide a telegraph channel between Melbourne and Adelaide for the transmission of overseas traffic conditionally upon the company operating the circuit at its own cost.

THE PACIFIC CABLE SYSTEM

Following on the construction of the transcontinental telegraph line from Halifax to Vancouver in 1874, a proposal that a submarine cable should be laid across the Pacific Ocean was originated in about 1879. Mr. Sandford Fleming, Engineer-in-Chief of the Canadian Pacific Railway, was one of those who were most active in the matter.

It is interesting to note that in the early stages of the discussions, because of the absence of information concerning the Southern Pacific Ocean and the impression that physical difficulties presented insuperable obstacles to the laying of a cable on a direct route between Canada and Australasia, it was suggested that the cable should be laid between Vancouver and Japan, touching at islands in the Aleutian and Kurile groups, as mid-ocean stations. From Japan, connection to Australasia via the Eastern Extension Company's submarine network to Singapore and Darwin was proposed. Action was actually taken to obtain the necessary licences from the Governments concerned for the landing of the cable on the islands mentioned, and in 1881 the Canadian Parliament passed an Act incorporating a company to lay a cable on this basis, but the plan was abandoned. Later on, after further data had been obtained in regard to the Southern Pacific, the conclusion was reached that the physical features of that ocean would permit a cable to be laid on the direct route from Canada to Australia, thus obviating the long detour via Japan.

The Pacific cable project on this new basis formed the subject of discussions at the Colonial Conference held in London during 1887, and resolutions were carried favouring adoption of the plan.

Early in 1893 a Postal and Telegraph Conference, which was held at Wellington, New Zealand, and at which all the Australasian Colonies were represented, indicated its approval of the establishment of a Pacific cable.

For a number of years the Canadian authorities had urged the establishment of direct cable communication between Canada, Australia, and New Zealand, with the object of developing closer commercial relations between those countries. At the Australian terminal, the Queensland Government, quite naturally, strongly favoured the project of a direct line, because Queensland would be the first point of contact in Australia.

At a Colonial Conference which took place at Ottawa in 1894, and at which the Imperial Government, the Canadian, South African, and all the Australasian Governments were represented, the Pacific cable project was supported, and the Canadian Government was requested to call tenders for the work. When these tenders were received they indicated that the work could be undertaken at a much lower cost than had been anticipated.

Strong support for the project had been developing in the meantime, particularly in Canada, Australia and New Zealand, and in May, 1895, the Association of Chambers of Commerce of the United Kingdom, representing 88 Chambers, arranged for a numerous and influential deputation from the association to wait on the Prime Minister of England to urge action to establish "All British" postal and telegraph routes within the Empire.

The scheme was further discussed at a Post and Telegraph Conference, which was held at Sydney in January, 1896, and at which all the Australian Colonies and New Zealand were represented. This conference favoured the plan, and expressed the opinion that the Pacific cable should be constructed and owned by the Governments concerned, and that the cable should land only on British territory. The South Australian representative indicated that his Government was willing to join in the project, provided that a guarantee was given that the financial position of South Australia as regards the Adelaide-Darwin line would be maintained on the basis of the average of the previous five years. One of the reasons why the Governments of the Eastern States were anxious to see a cable landed on the Pacific seaboard was that on occasions the overland land line was subject to interruptions extending over more than 24 hours, and it was thought that it might be advantageous to avoid the use of the land line. In this connection, it might be mentioned that at the Intercolonial Postal and Telegraph Conference, held in Hobart in 1898, the following resolution was carried:

"This Conference has heard with satisfaction from the representative of South Australia of the intentions of the Government to take immediate steps for the improvement of the overland telegraph line, and urges him to impress on his Government to lose no time in effecting the improvement suggested, and hopes that the West Australian Government will take similar steps with regard to its overland line."

The Imperial Government, in June, 1896, appointed the Pacific Cable Committee, comprising in all six members, including the Agents-General for New South Wales and Victoria and the High Commissioner of Canada, to inquire into the practicability of the Pacific Cable project from the technical viewpoint; as to what route should be selected for the cable; as to the cost of installation, maintenance and annual working expenses; estimated revenue from traffic; and as to whether the cable should be owned and operated by the Government or by a subsidised company. The Committee was not, however, asked to report on the necessity for the cable.

After hearing extensive evidence from experts, the Committee supported the proposal as a practicable proposition and recommended the route which was eventually chosen. The estimated capital cost was set down at from £1,500,000 to £2,000,000; the annual working expenses at £22,000 and the revenue £75,000. The Committee favoured ownership and operation of the installation by a Board comprising representatives of all the Governments concerned.

After the exchange of a considerable volume of correspondence agreement was ultimately reached between the Governments concerned in regard to the ownership and form of management of the undertaking, and the Imperial Government then enacted "The Pacific Cable Act 1901" to provide for the construction and operation of a submarine telegraph cable from Vancouver to Queensland and New Zealand. Under the arrangements agreed upon, the various Governments undertook to finance the scheme in the following proportions:—Imperial Government, 5/18ths; Canada, 5/18ths; New Zealand, 2/18ths; New South Wales, Victoria and Queensland, 2-18ths each. The Governments of South Australia and Western Australia did not participate in the scheme because of the anticipated loss in revenue that would be entailed by the diversion of traffic from their overland lines to a competitive system. On the creation of the Commonwealth, the current obligations of the States as regards the Departments of the Posts and Telegraphs were assumed by the Commonwealth, under Section 85 of the Constitution of the Commonwealth, and thus the Federal Government became responsible for 6-18ths (one-third) of the liability associated with the Pacific cable scheme.

After the Pacific Cable Act had been passed, the project was pushed forward vigorously, the shore end being landed at Southport, Queensland, in March, 1902, and the work of laying the cable was completed on 31st October, 1902. The cable was opened for traffic on 7th December, 1902. The cable was laid from Bamfield on Vancouver Island to Fanning Island (3,458 nautical miles), thence to Fiji (2,043 nautical miles), Norfolk Island (982 nautical miles) and Southport, in Queensland (837 miles), a branch cable connecting Norfolk Island with Doubtless Bay (519 miles), the total length thus representing 7,839 nautical miles.

From the time of the commencement of operations until the sale of the system to the Merger Company in 1929 the Pacific system was managed by a Board consisting of representatives of the various Governments concerned.

Experience over a long period confirmed the opinions expressed by experts, prior to the cable being laid, that the great depth at which the Pacific cable is laid and the character of the ocean bed would tend to minimise the possibility of interruption. In both the Bamfield-Fanning Island section (3,458 nautical miles), which represents the longest continuous stretch of submarine cable in the world and the other long section between Fanning Island and Suva, not one interruption occurred during a period of more than 20 years owing to natural causes, although it was interrupted by a hostile enemy act at Fanning Island in 1914. The section from Bamfield to Fanning Island lies at great depths, the soundings for a great portion of the route being from 2,800 to 3,400 fathoms.

In 1912, the Pacific Cable Board, with the approval of all the Governments concerned, laid a cable between Sydney and Auckland at a cost of £177,000.

The volume of traffic moved over the Pacific cable expanded steadily from year to year. In December, 1903, when several manual retransmissions were involved, messages relating to the test cricket match then being played in Sydney were transmitted to London in 3½ minutes over the Pacific cable chain, and this achievement was acclaimed by the London press. The full benefits of this alternative route between Australia, New Zealand and the United Kingdom were not realised, however, until the 1914-18 war period, when it carried a great volume of traffic of vital importance. The growth in the volume of traffic circulated over this route to and from Australia is indicated hereunder:—

Year	Number of words
1910	2,197,000
1914/15	6,063,000
1919/20	8,655,000
1924/25	11,072,000
1926/27	11,956,000
1927/28	9,408,000
1928/29	8,519,000
1929/30	6,582,000

Separate records are not now maintained by the Department of traffic routed over the Pacific cable, as since the Merger (referred to in paragraph 116 hereof) senders are now given the option of routing their messages either "via cable" or "via Beam." The effect of competition from the Beam wireless service from its introduction in 1927 will be noted from the above table.

Beyond Vancouver, traffic circulating via the Pacific cable to and from Europe is transmitted over the Canadian land line system. In 1910 the Pacific Cable Board leased a copper wire between Montreal and Bamfield, thus extending the Pacific system to Montreal. Beyond Montreal traffic was, until 1917, circulated over the connecting cables of the Commercial Cable Company, Western Union Company or P.Q. Cable Company. In 1917 one of the former German trans-Atlantic cables was taken over by the British Government and diverted to Penzance in Cornwall and Halifax, and a second cable was purchased by the British Government from the Direct United States Cable Company in 1920; these two cables in later years have been used for the movement of traffic routed via the Pacific.

Both the Eastern and Pacific routes were interrupted at different times during 1914-18 by hostile acts of the enemy, the Pacific route in September, 1914, when a party from the "Nurnberg" cut the cables at Fanning Island and the Eastern route in November, 1914, when the "Emden" destroyed the cables at Cocos a few hours prior to her destruction by H.M.A.S. Sydney.

Even with the two routes in full operation, the facilities available at the time were inadequate to enable the traffic load to be circulated expeditiously, thus necessitating a curtailment of services. On occasions when interruptions to cable communication occurred, involving the concentration of traffic on only one route, the congestion caused was very serious.

The capital cost of the original Pacific Cable scheme represented approximately £2,000,000, which sum was borrowed by the Imperial Government from the National Debt Commissioners, the amount being repaid, with interest at 3 per cent., by means of an annuity of £77,545, running for 50 years from 1903. In addition to this sinking fund a minimum sum of £39,150 was transferred annually to a renewal and depreciation account.

For the first 13 years of the operations of the cable, it was necessary for the Board to make demands on public funds, as during each of those years, the expenditure, including the above fixed payments, exceeded the receipts of the cable. Over this period the total losses amounted to £713,279, the Commonwealth's proportion of which was £237,426. The greatest loss was experienced in the first year's operation, namely £90,500, and it steadily declined to £1,915 in 1914/15.

From 1915 to 1928, however, there was a surplus on each year's operations, after payment of the annuities. From this surplus, special contributions were made each year to the Reserve and Renewal Fund, the purpose being to provide for the heavy depreciation in the value of pre-war holding of securities and to meet requirements for duplication of the existing cables. The cost of laying the Auckland-Sydney, Southport-Sydney and Suva-Auckland extensions were met from the Reserve Fund.

On occasions when a surplus remained after making special contributions to the Reserve, such surplus was used to reduce the outstanding debt, in accordance with the Pacific Cable Act, these payments being supplementary to the fixed annuity payments. The amounts so applied during the 7-year period ended 1921/22 represented £91,515. During the period from 1920/21 to 1927/28, however, very heavy payments were made to the Reserve Fund to meet the cost of duplicating the Pacific cable system, the total of these payments representing £1,151,000 or an average of £144,000 annually.

The work of duplicating the Pacific cable system was commenced in 1923 when cables were laid between Suva and Auckland (1,255 nautical miles) as well as between Southport and Sydney (510 nautical miles) at a cost of £350,000. The work of installing the duplicate cable between Suva and Bamfield was completed during November, 1926, these cables being of the modern, high speed type, the speed of operation of the new cable being $3\frac{1}{2}$ times greater than that of the older one. The total cost of duplicating the system represented nearly £2,750,000.

During the year ended 31st December, 1910, the proportion of the total traffic circulating over the Pacific system between Australia and places overseas represented 46.6 per cent. and for the year ended 30/6/1927, 47.1 per cent.

CHANGES IN THE DESIGN AND METHOD OF OPERATION OF SUBMARINE CABLES

The invention of the "loaded" cable in about 1921 represented an important advance in submarine communication practice. The loaded cable incorporates a narrow tape of iron-alloy which is wound over the copper core to counteract the capacity effect and thus to reduce the impedance of the cable. The use of the loaded cable permits signals to be transmitted at very much higher speeds than is practicable over the unloaded type of link—even up to ten times greater speeds in some cases. Fundamental changes have also taken place in the method of operating cable channels, and developments in this connection are briefly outlined hereunder:—

(a) In the early period of undersea cable operations, the signalling arrangements incorporated manually-operated keys which were depressed so as to cause electrical impulses, in the appropriate order, to be passed through the cable to convey the desired intelligence, in accordance with the cable code. At the reception end, these impulses were passed through certain delicate equipment which controlled the movements of a beam of light across a screen, the telegraphist in attendance being required to read the signals thus formed and to record the messages on the appropriate forms;

(b) Subsequently a sensitive recording device was evolved, the received signals being registered in ink on a paper tape in the form of variations in a continuous ink-line above and below a virtual zero line, the current activating the primary receiving equipment being equivalent to only a few microamperes. The code employed in cable operation is similar to the morse code used on land line communication channels, but in cable practice a dot is represented by an impulse above the zero line and a dash by an impulse, of the same duration as that of the dot, below the zero line. A specimen of the reproduced signals with this form of recording device is furnished in Fig. 1, and it is interesting to compare this example of the Cable Signal records with the undulator signals used on the Beam Wireless Services as shown in Fig. 2.

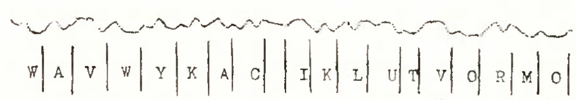


Fig. 1.—Reproduction of Signals on Syphon Recorder Tape as formerly used on Cable Systems.

A dot is represented by an impulse above the zero line; for two dots the signal is prolonged, while for three dots the signal is still longer. Compare the dot in the letter A with the signals in I and V respectively.

A dash is indicated by an impulse below the zero line, having the same duration as that of a dot. The signal for two dashes is more prolonged, while that for three dashes is still longer. Compare the single dash in T with the signals for M and O.

Fig. 2.—Reproduction of Signals on Undulator Tape as used on Beam Wireless Services.

This method of recording is somewhat similar to that formerly employed in the Wheatstone system, except that instead of blank spaces between the dots and dash signal elements, as well as between letters and words, here we have a continuous line, the actual signals being indicated above the zero line.

(c) The application of the duplex principle to cable operation later rendered it practicable to transmit two messages simultaneously over one cable, one message in each direction. The balance network necessary on long submarine cables is much more complex than the one associated with land line telegraph channels;

(d) The next advance was the introduction of equipment to permit automatic transmission, utilising keyboard perforators, operated at speeds comparable with those attained by typists, for the preparation of the requisite combinations of perforations on a paper tape so that when the tape is passed through an automatic transmitter, the appropriate signalling impulses, to correspond with the intelligence to be transmitted, are sent over the cable. The introduction of this apparatus was a big step forward in cable communication practice;

(e) With the early type of equipment the transmission speeds attained were in the region of 10 words per minute, and it was necessary for the messages to be written down and retransmitted by hand over each separate cable section. For example a message from London to Australia in the earliest days of cable communication passed through about 36 hands. By the adoption of the Regenerator system in more recent years, however, the speed of operation has been substantially increased and there is now no limit to the number of cables which may be linked together as a chain, thus enabling transmissions to take place over long distances, without involving manual interceptions and retransmissions. With this system, apparatus is employed so that the minute electrical impulses arriving at the reception terminal are amplified to a stage where they are capable of operating equipment which automatically reproduces a perforated tape, equivalent in all respects to that used at the transmission terminal. The perforated tape thus reproduced may be fed into the transmitter on a different cable, where onward transmission is necessary, or it may be utilised to operate a local printing mechanism, which will reproduce the message, in the form of Roman characters, on a paper tape which may be gummed to a telegram form for delivery;

(f) Calling devices are utilised in connection with the automatic working, enabling any intermediate station to be called by any other station in the chain, a call being selective as predetermined by a certain combination of dots and dashes. Provision is also made for the attention of all stations on a chain to be obtained simultaneously by means of a general call signal. An audible (bell) as well as a lamp signal is given at the called station;

(g) In recent years the introduction of further appliances permits more than one message to be sent in the same direction simultaneously by providing in effect two independent communication channels over the one cable;

(h) Normally Australia is connected to three independent chains, namely:

(i) via Cape cable—Durban-Rodrigues-Cocos-Perth-Adelaide.

(ii) via Halifax — Montreal-Vancouver - Fanning Island-Suva-Norfolk Island - Southport-Sydney.

(iii) via Gibraltar — Malta-Alexandria - Suez-Port Sudan - Aden - Seychelles - Colombo-Penang - Singapore - Batavia - Cocos-Perth-Adelaide.

RADIOTELEGRAPH SERVICES

Experiments with radiotelegraphic communication were carried out by a few people in Australia in 1898, and in 1905 the Federal Parliament passed the Wireless Telegraphy Act which conferred on the Postmaster-General the exclusive privilege of establishing, erecting, maintaining, and using stations and appliances for the purpose of transmitting messages by wireless within Australia and receiving messages so transmitted; transmitting by radio messages from Australia to any place or ship outside Australia; and receiving in Australia messages transmitted by wireless from any ship outside Australia. Provision was made, however, for the Postmaster-General to grant licences for the establishment, erection, and maintenance or utilisation of stations or appliances for the purpose of transmitting or receiving messages by wireless telegraphy, subject to such conditions and on payment of such fees as are prescribed.

The Commonwealth Government arranged for radiotelegraph stations to be erected at Sydney and Perth in 1912, this equipment having been provided by the Australasia Wireless Company under contract, and other radio installations were later established at Melbourne, Brisbane, Adelaide, Hobart, Thursday Island, Cooktown, Rockhampton, Townsville, Darwin, Wyndham, Broome, Geraldton, Flinders Island, Port Moresby, Esperance, and Thursday Island, the system employed having been devised by Mr. J. G. Balsillie, the engineer for radiotelegraphy. These stations were placed under the control of the Postmaster-General.

The purpose of these stations was primarily to provide a means of communication between ships at sea and places in the Commonwealth. The power employed was such as to permit communication with ships over distances of approximately 500 miles during daylight hours and 1,500 miles during darkness. The stations were also capable of inter-communication, and in the event of an interruption to the land line system they were able to render assistance in the movement of internal traffic. The volume of traffic dealt with by these stations during the year ended 30/6/1915 represented 38,000 messages, containing approximately 1,048,000 words. In 1915, the control of the Commonwealth radio installations was transferred to the Department of the Navy in the light of wartime requirements, and six additional stations were erected in the Territory of New Guinea during that year. The control of the radio services reverted to the Postmaster-General in September, 1920.

In 1920, the Imperial Wireless Committee recommended the introduction of an Imperial Wireless Chain, providing for the establishment of radiocommunication services between Empire countries utilising high power, long wave installations, with relay stations at convenient intermediate centres. During the following year, Amalgamated Wireless (A/asia) Limited submitted a proposal to the Federal Government that the company should be given a franchise to undertake the construction, maintenance, and operation of the necessary stations and equipment for a direct commercial wireless service between Australia and the United Kingdom, subject to the Commonwealth contributing £500,000 towards the capital of the company and being entitled to subscribe so much capital that at all times it might hold a majority of the shares.

At the Imperial Conference in 1921 the Prime Minister (Rt. Hon. W. M. Hughes) opposed the recommendation of the Imperial Wireless Conference. He refused to be a party to such an arrangement as had been proposed, and he urged the establishment of a direct radiotelegraph service between Australia and the United Kingdom. The delegates of the other countries accepted the committee's scheme, but the Commonwealth was given freedom to make arrangements for direct wireless communication with Great Britain.

The Prime Minister introduced the proposal of Amalgamated Wireless (A/asia) Ltd. to Parliament in December, 1921, and the plan was agreed to, subject to investigation by a Parliamentary Select Committee, comprising representatives of both the Senate and the House of Representatives. After an inquiry extending over a period of three months, the Select Committee reported that it was unable to recommend the adoption of the draft agreement as it then stood. The Committee, however, submitted an amended draft agreement embodying certain alterations, which it recommended should be executed by the Government.

The principal changes suggested by the Committee were:—

(a) The company should within 6 months of the date of the agreement or within such extended time as the representatives of the Commonwealth on the Board may approve, enter into a contract for the erection and operation of the Australia-United Kingdom radio service, and that such service should be capable of maintaining communication throughout 300 days of every year on a minimum basis of 20 words per minute each way for 12 hours per day;

(b) the company should within a period of two years arrange for the erection of a station in Canada capable of communicating with an installation in Australia;

(c) the company should take over the existing Commonwealth radio stations, including those in Papua and the Territory of New Guinea, as well as Flinders, King and Willis islands, the company to bear the loss involved in the operation of those services, after the lapse of a period of seven years in the case of the stations in New Guinea and three years in respect of the other stations. (The loss associated with the operation of these stations was set down at £43,000 for the year ended 30/6/1915.)

An agreement, embodying these provisions, having been signed on 28th March, 1922, by the Prime Minister, on behalf of the Commonwealth, and representatives of the company, the Commonwealth radio stations were transferred to the company as from 8th May, 1922.

Amalgamated Wireless (A/asia) Ltd., however, found it impracticable to secure authority from the British Post-office for the company to establish a radio station in the United Kingdom, because the Home Government had decided to undertake the operation of the British terminal of all such radiotelegraph services itself. A supplementary agreement was therefore made between the Commonwealth and the company on 20th August, 1924, relieving the company of its obligation to arrange for the operation of a suitable corresponding station in the United Kingdom, as stipulated in the Principal Agreement of 1922, and the company undertook to erect one high-power station capable of communicating with England and Canada with a minimum guaranteed capacity of 21,600 words per day each way on 300 days, i.e., 12,960,000 words annually. In this connection it is interesting to note that during the year ended 30/6/1943, which was a record period, the total load moved between Australia and the United Kingdom represented 20,266,000 words, and the total Beam load for the 12 months to and from all points overseas amounted to 38,098,000 words. The 1924 Agreement also extended the period during which the Commonwealth should bear the loss on the Commonwealth coast stations from three to four years, and reduced the period from seven to five years as regards the radio stations in the Territory of New Guinea.

(To be Continued.)

SOME NOTES ON THE USE OF PLASTICS

B. Edwards and H. C. Lake

The wide-spread application of pottery ware, glass and mounded rubber manufactures to the every-day needs of mankind, is sufficient warrant for the assertion that mouldable raw materials have always fascinated the minds of inventive men. It was not, however, until the discovery of "celluloid" and, later, of "bakelite," that the full possibilities of mouldable materials came into proper perspective. These substances, and many others since discovered, are known as the synthetic resins, or, more commonly, as Plastics.

The synthetic resins are generally classified under two headings:

1. Those which undergo a chemical change when subjected to heat and pressure in the mould. These are called thermo setting resins.
2. Those which merely undergo physical change and the substance of which, therefore, is capable of being re-moulded to another shape after being ground to a suitable grain size. These are called thermo plastic resins.

Both types are plastics in the modern sense, in that they are of organic derivation.

The most commonly used of the thermo setting resins is phenol-formaldehyde. This substance results from the controlled reaction between carbolic acid and formalin. The natural resin colour ranges from clear to amber, and is greatly affected by utlra-violet rays. Various opaque colours are available in phenol-formaldehyde moulding powders. They could not be called exciting, however, and are likely to fade or darken in a short time after moulding. Blue is the worst colour in this regard. The material with suitable fillers has, however, properties that ensure its choice before other phenolics, for a majority of applications. The special properties produced by various fillers are indicated in the following table. With wood-flour as a filler the material can be used for a variety of purposes.

Filler	Special Property
Cotton	Shock resistance.
Chopped Canvas	Heavy impact.
Asbestos	High temperature and close dimensional stability, etc.
Mica	Low dielectric loss, low moisture absorption.
Carbon	Electrical conductivity.
Graphite	Minimum friction.
Iron	Permeability cores.

Urea-formaldehyde is another well-known thermo setting material. It is popular because of the wide range of attractive colours—clear, opaque, translucent, full, pastel—in which it may be obtained. The urea powders, unfortunately, produce mouldings which are not always dimensionally stable, and on which the surface is likely to craze with heat or moisture. Urea can be produced from ammonia and carbon dioxide. It is re-acted with formaldehyde to produce the urea-formaldehyde resin, which is crystal clear and resistant to ultra-violet rays. The filler used with this resin is chemically pure wood cellulose (finely divided paper), hence the possibility of obtaining fine colours in the mouldings. Being odourless, tasteless, and substantially colour fast, this resin is widely used in the production of table ware. Urea powder must be kept in cold storage if the holding time is to be more than a few weeks. It is probable that the melamine-formaldehyde resin, now reserved in America for war uses, will displace urea for moulding because of its better heat and moisture resistance.

Urea-formaldehyde glue for the laminating of wood is being widely used at present on account of the scarcity of timber in large sizes. This glue requires merely cold pressure and is, therefore, easier and cheaper to use than phenolic adhesive. The ambient temperature, however, should not be below 70 degs. F., and a pressure of at least 50 lbs. per square inch must be applied at every point over the gluing surface.

Matters of importance to moulders, and of interest generally, are the curing time and so called "flow" of the powder. Curing time is the duration for which heat and pressure need to be applied to the powder in the mould in order to ensure complete chemical change or polymerisation. Although curing time is influenced, among other things, by the wall thickness and intricacy of the moulding, and by the filler incorporated in the powder, any adjustments in this time which may be found necessary during the trial run of a moulding are based on the flow number grading of powders.

Thermo setting resins, so far as the moulder knows them, may exist in three states, as under:

State A	State B	State C
Liquid	**Partly Cured**	**Cured**
	Flow Numbers	
	10 —— 25	

Fig. 1.

Liquid resins are free of fillers. In this state they are used in the preparation of paints, etc., and, in the moulding field, for casting into lead or other forms of moulds. Once the technique of casting resin has been mastered, it is invaluable in the making of models, certain forms of jigs for drilling and even for repairs. Cast resin is available on the market in rods, and many other forms from which machined parts can be produced.

Partly-cured resin powder, already prepared with filler and colouring medium, is the usual commercial form. As the diagram (Fig. 1) indicates, the powder may be more or less cured, and this state is indicated by the flow number. The lower the flow number the more readily the liquified powder will flow to all parts of the mould, and the longer the final curing time will be. This adjustable property of moulding powder allows of a selection being made to meet intricate or deep draw mouldings, or, on the other hand, to reduce the moulding cycle time to a minimum. Recently, high-frequency heating and transfer moulding have been introduced with the latter feature as one of the objectives. High-frequency heating, however, is as yet a novelty in this country.

Although thermo-setting resins may be extruded, and often are injected by the transfer method, the most common practice is to form them in the compression type of mould.

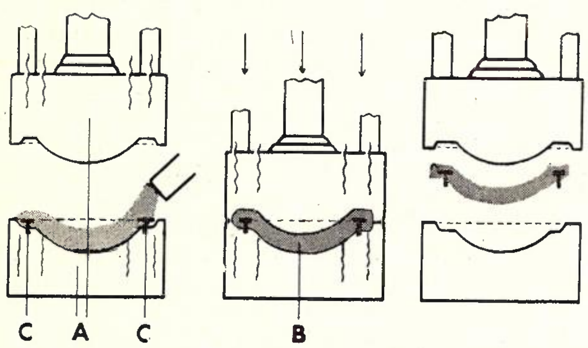


Fig. 2.—Compression Mould.
A—Top and bottom halves of mould.
B—Powder under pressure and heat.
C—Inserts.

Heat and pressure, of the order of 300°-400° F. and 2000-4000 pounds per square inch respectively, are required in the process of transforming the phenolic resin powder into the finished infusible state of the completed moulding. As is well known, inserts of metal or other material may be moulded into the finished article.

Compression moulds must be manufactured of high grade steels capable of resisting the effect of heat, high pressures, and heavy abrasion. They are often plated with hard chrome to withstand the latter, as well as to withstand the corrosive effects of generated gases, and to improve the surface of the product.

Mould design must take into account many details, among which are:—

The requirements of the customer
Loading and manipulation time
Free extraction of the product from the mould
Insert rigidity during moulding and free draw
Loading space for the powder (bulk factor)
Gas escape
Shrinkage after moulding (varies with the type of powder used)
Flash or positive mould.

Figures 3 and 4 show a mould for producing one half of a "buttinski" body. The upper part of Fig. 3 is the cavity and the lower part is the core. It will be seen what complexity is introduced because of the need for moulding-in

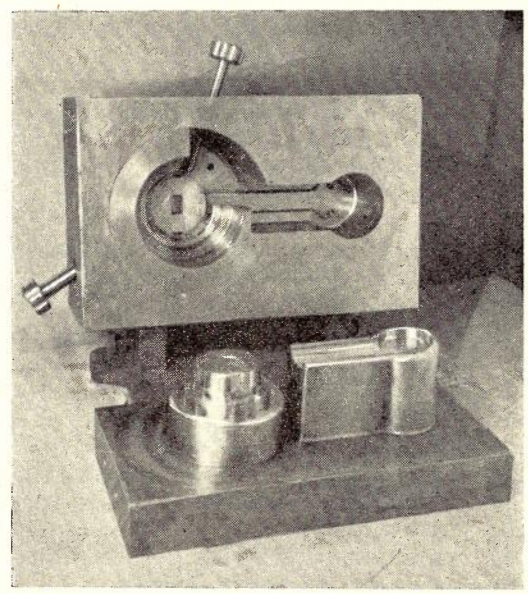


Fig. 3.—Positive Type Compression Mould for Buttinski.

the brass band, and certain screw threads to hold the dial. In this example extraction has been the main problem.

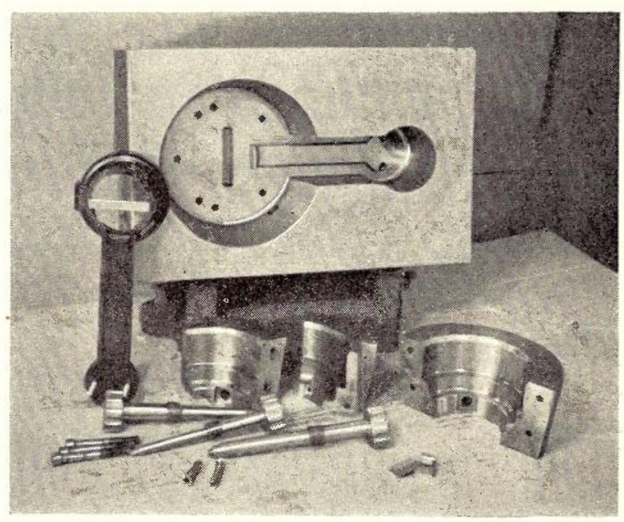


Fig. 4.—Cavity of Mould shown in Fig. 3, but with Parts Dismantled.

When moulding thermo-setting resins, and particularly those with reinforcing fillers, the stress tending to distort inserts standing in the mould may be considerable. Even substantial steel pins forming part of the mould may be bent or sheared off due to pressure transmitted through the resin. The transfer method of moulding eliminates these uneven stresses, and makes possible the moulding-in of quite fragile inserts, even inserts made of brittle material such as glass.

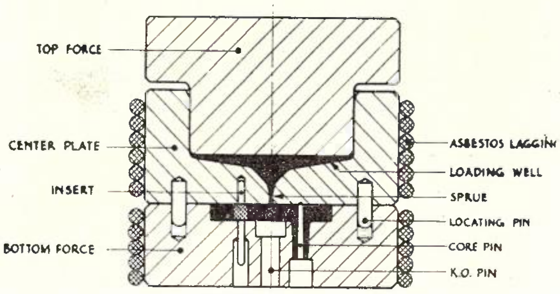


Fig. 5.—Example of the Use of a Transfer Type of Mould for Thermo-setting Resin.

The top force of the mould takes the form of a ram which injects the already liquified resin into the mould cavity where the delicate inserts are held. The possibilities of this method of moulding hardly need enumeration, but some of the less evident advantages are:—

Maximum dimensional accuracy of the product

Longer mould life

Improved uniformity of cure in cases of difficult cross-section.

Transfer moulds must sometimes be used in an angle press, one ram arranged to hold the mould closed, and the other to inject the moulding material. Where only one ram is used, as in Fig. 5, there must be an excess area of 20 per cent. or more in the ram cylinder over the projected area of the moulding in order to keep the total pressure in the cavity always less than that under the ram. If the reverse arrangement of pressures were to develop, the mould would tend to open.

The name of the man who invented the first of the thermo-plastics was John Wesley Hyatt, and, strangely enough, he was searching for a material from which to make billiard balls. That was in 1869. The celluloid or cellulose nitrate solid which Hyatt discovered is still in very wide use. From billiard balls, it has passed over into mallet heads and tool handles, applications which call for the same toughness and impact resistance. Cellulose nitrate plastics are made from cotton linters (short cotton fibres) treated with sulphuric and nitric acids and plasticized with camphor. Cellulose nitrate burns easily.

The number of thermo-plastic materials is very great already, and is being augmented constantly. New demands in the electrical and other fields stimulate the search for plastics possessing the desired characteristics. Cellulose acetate, for example, because of its easy mouldability, and adaptability to colour, has been universally used for switch plates, coloured terminals, instrument and radio housings, etc., as well as for domestic appliances and imitation jewellery. The insulation demands of higher frequency ranges have latterly resulted in the production of polystyrene with its almost ideal electrical properties. Even more recent is the advent of the material called Styramic, which is a development in the direction of raising the useful heat range of the thermoplastics.

Polystyrene is prepared from ethylene (made from natural gas) and benzine. Apart from its electrical properties, which are well known, it will resist hydrofluoric acid, its moisture absorption is negligible, it transmits light very readily, and has a high resistance to alcohol. Polystyrene is sometimes confused with the acrylic material, methyl methacrylate, which has such remarkable optical properties—better transparency than the best glass, and the property of conducting light around opaque obstructions. Its resistance to alcohol, although generally stated to be good, has not been stubborn enough, however, to prevent methyl methacrylate being superseded as a material for dental plates.

The generality of products made from thermoplastic resins are moulded by the injection method in an automatic machine. The need merely to cool off the thermo-plastic in the mould, after injection in the liquid form, enables very quick production to be achieved. The cycle for the majority of small jobs is only a matter of seconds, as against minutes for similar thermo-setting jobs.

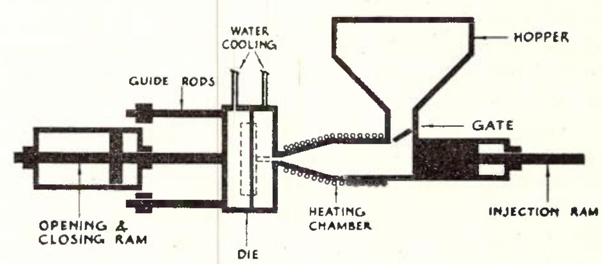


Fig. 6.—Schematic Diagram of Automatic Injection Moulding Machine.

The dies or moulds required for injection moulding of these plastics are easily made, and cheap compared with compression moulds. Quite frequently, they consist merely of a series of plates with the necessary cavities and forms let into them.

Still further cost reductions accrue to this type of moulding, because there is very little waste of material. Sprues, runners, rejects, etc., are reground into the crystal-like powder usually supplied, and put back into the hopper for remoulding.

Fig. 6 will be generally obvious. The machine is automatic in that the cycle of movements is electro-mechanically controlled and timed, and follows somewhat in this way:

1. Required amount of powder measured through gate.
2. Ram forces powder into heating chamber where it liquifies.
3. Ram injects liquid resin into die.
4. Water circulates and cools resin while ram keeps the pressure on the moulding.
5. Safety gates open. Mould opens. Product extracted.
6. Safety gates close; mould closes and cycle repeated.

Most extrusions, in the past, have been of thermo-plastic material, but technique has recently been developed for extruding thermosetting resins. Extrusions are generally intended for further fabricating, and come in the form of rods, tubes and special sections.

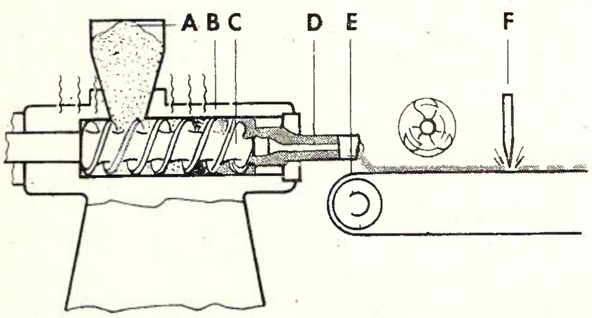


Fig. 7.—Schematic Diagram of Extrusion Moulding Machine.

In Fig. 7 the hopper of powder is shown at "A." The heated body "B," and the screw stuffer "C," combine to force the liquified resin through the die, "D," on to the conveyer, "E," and past the cooling gear and cutter, "F." In the newest machines several colours can be worked into the one extrusion.

Fig. 8 shows three transmitter inset cases. The first two are of phenolic resin compression moulded; one of them being nickel plated. The third is of polystyrene, injection moulded, and exemplifies one of the very useful properties of thermo-plastics. They can be modified, under heat, after first moulding. In this case, the

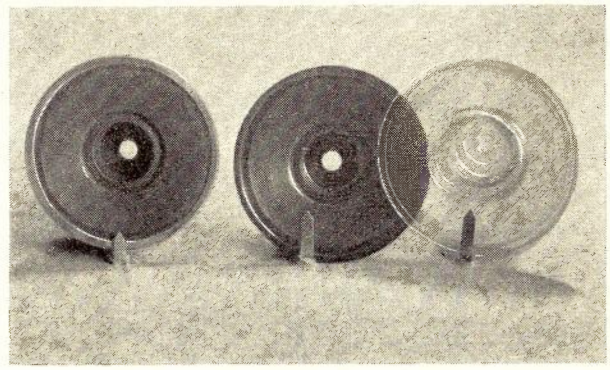


Fig. 8.—Transmitter Inset Case.

recess which holds the spring ring, used for keeping the silk washers in place, is formed under a hot tool from a small flange left for the purpose. In the phenolic cases, the spring recess has to be machined.

In conclusion, it might be useful to restate some of the advantages which might be gained if a contemplated design or re-design is suitable for production in plastic materials.

Intricacy in the part is possible without excessive cost.

Saving in weight is often possible.

The precision work put into the mould can be readily reproduced in every part moulded.

Fast production of identical parts; or parts which must match-up.

By the use of inserts, and because of the insulating properties of plastics, parts can be designed for faster assembly.

Final machining and finishing is reduced to a minimum.

Polishing, plating, painting, colouring may be eliminated.

Thanks are due to Messrs. B. King, N. Fienberg and J. Joyce of A.C.I. Plastics Division, for helpful suggestions, and criticism of this article.

THE DESIGN AND CONSTRUCTION OF UNDERGROUND CONDUITS FOR TELEPHONE CABLES

A. N. Hoggart, B.Sc.

PART III.: EXCAVATION

The cost of excavating the ground for the laying of conduits represents a high proportion of the total cost of installing a conduit run. The methods of excavation adopted in any instance and the manner in which these are applied can, therefore, have a marked influence on the cost of the work. The use of mechanical equipment will, in many cases, effect substantial economies in conduit work; this aspect will, however, be covered in a subsequent article in these series, the general principles and hand methods being dealt with at this stage.

Pilot Holes: Although the location and depth of the trench may have been mapped out by the detailed survey, there is always a possibility of unforeseen obstructions being encountered, particularly in city areas. It is, therefore, a good plan to sink pilot or test holes before commencing excavating along any route where there is any possibility of unmarked obstructions necessitating an alteration to the intended location of the conduits. This procedure will frequently avoid wasted excavating work.

The number of pilot holes to be dug is largely a matter for the judgment of the supervising officer, but generally, as a minimum, one should be dug at the location of each manhole, with one or more at intermediate points, depending on conditions. The pilot holes should be dug at right angles to the route, and should extend to at least the full width of the excavation for the manhole, and preferably the full available width of the footpath. They should be at least six inches deeper than the proposed trench, and the bottom and sides should be well probed for foreign bodies. When the pilot holes reveal any obstruction to the proposed conduits, further pilot holes should be sunk, so that the best track can be determined.

Marking Out: Having fixed the location of the trench, in light of information gained from the pilot holes, the sides of the trench should be marked out before operations are commenced. A suitable method of marking is to drive a peg at each end of the section with intermediate pegs in line at approximately 30 ft. intervals, and then draw a line tight along the outside of the pegs. The line is then marked on the ground by means of the sharp point of a pick on the outside of the line so that the tendency will be to press the line against the pegs. Both sides of the trench should be marked in this manner.

To avoid unnecessary work the trench should be no wider than is sufficient to provide adequate working room, and to accommodate the conduits —generally to enable the conduits to be conveniently laid—the trench should be not less than 3 ins. wider than the conduits.

Cutting Pavement Surface: So that the pavement can be satisfactorily repaired, care is necessary in cutting the surface in the first instance. In particular the pavement should be cut in straight lines, to ensure that the re-instatement work will be as sightly as possible.

Asphalt cutters or a mattock should be used for cutting asphalt. The asphalt cutter should be kept sharp, and best results are obtained by using a succession of light blows, making the first cut along a section of several feet and then following up with additional cuts as necessary.

Stone slabs can readily be lifted, but care is necessary to avoid flushing (i.e., breaking off flakes parallel to surface) or cracking stones so that they may be available for re-instatement.

The treatment of concrete pavements depends on the manner in which the pavement has been laid down. If small pre-cast concrete slabs have been used it should be practicable to lift the slabs along the line of trench. In such cases the slabs can usually be reset in position when re-instating the trench, and accordingly care needs to be exercised to avoid damaging the slabs during the work.

Many concrete pavements are now cast-in-situ. If the slabs are cast "alternatively" with distinct joints between the slab, it frequently will be practicable to lift the slabs, particularly if paper has been used in the forms. Wherever possible it is desirable that the slabs be lifted rather than cut the concrete as it is extremely difficult to restore a concrete path that has been cut without spoiling its appearance. In some cases it has been found that the slabs could not be lifted in the ordinary way, but a half-inch gap chiselled along one side of each slab enabled this to be done. In re-instatement the gap was filled with neat cement.

If cast-in-situ concrete pavements require cutting, special care is necessary, as satisfactory re-instatement cannot be made in the case of an irregularly shaped opening. Unless the municipal authority for its own convenience desires to replace a complete slab or cut away the remaining portion of the concrete to form a straight edge, the aim in cutting concrete should be to provide straight edges. This will enable an effective repair to be made, finished by a groove along the junction of the new and the old work.

Pneumatic concrete breakers operated by an air compressor should preferably be used for cutting concrete. Where this equipment is not available, medium or large cold chisels and a 2 lb. hammer can be used. If an attempt is made to break large pieces off the concrete, it is likely that the entire slab may be cracked. It is, therefore, preferable to start at an edge or junction between slabs, and work towards the line of the final cut by flaking off small pieces.

In all cases the pavement material should be kept separated from the soil, so that it may be readily available for re-instatement purposes.

A lawn can be readily restored to its former condition if a little care is exercised in cutting and replacing the turves. A spade should be used to cut and lift the turves, although an axe or a mattock may be used for the preliminary cut along the sides. The turves should be cut neatly, about $1\frac{1}{2}$ to 2 inches thick and should be laid on one side of the trench clear of other soil. The top soil should also be kept apart from the remainder and when the trench is refilled placed on the surface again. The turves should be handled gently and when being replaced a small gap should be left between them to allow them to spread slightly when being lightly rammed. In dry weather the lawn should be watered before commencing operations, and if any appreciable period will elapse before the turves are re-instated they should be covered with damp bags. A thorough watering after relaying is also desirable in dry weather.

Hand Methods: Where mechanical aids are not available trenching is carried out by pick and shovel methods in normal soil, stone, etc., being broken down by the use of hammer and gad, plug and feathers or explosives. With hand

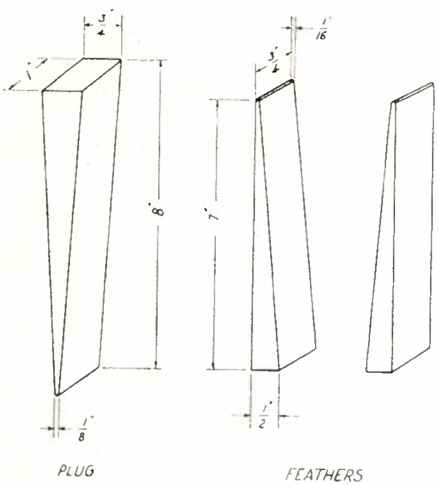


Fig. 13.—Plug and Feathers.

methods care is necessary to ensure that the trench is dug straight and that there is no tendency for the walls of the trench to be undercut or allowed to creep in. The excavated earth should be thrown well clear of the trench, at the same time ensuring that it does not cause any unnecessary obstruction to traffic.

Use of Plug and Feathers: It frequently occurs that it is necessary to excavate rock formation and it is not practicable to use explosives; in such cases plug and feathers may assist considerably in breaking down the rock. As illustrated in Fig. 13 the plug is a steel wedge 8 inches long by one inch wide and tapering from $\frac{3}{4}$ inch thick at the top to $\frac{1}{8}$ inch at the bottom. A feather is a steel wedge 7 inches long by $\frac{3}{4}$ inch wide tapering from $\frac{3}{4}$ inch thick to 1/16 inch thick.

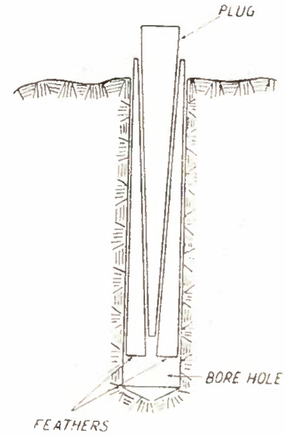


Fig. 14.—Use of Plug and Feathers.

The method of use is illustrated in Fig. 14, a hole is bored in the rock about 1 inch deeper than the length of the plug, using a rock drill. The plug and feathers are inserted in the hole as shown, leaving the feathers exposed for about one inch. If the hole is too large, liners consisting of strips of hoop iron may be inserted between the plug and the feathers. The plug is driven into the hole by means of a 10 lb. hammer until the stone cracks. The piece is then levered off by means of a bar and the operation repeated until the desired amount of rock has been removed.

The number, placement and direction of the holes will depend on the lay and grain of the rock and the workman will need to exercise judgment in deciding the position of holes. Generally the hole should be fixed so that a fair-sized piece of rock will crack off.

Use of Explosives: It is frequently necessary to use explosives when excavating in stone. For conduit work gelignite is most suitable, as it is safe to handle if ordinary care is exercised, and has a shattering rather than a lifting effect. It is fired by means of a detonator.

Gelignite is generally supplied in plugs about 4 inches long by $\frac{7}{8}$ inches in diameter. As it is exploded by shock or concussion, care in handling and storing it is necessary. The detonator consists of a copper tube about $1\frac{1}{2}$ inches long by $\frac{1}{4}$ inch in diameter, about one third fitted with fulminate of mercury. The detonators are very easily exploded by shock or heat and, therefore, require very careful handling. They are sufficiently powerful to cause serious personal injury. Detonators should be stored in a dry place away from other explosives.

The type of fuse normally used is the "Miner's Safety Fuse" and burns at the rate of 2 feet per minute. Each coil of fuse should be tested before use by cutting a short piece off and lighting it. It should burn slowly and shoot through the last half inch. Fuses should always be kept dry.

Generally a fuse two feet long will be satisfactory, but where a number of shots are to be fired, different length fuses should be used so that the explosion of each charge can be counted. The ends of the fuse should be cut square to avoid possible misfire.

One end of the fuse is inserted into the detonator until it touches the fulminate of mercury, and the open end of the detonator is carefully crimped on to the fuse by means of special fuse pliers. Other methods of crimping should not be used as these are liable to be dangerous. The detonator should be examined before use to ensure that it is free from sawdust or dirt.

The detonator is then inserted into a hole formed in a half plug of gelignite, the hole being formed by using a round piece of wood about the thickness of a lead pencil, or a special attachment provided on the fuse pliers for the purpose. The fuse, detonator and half plug constitute the primer and is now ready for use—see Fig. 15.

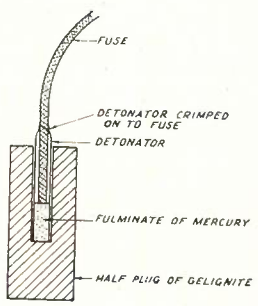


Fig. 15.—Gelignite Primer.

A hole having been drilled in the rock and cleaned out thoroughly, the required charge (one plug of gelignite will usually suffice in conduit work), is placed in the hole and firmly pressed in with a wooden tamping rod. The primer is next carefully inserted in the hole and covered with about 3 inches of loose earth, which is pressed firmly over the charge with a tamping rod. The hole is then filled with soil, each handful being firmly tamped. Tamping should take the form of firm pressure with a wooden rod, rather than blows; the use of steel rods or the application of blows is liable to explode the charge. Fig. 16 shows a charge prepared for firing.

The charge can then be fired, having first arranged for all workmen to be well clear, and for any traffic to be stopped at a safe distance. A special fuse lighter can be obtained which burns with a fierce heat and is the most satisfactory method of lighting the fuse. Before firing, the trench should be covered with boiler plate about 6 feet by 4 feet by not less than $\frac{1}{4}$ inch thick and weighted down by stones. Alternatively a blasting mat made from 3 inch or heavier rope may be laid in the trench and weighted down with stones, the fuse passing through a hole in the rope.

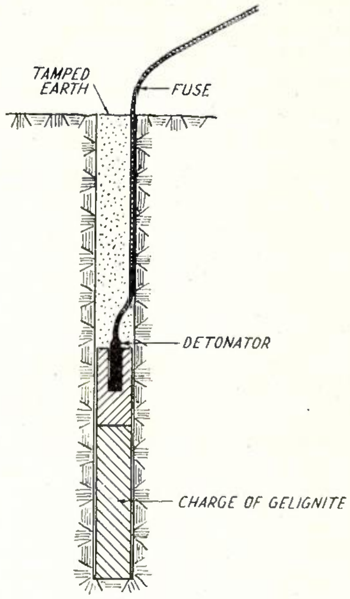


Fig. 16.—Charge of Gelignite Prepared for Firing.

In the event of a misfire a minimum period of 20 minutes should elapse before returning to examine the cause of the failure of the charge to explode. This is necessary, as a faulty fuse may smoulder for 10 minutes or more and then fire the charge. The safest method of dealing with an unexploded charge is to drill a fresh hole adjacent to the faulty charge (about 8 ins. away is suitable) and fire a fresh charge, which should detonate the other. In drilling the new hole care is necessary to avoid fouling the unexploded charge. After firing the shot the debris should be closely examined for unexploded detonators or pieces of gelignite.

Small charges are the most suitable for trench work, as large charges are liable to break down the sides of the trench, causing unnecessary work. The amount of charge and direction and location of the hole will be determined by the judgment and experience of the workman, but generally the hole should be drilled at an angle to obtain the best lifting effect. It will be apparent that explosives should only be used by experienced workmen.

Charges can be safely fired in the vicinity of building provided all the precautions referred to above are taken. It is advisable to make an inspection of all buildings in the immediate vicinity and record any existing defects such as cracked walls or windows, broken plaster, etc., so as to be available for evidence in the event of any claim for damages to property arising from the use of explosives. Blasting should be avoided where other underground services, water, gas, etc., are in close proximity to the trench.

The use of explosives is generally covered by regulations of the Municipal Authorities or other bodies and in all cases the requirements of these should be carefully followed.

Blasting powder is sometimes used, but is not generally as economical as gelignite. A larger and deeper hole is required, into which the powder is poured. A piece of fuse is inserted at least 3 inches into the powder and the hole filled and tamped in the ordinary way. No detonator is used, but the fuse is fired as before. If the hole is damp the powder should be placed in a water-proof bag before inserting in the hole.

Charges can also be fired electrically, but this method is not regarded as generally economical for conduit work. Special equipment is required for the purpose and generally one shot only can be fired at a time, as no means are available for counting individual shots, unless special equipment is available for firing each shot.

Obstructions: Where obstructions such as other mains are encountered in the trench, it may be more economical to arrange for the removal of the obstruction than to alter the trench to clear the foreign main. The authority owning the obstructing main may be agreeable to making the diversion and therefore the question is worth discussing with the authority concerned.

Where other mains are exposed in the trench, it is necessary for these to be adequately supported; if necessary, pipes can be supported readily by means of ropes or chains slung from baulks of timber placed across the trench. If there is any liklihood of subsidence due to the operations being carried out, it would be advisable to provide brick or concrete piers to support the mains, at the same time ensuring that sufficient space is available for access to joints, etc., in the mains for repairs.

If it is necessary to increase the depth of the trench to avoid obstructions, the effect on the overall grading of the trench must be considered, to ensure that a uniform grade of not less than 1 in 200 is provided throughout so that the conduits will drain readily. It is essential that no hollow be left in the trench at the obstruction, otherwise water and silt may collect in the ducts, forming a corrosion hazard, or alternatively the silt may block the ducts.

Working in Traffic: It is inevitable that conduit works will cause some inconvenience to traffic, and it is accordingly necessary to so arrange the operations to reduce obstruction to traffic to a minimum. Suitable guards such as ropes or barrier posts and rails should be placed round works and lights provided at night time. Excavated soil and other material should be so placed as to cause minimum interference to traffic, and unwanted or surplus soil or material should be removed as soon as possible.

In order to provide access to premises, etc., it is a good plan to place temporary bridges across the trench. In paved footways this can frequently be arranged by leaving one or two slabs undisturbed.

It is frequently the practice when crossing roadways to open up portion of the trench only, lay the conduits and fill in, and then proceed with the remaining section, thus maintaining a traffic way at all times. This method is subject to the disadvantage that, if an unforeseen obstruction is encountered in the second section, it may be necessary to alter the conduits previously laid in the first section. If, therefore, there is any likelihood of encountering obstructions in the crossing, it is preferable to excavate the whole of the trench in the one operation and provide a temporary bridge for traffic. Such a bridge should be of a substantial nature, and the sides of the trench should if necessary be supported by timber, as described later, to prevent subsidence as the result of the passage of traffic.

Levelling: Assuming levels and depths of trench have been set out during the detailed survey of the route (see Part I., Journal, Vol. 4, No. 6), it will be necessary to finish off the bottom of the trench at the depth laid down. The usual practice is to mark manhole positions by means of pegs driven into the ground along the centre line of the trench, and to use the top surface of the peg for fixing the ground level at the point. Before commencing excavating, these pegs should be off-set clear of the trench by means of a spirit level and straight edge as shown in Fig. 17. The depth of the trench is

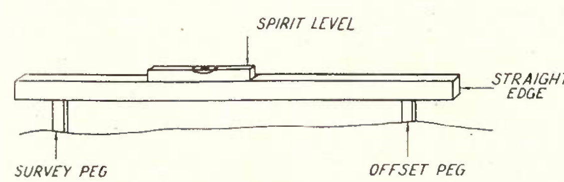


Fig. 17.—Offsetting Survey Peg.

then determined by placing a straight edge across the trench, with one end placed on the offset peg and adjusted to level with a spirit level. The depth of the trench is then measured from the bottom of the straight-edge. If the trench has been excavated to about the required depth, a peg is driven into the bottom of the trench so that its top is at the required depth. In the case of paved surfaces, e.g., concrete, the depth can be measured from a straight edge placed across the top of the trench, taking care the surface is clear of dirt.

The depths at the ends of a manhole to manhole section are thus fixed. To ensure a uniformly graded trench the levels at intermediate points are checked by means of boning rods. These are made of timber, as illustrated in Fig. 18, and it is important that all three rods in a set are of identical length. It is usual to paint the three rods in different colours, say red, black and white.

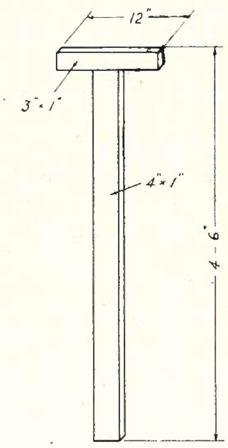


Fig. 18.—Boning Rod.

As the distance between manholes is usually of the order of 300 feet and continual boning over this distance tires the eye, it is advisable first to bone to the half-way point in the length and then bone intermediate points over the shorter distance. The sight rod (white) is first set up on the distant peg and fixed to a stake driven behind the peg. The remaining rods are set up, one on the near peg and the other at the point to be boned. The depth of the trench at the intermediate point is checked by sighting along the tops of the rods and if of sufficient depth a peg is driven in. The intermediate rod is placed on this peg and the peg adjusted until the tops of the three rods are sighted in line. The

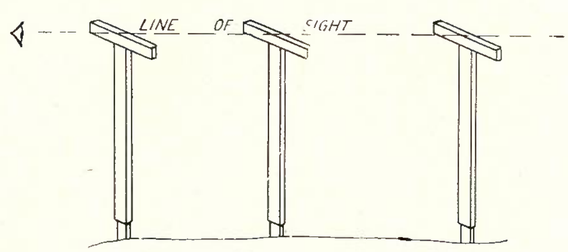


Fig. 19.—Use of Boning Rods.

method is illustrated in Fig. 19. The two half sections of the trench are boned and pegged at intermediate points, usually at 9 ft. intervals, in a similar manner sighting over half the length of the section only. The bottom of the trench should then be filled to the top of the pegs with fine loose earth and levelled with a square-mouthed shovel. To provide a firm footing for the conduits the bottom of the trench should be well consolidated by ramming if necessary. Loose sand should not be used in the bottom of the trench as it does not compact readily and, therefore, will not provide a firm, even foundation for the conduits.

In some cases it is not practicable to open the full section of the trench at the one time, in which case it will be necessary to work from surface levels. Assuming the trench is to be 4 ft. deep at one end and 3 ft. at the other, a peg is driven in alongside the survey peg at the shallower end such that the top of it is higher than the existing peg by the difference in depths of the two ends of the trench, i.e., in this case 1 ft. A new peg is boned at the end of the section to be opened, sighting from the survey peg at the 4 ft. deep end of the trench to the new peg at the far end. The bottom of the trench should then be 4 ft. below this peg and the level can be transferred to the bottom of this trench by means of a straight edge and spirit level as previously described. This method will ensure that the conduits have been laid at even grade throughout the length, although portion of the trench only has been opened at a time.

If levels have not been previously taken at the detailed survey, the fall in the ground can be determined by means of boning rods. At the higher end of the section a peg is first driven in till the top is flush with the surface of the ground. A second peg is inserted along the line of the trench six to ten feet away, and the top of this is adjusted to the same level as the first peg by means of a straight edge and spirit level. Two boning rods are set up on these pegs and a third rod is held at the far end of the section and raised or lowered till the tops of the three rods are sighted in line. The distance from the bottom of the sight rod to the ground gives the fall. This method can also be applied to check the grade of a length of trench.

The use of boning rods is sufficiently accurate for determining the levels of a conduit run in most cases provided reasonable care is exercised in their use. Accuracy is assisted by observing the following precautions:—

(a) Rods should be frequently checked to ensure they are of the same length; dirt should not be allowed to cake on the bottom of the rods.
(b) Rods should be kept clean and well painted; some dark material behind the white rod will assist sighting.
(c) All rods should be held perpendicular.
(d) Boning should be carried out as far as possible, looking away from the sun; if a long sight is necessary select a time when the light is good.

Timbering of Trenches: Where the nature of the soil is such that the walls of the trench are not self-supporting, it is necessary to timber the trench. The depth of trench that can be excavated without timbering will depend on the nature of the soil; in firm ground timbering is likely to be required for trenches deeper than six feet, but much less in loose soils. Timbering may also be necessary to support other authorities' underground plant where the trench is being excavated in close proximity to such plant. Under these conditions there is always a danger of collapse of the walls of trench disturbing the other authorities' plant, and may be the case in soil which normally does not require timbering.

Close timbering as illustrated in Fig. 20 is used

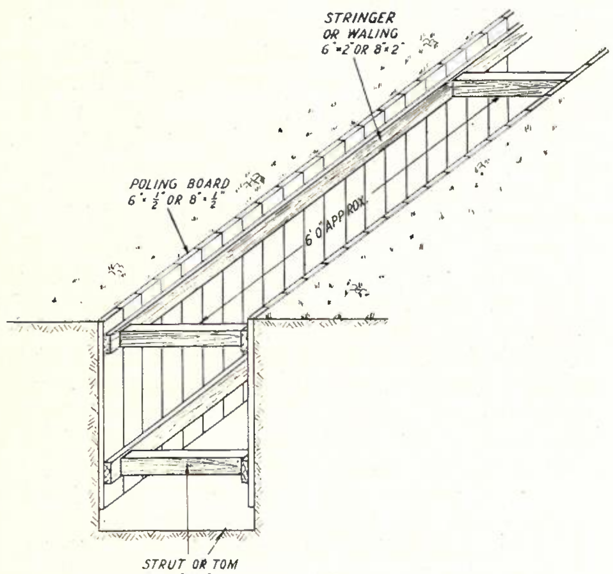


Fig. 20.—Close Timbering—Loose Soil.

in wet loose ground or sand. The diagram also shows the common names of the various members and the usual sizes of timber used. In close timbering the poling boards are placed vertically to permit of them being driven into position as the trench is deepened, and also to permit of ready recovery of the timber. The number of stringers required will depend on the depth of the trench—for trenches up to 4 ft. deep two stringers will be sufficient and three for trenches over 4 ft. up to 8 ft. For deep trenches the lower stringers and struts will need to be larger than shown to withstand the extra pressure. The stringers should preferably be 13 to 14 ft. long, as this permits the struts to be placed 6 to 7 ft. apart, thereby providing a convenient space for the workman. A spacing of greater than 7 ft. should not be used owing to the likelihood of the pressure of the soil causing the stringers to bulge, thereby reducing the effective width of the trench. If the pressure is too great due to too widely separated struts there is a danger of the stringer breaking.

The procedure of inserting timbering is as follows:—

(a) Timbering will normally commence when the trench has been dug to 18 ins. to 2 ft. in depth, as at this depth the tendency of the walls to collapse generally becomes apparent.

(b) Before commencing timbering the walls of the trench should be checked to ensure they are straight and plumb.

(c) Assuming stringers 13 to 14 ft. long are used, three poling boards should be placed on each side of the trench, one at each end and one in the centre of the stringer. The top stringers are placed in position and held secure by driving the struts into position between them. The struts should be cut so that they will jam the stringers in position.

(d) The bottom stringers are placed in position and secured as above. The remaining poling boards are then placed in position.

(e) As the trench is excavated, the poling boards are driven down and stringers lowered as required.

It is important that great care be exercised in timbering trenches to guard against possible collapse; in particular the following points should be closely watched:—

(a) Poling boards must be straight and plumb, and placed close together.

(b) Stringers must run with the grade of the ground and be opposite each other.

(c) Struts must be set at right angles to both poling boards and stringers. Struts not correctly put in are dangerous and are liable to slip or break, with consequent collapse of the trench.

(d) If the soil runs or seeps through the cracks between the boards the spaces should be filled with paper or other suitable material. Otherwise a hollow may form behind the poling boards, which may cause the timber to collapse.

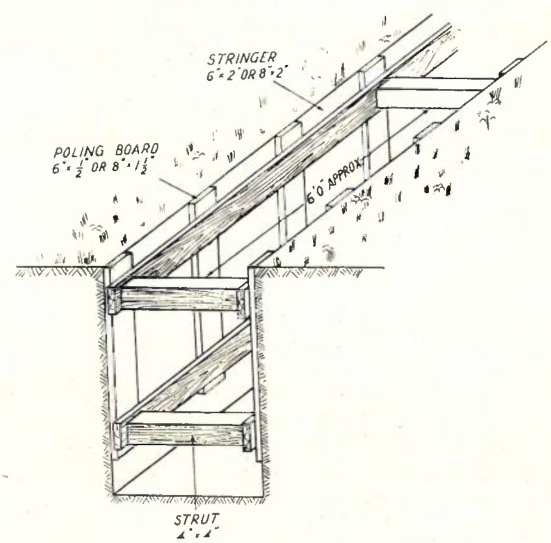


Fig. 21.—Open Timbering—Moderately Firm Soil.

Where the soil is firm but exhibits a tendency to crack a foot or so away from the trench and gradually slip in, the timbering method shown in Fig. 21 is suitable. These conditions occur under certain soil conditions (greasy back clay) and may occur where an old trench runs alongside the trench being excavated. The poling boards in this case are spaced up to 2 ft. apart depending on the soil conditions.

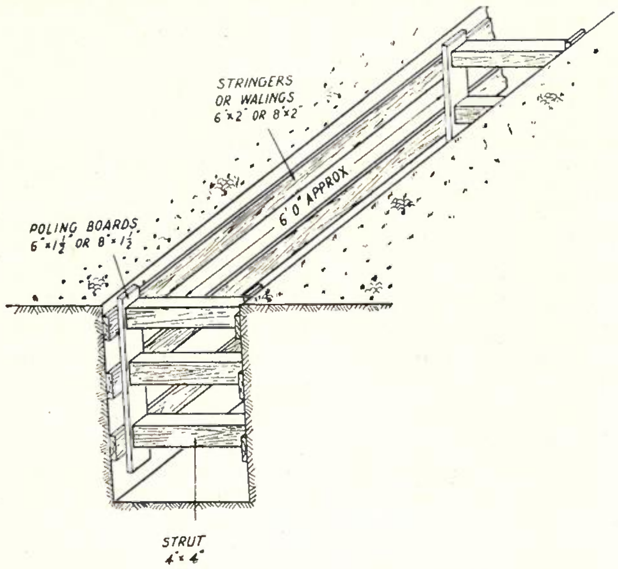


Fig. 22.—Open Timbering for Supporting Top Portion of Trench.

Fig. 22 shows another method of timbering and is applied chiefly where the top portion of the trench requires timbering. The number and spacing of the stringers are determined by the nature of the ground. Where the edges only of the trench require support, one stringer on each side may be sufficient, in which case the poling boards are omitted.

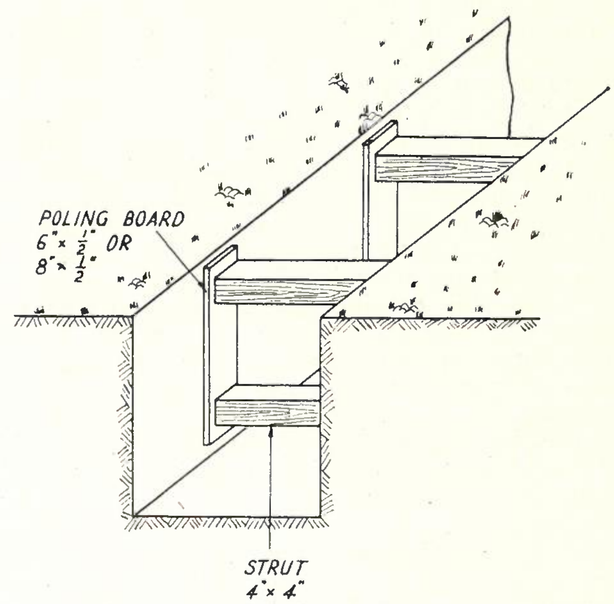


Fig. 23.—Timber Support where Walls of Trench Inclined to Fret.

Where odd parts of the walls are inclined to fret, a simple support as shown in Fig. 23 may prove effective.

(To Be Continued.)

MOBILE EMERGENCY GENERATING PLANT

S. W. McGill

Mobile alternating current generating units have been acquired by the Department for the purpose of supplying power to Telephone Exchanges in the event of interruption to the normal commercial power supply.

General: Two types of units are in use, their nominal ratings being 34 KVA. and 28 KVA. at 80 per cent. power factor. The layout of the two types is similar, but a heavier baseplate and construction are provided to accommodate the larger engine and alternator of the 34 KVA. unit, which is illustrated in Fig. 1.

General Description of Prime Movers: The prime mover for each unit consists of a four-cycle high-speed airless injection compression ignition engine, manufactured primarily for use in motor vehicles. The engines are direct-coupled to the alternators. The maximum engine speed recommended by the makers is 1700 r.p.m., but to provide for long running periods without impairing the life of the engine, the engines are run at 1000 r.p.m. At this speed the maker's performance curves indicate that the 5-cylinder engine associated with the larger unit can develop approximately 55 b.h.p., and the 4-cylinder engine associated with the smaller unit can develop approximately 44 b.h.p.

The complete working cycle, that is, two complete turns of the crankshaft, requires an air intake, a compression stroke, at or towards the

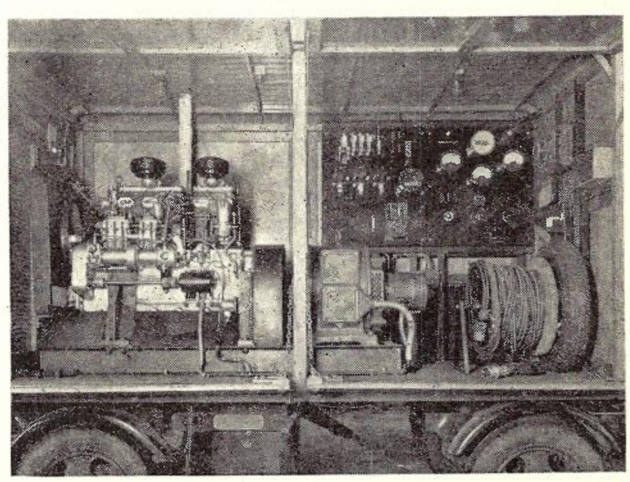


Fig. 1.—Portable Alternator for Emergency Use.

end of which a charge of fuel is injected into the combustion space and ignited by the high temperature, giving the power stroke, followed by the exhaust stroke. The fuel tank is located immediately beneath the engine under the chassis, the fuel being delivered to the engine by a pump driven by the engine.

The injection of the fuel into the combustion space is effected by an injection pump, one to each cylinder, which forces the fuel through a sprayer situated at the summit of each cylinder. In order that the fine passages of the sprayers should not become clogged with foreign matter, two filters are provided in the fuel supply line to avoid this contingency. Each contains two gauze cartridges or elements, which are removable for cleaning purposes. Each fuel charge is accurately measured by the injection pump, the amount of the charge being varied and controlled by the automatic governor to maintain the engine at 1000 r.p.m. under varying conditions up to full load.

Lubrication is effected by a circulation pressure system, fed by a pump, gear driven from the engine crankshaft, which delivers oil at a pressure of 45 lbs. per sq. in. at 1000 r.p.m. There is an arrangement of filters such that all lubrication oil is filtered before delivery to the various bearings. A connection is provided to a pressure gauge in order that lubrication oil pressure may be observed.

Engine cooling is carried out by water circulation through a radiator of conventional design, with belt-driven fan. Circulation is effected by a centrifugal pump, positively driven by the camshaft at crankshaft speed. Cooling water temperature is regulated by a thermostatically controlled valve, which restricts the circulation of the water around the cylinder jackets until its temperature is raised to the correct working value, with the minimum delay after starting from cold. The recommended temperature of the outlet water is 140 deg. F. to 160 deg. F., and under no circumstances should 175 deg. F. be exceeded. A thermostatically controlled alarm bell is fitted, which indicates the approach of excessive high temperature conditions.

Electric starting is provided, the 12-volt battery for this purpose being charged by a generator mounted on the engine. The starter battery is also used for lighting the interior of the trailer before the alternator is generating, and for operating the release coil of the 3-phase contactor associated with the control panel.

General Description of Alternators: The alternators are of the salient pole rotating field type, with direct coupled exciters of normal D.C. shunt generator construction. The continuous rating is 36 KVA. at 440 volts, 3 phase, 47.5 amps. As the alternator is required to generate at 415/240 volts, the phase current being limited to 47.5 amps, its actual continuous rating becomes 34.2 KVA., equivalent to 27.4 KW. at 80 per cent. power factor. Similarly the smaller alternator has a continuous rating of 30 KVA., 440 volts, 3-phase, 39.4 amps., which at 415 volts becomes 28.4 KVA., equivalent to 22.7 KW. at 80 per cent. power factor. It will be observed that the output of the engines is in excess of that required to drive the alternators at their continuously rated output. This was intentional, and was specified, so that the engines could be run for long periods without distress, and to give adequate overload capacity. It is mentioned in passing that the British Standard Specification, No. 649-1935, gives a general recommendation that the B.H.P. rating of diesel engines driving alternators should not be less than the continuous maximum rating of the generator multiplied by 1.50. This assumes a conversion of mechanical to electrical energy by the alternator of not worse than 89.5 per cent.

Control Panels: The control panels associated with the two types are identical, with the exception of the manual exciter field regulators, which are wound to different resistance values to suit the individual characteristics of the exciter fields of each alternator. Each panel has mounted upon it the following equipment:

(1) A 3-phase contactor operated from the A.C. supply and released by the 12-volt starter battery.
(2) Three overload relays.
(3) A low voltage relay.
(4) Automatic voltage regulator of the carbon pile type.
(5) Moving iron ammeter which measures the current in one phase.
(6. Moving iron voltmeter with transfer switch to permit observation of the voltage between any two phases.
(7) Moving coil exciter ammeter, which indicates the amount of current supplied from the exciter armature to the exciter and the alternator fields.
(8) Control circuit switch, which prepares a circuit for the energising of the main contactor.
(9) A push-button station for closing and releasing the main contactor.
(10) A circuit breaker release coil switch which prevents the tripping of the main contactor due to operation of the low voltage relay when starting large motors.
(11) A frequency meter.
(12) An ammeter shunt switch which prevents damage to the ammeter in cases where the starting current of motors is beyond the range of the ammeter.
(13) Pilot lights, the red indicating that the set is running with main contactor open, and green indicating that main contactor is closed and alternator generating.
(14) Fuses for protecting the following: voltmeter and frequency meter (3), control circuit (3), 240 volt lighting in trailer

(2), 12 volt lighting and control circuit from starter battery (2).

(15) "Cut-out" and ammeter associated with the starter battery charging generator.

(16) Neutral link, on which is terminated the star point of the alternator stator windings, the metal framework of the alternator, engine, etc., and the neutral wiring of the unit. The neutral is connected to the power supply earth at the exchange, via the centre conductor of the flexible cable used for connecting the alternator to the exchange installation.

(17) Push button associated with the electric starter on the engine.

The carbon pile voltage regulator is similar to the type in use for controlling the voltage of motor generator sets in exchanges. The controlling circuit measures the voltage across a pair of phase terminals of the alternator, this voltage being rectified by a copper oxide rectifier and applied to the torque motor winding. Variations of voltage in the controlling circuit act on the rotor of the torque motor, which is mechanically coupled to and varies the contact resistance of the silver contacts associated with the carbon pile. The carbon pile, which acts as a variable resistance element, is connected in series with the exciter field hand regulator, thus varying the voltage delivered by the exciter to the alternator field. The direction of rotation of the torque motor is such that an increase in the phase voltage causes separation of the elements of the carbon pile, thus increasing the resistance, which, in turn, lowers the exciter voltage.

The manually operated exciter field regulator, and outlet socket for connection of leads to the external load, are fitted adjacent to the control panel. The four-core 163/.018 tough rubber sheathed flexible cable, approximately 100 ft. long, and fitted with 4-point sockets at each end, is wound on a cable drum permanently mounted in the trailer. Adjacent to the manual exciter field regulator is a wooden box, in which is kept the cards on which maintenance and operating details are recorded. The control panel, with plug and cable, can be seen in Fig. 1. A schematic circuit diagram of a complete unit, with details of the wiring arrangements at exchanges, is shown in Fig. 2.

Circuit Description: The manual exciter field regulator and the rheostatic element of the automatic voltage regulator are in series between one side of the exciter armature and the exciter field. They act together to regulate the exciter

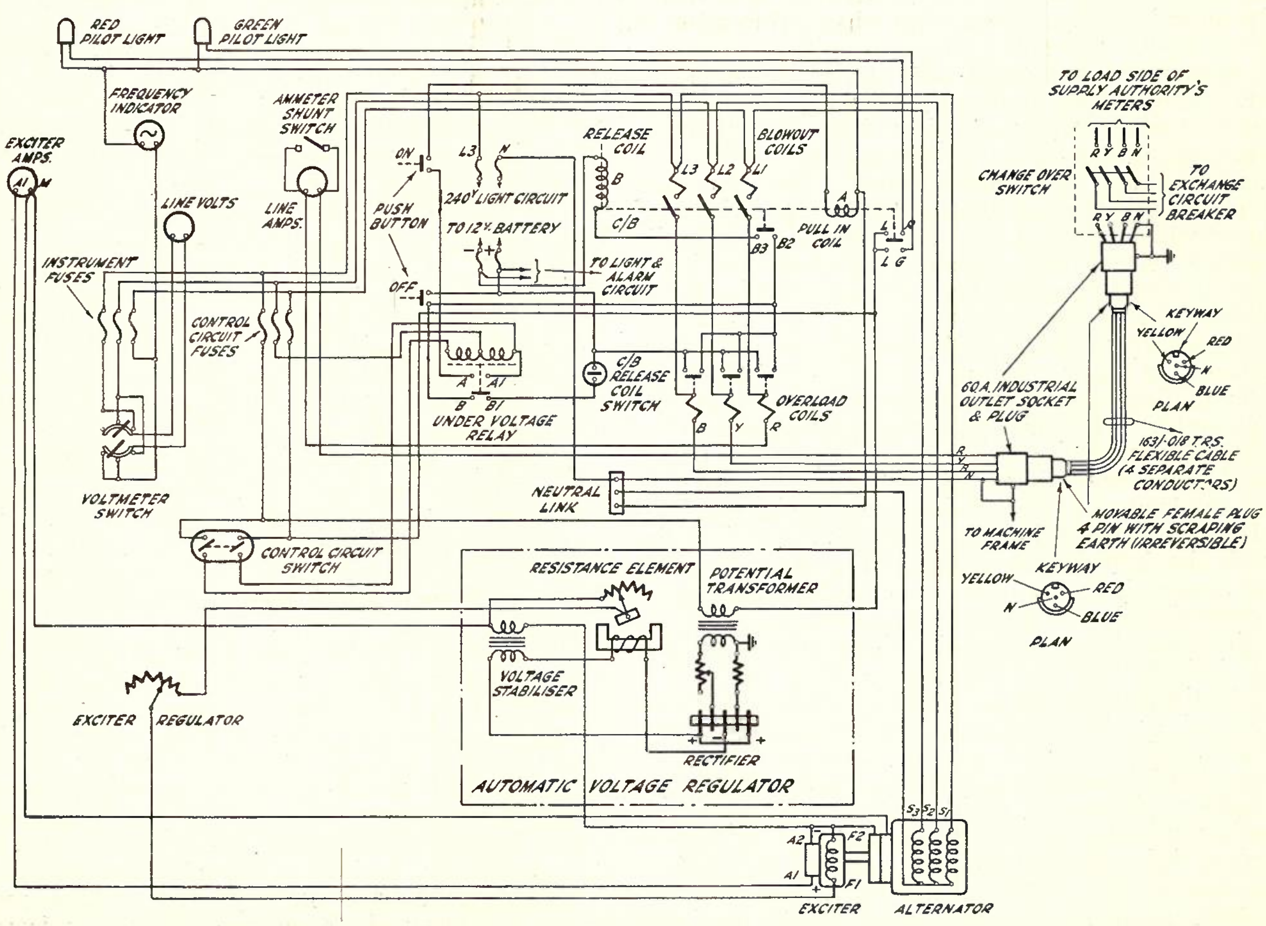


Fig. 2.

voltage, supplied via the sliprings to the alternator field, to keep the alternator voltage constant under varying load. When the alternator is generating the red pilot light is energised via S_3 through control circuit fuse through contacts on circuit breaker, through lamp to neutral. Closing the control circuit switch energises the undervoltage relay, the contacts A and A_1 being made when the phase voltage has reached its correct value. Pressing the "on" button energises the circuit breaker "pull in" solenoid from S_3, control circuit switch, contacts A and A_1, "on" button, "pull in" solenoid, to neutral. A mechanical latch holds the circuit breaker closed when the "on" button is released. The closing of the circuit breaker opens the contacts associated with the red pilot light, closes the contacts associated with the green pilot light, and bridges B_2 and B_3, thus preparing the release solenoid circuit. The latter is operated by the 12-volt starter battery. The "off" push button, overload contacts, and contacts B and B_1, of the undervoltage relay, are in parallel, and the closing of any one of these energises the release solenoid, which trips the mechanical latch on the circuit breaker, causing it to disconnect the alternator output from the external load. The function of the release coil switch is to prevent the undervoltage relay from tripping the circuit breaker should the alternator voltage fall momentarily to a low value when starting a motor whose starting current is in excess of the normal capacity of the alternator. The switch is closed after the motor has been started, thus allowing the undervoltage relay to disconnect the alternator should the phase voltage fall below normal. The ammeter shunt switch is closed under similar conditions to those which necessitate the use of the circuit breaker release coil switch, thus preventing damage to the ammeter should the initial rush of current be beyond the range of the ammeter. The necessity for the inclusion of the two latter controls in the circuit will be appreciated when it is realised that the starting current of a 15-h.p. motor with Star-delta starter would exceed 50 amperes. The smaller alternator is quite capable of supplying sufficient energy to drive a fully loaded 28-h.p. motor, and the larger alternator a fully loaded 35-h.p. motor, but it would be impracticable to start these motors if the undervoltage relay was not made temporarily inoperative during the starting period.

Trailers: An illustration of a trailer in which a unit is installed is shown in Fig. 3. The body has adjustable sides and ends, which are open while the unit is in operation. The side flaps can be locked in a horizontal position to provide free circulation of air, with protection from the weather. Pressure brakes, operated from the towing vehicle, are fitted in addition to hand-brakes, intended for use during manhandling of the trailer into position at difficult locations.

Performance: The acceptance tests on the generating units provided for a 16-hour run at full load with 10 per cent. overload during the last hour. The units performed this task satisfactorily, the fuel consumption being approximately 0.56 lb. per KW/Hr. The exact calorific value of the fuel was not known, but, assuming a value of 19,000 B.T.U.'s per lb., which is commonly used for rough calculations, the figures indicate an approximate thermal efficiency for the complete generating units of 32 per cent.

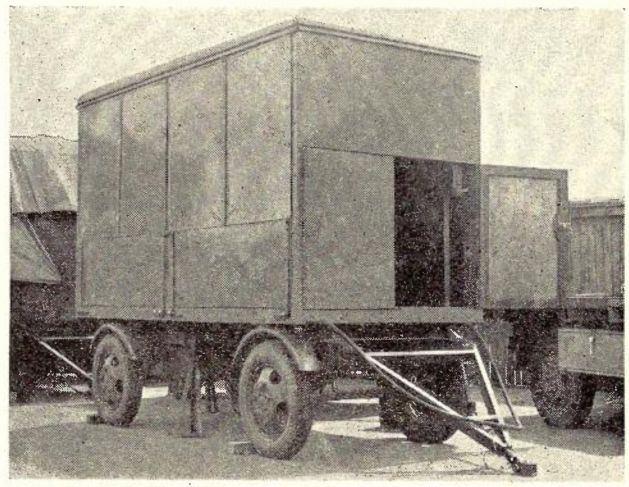


Fig. 3.—Portable Alternator for Emergency Use.

This remarkably good figure for a small unit indicates the progress made in diesel engine design. The actual fuel cost works out at approximately 0.77d. per KW/Hr., with fuel at £12/15/ per ton, which, it might be stated, is about three times the prewar price.

Further tests carried out showed that the engine governor, after some adjustment, complied with the specification, in that on suddenly taking off or throwing on the rated load, the maximum permanent change in speed of the engine did not exceed 4 per cent. of the rated speed.

In order that the machines should be kept in good condition so that they would be available for use if required, a maintenance programme was arranged with this end in view. Each unit is started weekly, and generates into an artificial load consisting of a 3-phase resistance element immersed in water. On alternate weeks one machine is allowed to run under these conditions for about one hour. Once per month a complete unit is towed to a nearby exchange, where it acts as a substitute for the commercial power supply for approximately one hour. An officer is detailed for the work, and it is his responsibility to ensure that the unit is kept clean, the fuel and crankcase oil kept at maximum, and lubrication attended to. Special attention is given to the starter battery. The trailer unit tyres are checked to ensure correct inflation pressure. Records of maintenance are entered on cards kept in the trailer units.

Arrangements for Use at Exchanges: The facilities for connecting a unit at an exchange were arranged so that service could be given speedily and safely, with no risk of danger from electric shock. In the absence of these facilities it would be necessary to disconnect heavy cables from switches and improvise arrangements to substitute cables from the engine alternators. Owing to the variations in mechanical dimensions of power switches, etc., in exchanges, it would be necessary to provide a set of spanners, etc., for the work at each exchange. It would be probable, also, that in the emergency adequate lighting would not be available or even permissible.

In view of the above, each unit was provided with flexible extension leads terminated in power plugs. Power sockets to receive the plugs were installed on the generator units and at the exchanges. The connections to these items of equipment were tested during installation for correct phase sequence to guard against reversed rotation of motors. Change-over switches were fitted between the load side of the Electricity Supply Authority's meters and the exchange circuit breaker. With the above arrangements, when emergency supply is required the extension leads can be run out, the plugs inserted at the generating unit and the exchange, and change-over switch operated to the emergency side. The emergency set is then ready for operation.

Conclusion: The generating units have demonstrated that they are capable of providing the service for which they were acquired. The non-inflammable nature of the fuel oil is a distinct advantage, in that no special arrangements are necessary for storage of supplies, which can be dispersed in 44-gallon drums at convenient locations. Regular maintenance is necessary, particularly to the starter battery and trailer tyres. The plant being run at regular intervals also assists in familiarising the staff concerned with the operation of the units.

DEVELOPMENTS IN CARRIER TELEGRAPH TRANSMISSION IN AUSTRALIA—PART 2

J. L. Skerrett

Carrier Telegraph Equipment Designed and Manufactured by the Department

As mentioned in the foreword to Part 1, the advent of war resulted in greatly increased demands for long distance telegraph service. During 1940 a commencement had been made in collaboration with the Research Laboratories on the design of a 4-channel carrier telegraph system which could be brought into use over comparatively short distances without interfering with the normal voice frequency speech channel or the application of a 3-channel carrier telephone system on the same pair of wires. The entry of Japan into the war in December, 1941, greatly intensified the demands for telegraph service and the manufacture of two of these systems was rushed to completion to meet urgent requirements, whilst the manufacture of a further three systems was commenced prior to the completion of the first-mentioned systems. These special 4-channel systems are termed "Type R" to distinguish them from existing Type B and V.F. carrier telegraph systems, and a brief description of their general features is as follows:—

The Type R System is a 4-channel duplex carrier telegraph system operating in the frequency range 3300 to 5220 cycles per second. The system is designed to operate on a 2-wire circuit, but it may be readily applied to a 4-wire circuit if desired. Eight different frequencies are employed, four in each direction, each frequency being an odd multiple of 60 cycles in the range 3300 to 5220 cycles per second. The carrier frequencies are spaced 240 cycles apart, with a separation of 480 cycles between the A and B terminal frequency groups.

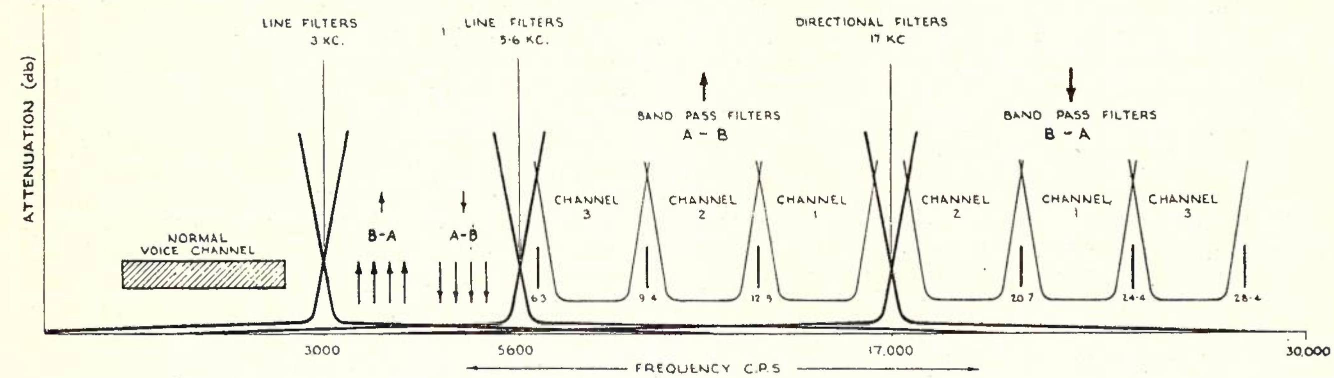
The channel frequency allocations are as shown in Table 3:—

Channel Number	"A" Terminal		"B" Terminal	
	Transmitting Frequency	Receiving Frequency	Transmitting Frequency	Receiving Frequency
1	4.50 Kc/sec.	3.30 Kc/sec.	3.30 Kc/sec.	4.50 Kc/sec.
2	4.74 ,,	3.54 ,,	3.54 ,,	4.74 ,,
3	4.98 ,,	3.78 ,,	3.78 ,,	4.98 ,,
4	5.22 ,,	4.02 ,,	4.02 ,,	5.22 ,,

TABLE 3—Type "R" System—Frequency Allocation

It will be noted that the Type "R" system operates in the frequency spectrum above the normal voice frequency speech channel range and below the lowest carrier frequency transmitted by the Type CS, CT, SOS, SOT carrier telephone systems and it may, therefore, be operated on a pair of wires which already carry a normal voice frequency speech channel and one of the abovementioned carrier telephone systems, as shown in Fig. 14. It follows, of course, that the Type "R" system can be applied to a pair of wires not equipped with a carrier telephone system.

system it is necessary to alter the modulator and demodulator oscillator frequencies of the carrier telephone system so that the wanted side-band falls within the range of the respective modulator and demodulator band filters. For example—channel 2 of a CN3 carrier telephone system could be employed by altering the carrier frequencies from 10.7 Kc/sec. and 16.5 Kc/sec. to 13.5 Kc/sec. and 21.8 Kc/sec. respectively.

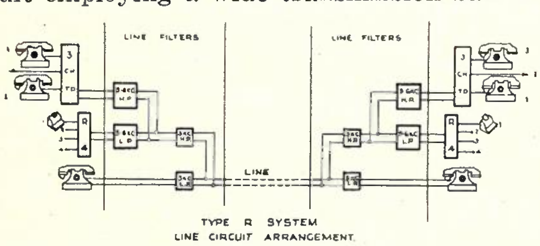


FREQUENCY ALLOCATION-V.F. SPEECH, TYPE R TELEGRAPH AND 3 CHANNEL TELEPHONE SYSTEM

Fig. 14.

The system is principally intended for application to open wire lines where it is arranged to operate between a 3Kc/sec. High Pass line filter and a 5.6 Kc/sec. Low Pass line filter, as shown in Fig. 15. It must be ensured that the circuit employed for the Type "R" system can transmit the frequencies involved (3.30-5.22 Kc/sec.) without too high an attenuation. A line equivalent exceeding 20 db. at 5 Kc/sec. is not recommended. This is equivalent to a distance of 200 miles on a 200 lb. copper circuit. The Type "R" system can, of course, be operated over a lightly loaded cable circuit with a cut-off frequency of not less than 5400 cycles per second and an attenuation not exceeding 20 decibel.

It will be noted that the application of the Type "R" system to a circuit precludes the simultaneous operation of a physical broadcast circuit employing a wide transmission band.



TYPE R SYSTEM
LINE CIRCUIT ARRANGEMENT

Fig. 15.

Intermediate repeaters for the Type "R" system have not yet been designed and its operation is, therefore, normally limited to the range stated above. It has, however, been employed over greater distances by operating it over a channel of a carrier telephone system. Due to the frequency allocation of the Type "R"

Actually more than 4 channels can be operated over a carrier telephone bearer channel in this manner as, by the use of two complete Type "R" systems and the employment of both an "A" and a "B" terminal at each end of the circuit, it is possible to derive eight duplex channels.

When applying a Type "R" system to a channel of a 3-channel telephone system care must be taken in the choice of the bearer channel as unwanted products of modulation can cause interference between telegraph channels.

It will be appreciated that the only justification for the operation of a Type "R" system over a carrier telephone link would be a shortage of voice frequency carrier telegraph equipment. If a voice frequency carrier telegraph system is available it can be applied to any carrier telephone channel without the necessity to retune the carrier oscillators, and there is no restriction on the choice of a telephone channel. Thus, the main function of the Type "R" system is to employ an unused portion of the frequency spectrum to derive four duplex telegraph circuits over short distances. The number of channels derived is not sufficient to normally economically justify its use on important main trunk routes, as many more channels can be obtained from a multi-channel voice frequency carrier telegraph system.

The Type "R" system has been designed for telegraph channels working at a speed of 50 bauds, and at this speed the distortion is small and such that Type "R" channels may be used as links in a long telegraph circuit comprising 3 or 4 links, providing the other links are of equal quality.

The complete terminal equipment of a Type "R" system is contained on one side of a 10 ft.

6 in. rack. The terminal layout is shown in Fig 16. The system operates from 24 volt negative and 130 volt positive and negative batteries. The approximate power drains for each terminal are as shown hereunder:—

Valves and Miscellaneous Circuits

24V. negative supply — 3.5 amps.
130V. positive supply — 150 milliamps.

Telegraph Loops

130V. positive supply — 100 milliamps.
130V. negative supply — 100 milliamps.

The above power drains do not include the send telegraph equipment as usually the telegraph office is situated at a distance from the carrier terminals. If the send telegraph equipment is to be supplied from the same power supply, an additional drain of 100 mA's on both the 130V. positive and negative telegraph batteries must be allowed.

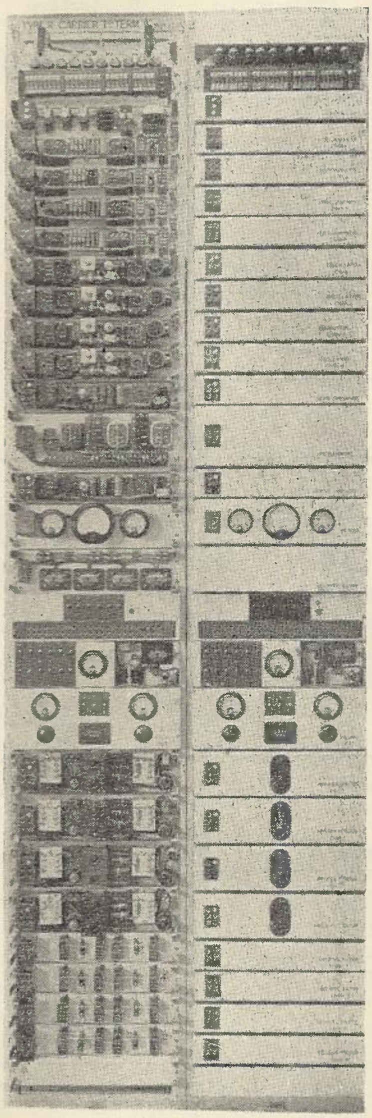


Fig. 16.—Type "R" System.

The first two Type "R" systems were completed in January, 1942, and were forwarded for installation between Adelaide-Alice Springs and Alice Springs-Darwin. The author accompanied the equipment. It will be appreciated from the foregoing description of the system that it was not intended for operation over such distances, but at the time these two systems represented the only available carrier telegraph equipment in the Commonwealth and their application to the Adelaide-Darwin route provided additional telegraph circuits which were urgently required and could not have been provided by any other means for many months.

The installation of the first system between Adelaide and Alice Springs was undertaken in advance of a suitable carrier telephone bearer circuit by operating the system over a normal physical speech circuit equipped with V.F. repeaters (22. type) inserted at intervals of 200 miles. The V.F. repeaters were modified by removal of their low pass filters and re-equalisation for operation up to 5.4 Kc/sec., whilst standard 5.6 Kc programme type line filter sets were installed en route. The system was brought into operation over this circuit in February, 1942, but the performance was not entirely satisfactory, due mainly to the high overall transmission equivalent necessitating the operation of amplifier equipment in the Type "R" system and V.F. repeaters almost at maximum gain in each direction of transmission with consequent tendency to overloading and interchannel interference. The fact that the V.F. repeaters at each station were operating on Stop 9 or 10 in each direction will illustrate the difficulties involved. Fortunately, the nature of the line—a relatively clear open wire pair with large separation between repeater stations—permitted the derivation of very satisfactory balance networks, thus making possible operation at the high gains referred to above.

Another contributory factor was the fact that this Type "R" system was the first of its type and naturally the field installation indicated the necessity for slight circuit modifications which were not apparent during the laboratory trials which were severely curtailed due to the urgency of the requirements.

Despite the difficulties of the problem, the system gave a reasonable service and a few days later a 3-channel carrier telephone system was brought into operation between the two centres concerned, and the Type "R" system was then superimposed on channel 2 of this system by retuning the carrier telephone modulator and demodulator oscillators as previously detailed. This permitted the derivation of four satisfactory duo directional simplex channels at a time when the traffic demands were at their highest peak. (It will be recalled that Darwin was first raided by the enemy during February, 1942.)

The second system was brought into operation five weeks later and the experience gained during

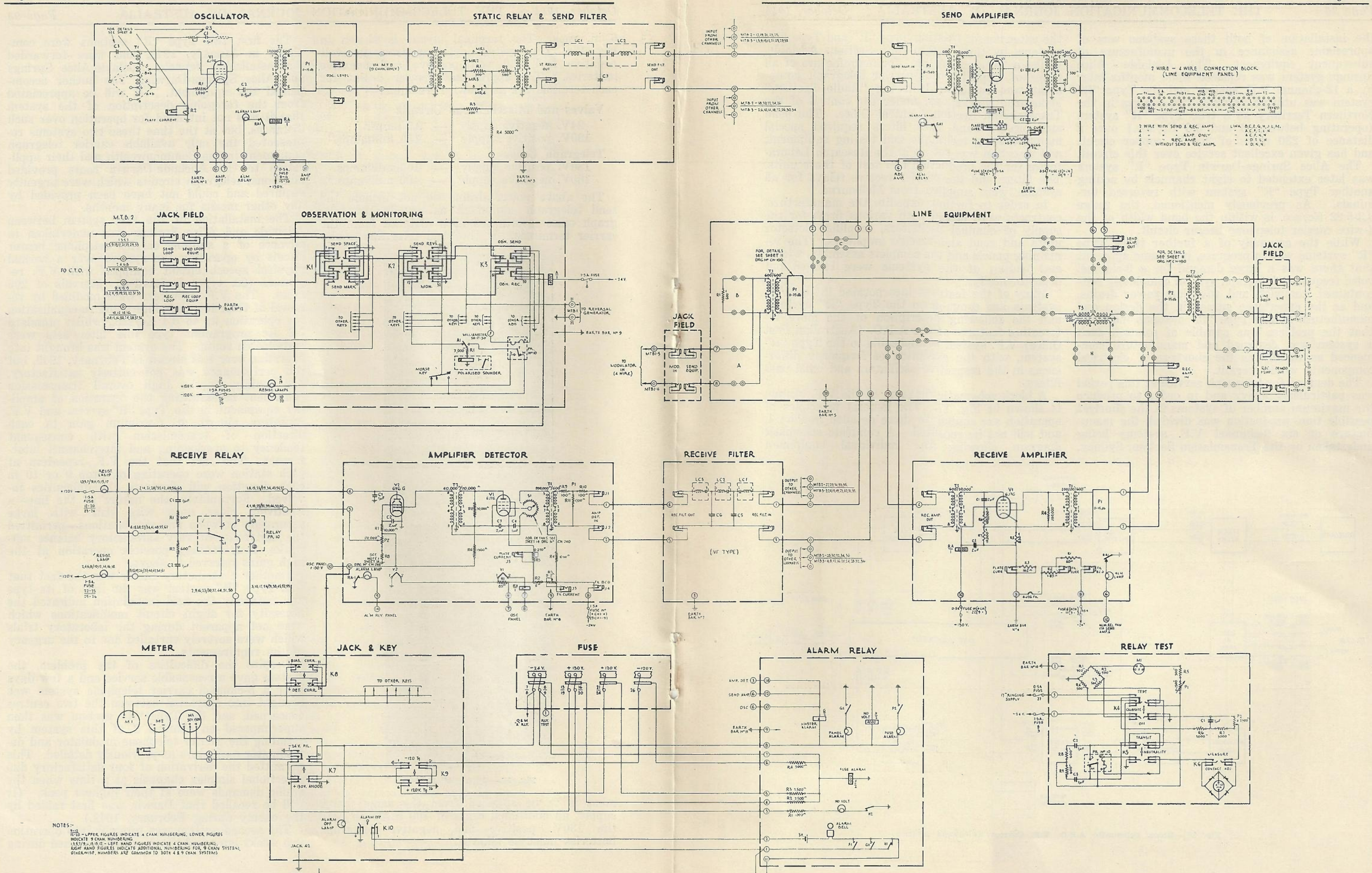


Fig. 18.—Wiring Schematic A.P.O. V.F. Carrier Telegraph System.

the installation of both these systems was of appreciable assistance in the manufacture of subsequent equipment. The Adelaide - Alice Springs system was replaced some months later by a 12-channel V.F. system and the Type "R" system was utilised between two centres in the Northern Territory as a true Type "R" system (operating between 3 and 5.6 Kc/sec.) over a distance of 230 miles of 200 lb. copper circuit and has given excellent service over this circuit.

The Alice Springs-Darwin Type "R" system was later extended to eight channels by adding another Type "R" system with reversed terminals. As previously mentioned, the range 3.3-5.22 Kc/sec. is within the band width of the 4-wire carrier telephone bearer circuit.

While the assembly of a further three Type "R" systems was in progress, it became apparent that there was a large demand for a 9-channel voice frequency telegraph system completely self-contained, compact, and with low power drains, and as the experience gained in the design and manufacture of the Type "R" systems indicated that the problem was capable of solution such a system was designed and manufacture commenced as rapidly as the shortage of electrical components would permit.

The demand for telegraph service at this period was particularly heavy and in order to produce the maximum number of systems in the shortest possible time production was divided, the manufacture of six 9-channel V.F. systems being undertaken by the Transmission Section, Sydney, the extension of existing Type "R" and Type "B" systems by the Transmission Section, Adelaide, whilst a "production line" for manufacture of all types of Departmental carrier telegraph equipment was established in the "Radio Section," Melbourne Workshops, under the control of the Transmission Section, Central Office. The send and receive band pass filters required special manufacturing technique and testing equipment, and a section was set up in the Research Laboratories for the production and test of those units. The filters and the carrier receive relays for all systems were supplied from Melbourne.

In order to further expedite the manufacture, contracts were placed with various firms for the supply of channel oscillators, amplifier detector units and send and receive amplifiers. The remaining panels and the complete assembly, wiring and testing of the systems were carried out departmentally.

Many of the features incorporated in the V.F. systems are common to the Type "R" systems and the following description of the more interesting features of the A.P.O. (Australian Post Office) V.F. system is applicable to the Type "R" system, with the exception of frequency differences in the respective oscillators and band pass filters.

A block schematic diagram of the V.F. system is shown in Fig. 17. The general principles of operation are similar to those detailed in Part 1, and will not be repeated. A complete schematic diagram showing the individual equipment

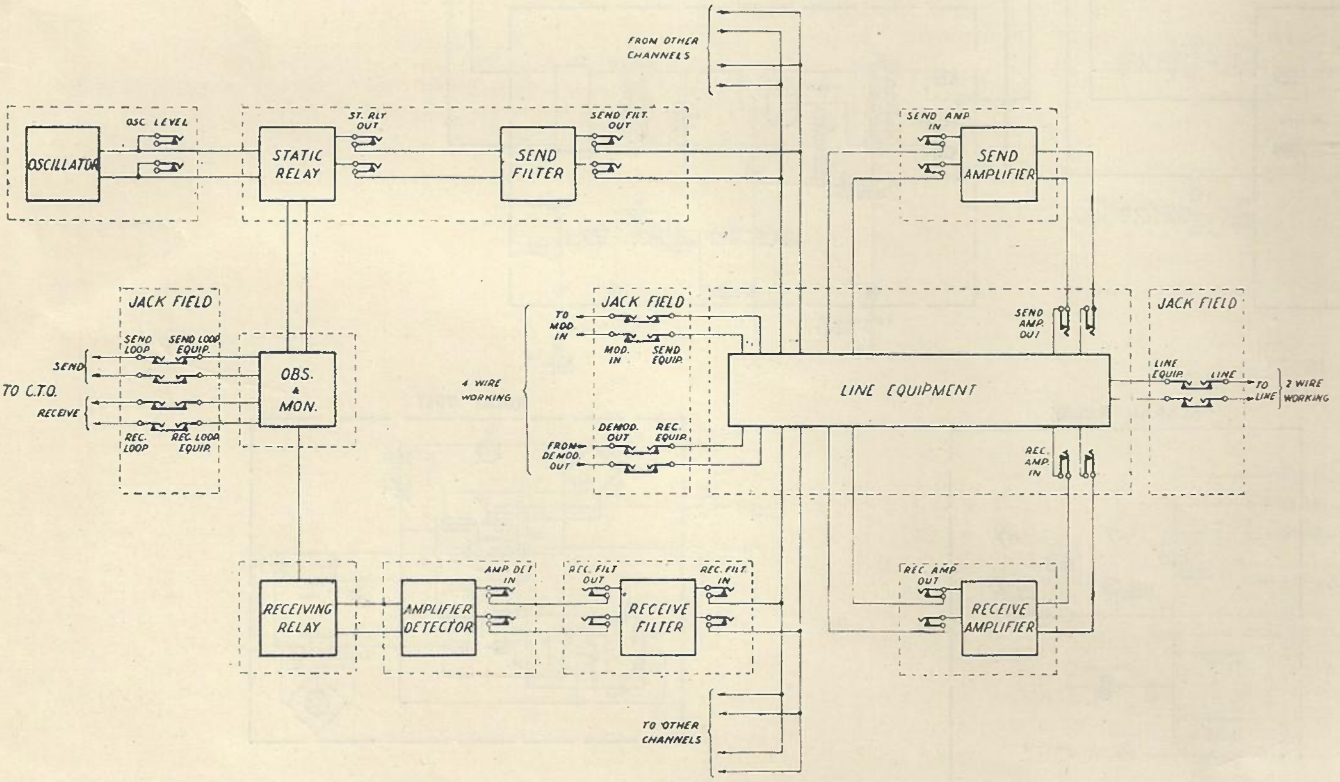


Fig. 17.—Block Schematic A.P.O. V.F. Carrier Telegraph System.

associated with a channel, together with the equipment common to the system, is shown in Fig. 18. Reference should be made to this diagram in connection with the brief description of the features of individual units, which follows.

Carrier Supply: The channel carrier frequencies are supplied from individual oscillator units. The oscillator is the conventional feedback type in which the energy transferred from plate to grid is controlled by a resistance. The frequency of oscillation is determined by a tuned inductor, the frequency being approximately fixed by the choice of tuning condenser. An interesting feature of the design is the tuned inductor, which has a variable inductance. The inductance variation is controlled by altering the position of a cylindrical iron dust core relative to a fixed outer shell carrying the inductor winding. The core movement is controlled by a special worm drive extended to the tuning dial, which is capable of being locked in any desired position. The use of a variable inductance considerably simplifies the choice of condenser components in respect to tolerances. Accurate condensers of the comparatively large capacitance values required, with a good temperature co-efficient, would have been very difficult to procure. The oscillator frequency is capable of a percentage variation of 5 per cent. in order that any individual oscillator can be tuned to the optimum value through the channel send and receive band pass filters for maximum detected current (that is, drive current applied to the carrier receive relay). The oscillator output is applied to the static modulator via a variable attenuator, which provides for adjustment of output level in steps of 1 decibel. The attenuator also serves to effectively mask the impedance variations which occur in the static modulator under marking and spacing conditions.

Static Modulator: The static modulator circuit employed has already been described in Part 1. The type of metal rectifier unit employed in this modulator is worthy of mention. Gold sputtered copper oxide Type H rectifier discs are used, three discs being connected in series in each unit.

A feature of this type of disc is that the required contact pressure between adjacent discs is extremely low and they are therefore mounted in a small cylindrical capsule approximately $\frac{3}{8}$ in. diameter and $\frac{3}{4}$ in. long, the discs being held in contact by a flat spring of light tension. The units in the series and shunt arms are selected in matched pairs for resistance characteristics to preserve the balance of the modulator circuit. The discrimination characteristic of this type of static modulator circuit employing the abovementioned rectifier discs is excellent, being greater than 45 decibel in all cases.

Filters: The send and receive band pass filters differ from the types employed on the 120-cycle spacing M.C.V.F. systems discussed in Part 1. This latter construction was rejected in favour of a more simple 3-element type, and the send filter consists of a single T section, whilst the receive filter is of double T section. In the voice frequency systems in contrast to the Type "R" systems an internal transformation has been employed in order that the series inductance coils can be reduced to 3 coils in lieu of 4 coils. This is somewhat similar to the method described for the 120-cycle spacing filters in Part 1. This development arose from the necessity to strictly conserve stocks of coils as it was difficult to secure supplies of suitable coils having the required Q values.

The basic structure and the various filter structures with associated formula are shown in Fig. 19.

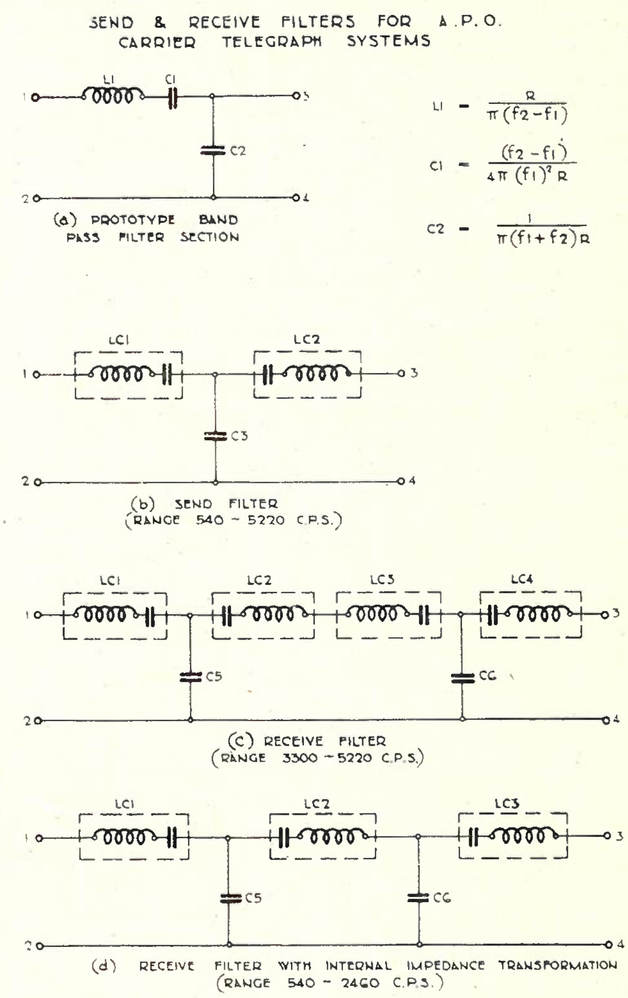
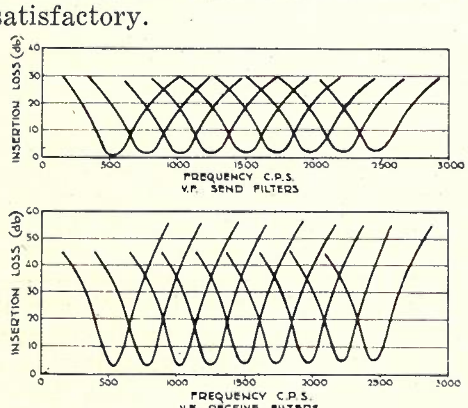


Fig. 19.

The design and manufacture of suitable filters introduced some very interesting and, at the time, difficult problems. The initial design work was directed towards the adoption of filter construction suited to the coils and condensers available, and considerable preliminary work was involved in testing laboratory models to determine the stop and pass band insertion losses and the discrimination between adjacent filters. It will be appreciated that the adoption of 240-cycle spacing between channels contributed considerably towards relaxation of stop band requirements whilst retaining as well as permitting a more effective pass band with consequent higher transmission speeds.

The value of the series inductance is a constant (0.796 Henries) at all frequencies, whilst the series condensers range in value from 138200 $\mu\mu$f to 1196 $\mu\mu$f and the shunt condensers from 0.6947 μf to 0.0508 μf. In the construction of the filters one of the difficulties was the production of coils which were a constant design value of 0.796 Henries at the various mid band frequencies. It was therefore necessary to correct the calculated capacitance values to compensate for coil deviations. It was found from a consideration of the design formulæ that the series resonant circuit consisting of L and C resonated at a frequency 60 cycles below the mid band frequency (that is, the theoretical lower cut-off frequency) and this was utilised to considerably simplify the manufacturing technique. In the first two systems the method adopted was to resonate a particular coil with a laboratory variable condenser to determine the value of the series condenser. The values having been determined, it was practicable to purchase suitable silver mica condensers accurate to within 1 per cent. of the measured value (this necessitated lining up the laboratory and the condenser manufacturers' testing bridges). The condensers were purchased 20 $\mu\mu$f below the measured value, and an 0-40 $\mu\mu$f variable air condenser was then connected in parallel with the series condenser and, after final resonance adjustments, the complete unit was potted and sealed in a copper can. The shunt capacitance values were not as critical, and paper condensers accurate to within ± 2 per cent. of the calculated value were found to be satisfactory.



FILTER ATTENUATION CHARACTERISTICS
9 CHANNEL A.P.O. V.F SYSTEM.

Fig. 20.

In all the remaining systems this method was rejected in favour of the use of condensers ± 1 per cent. of the calculated value, the associated coils being initially wound to a ± 1 per cent. tolerance and corrected to the required value by adding or removing the required number of turns whilst connected in series with the condenser in a resonance bridge test circuit. All condensers and coils are carefully measured when first received, and a carefully tabulated chart greatly facilitates the selection of coils suited to certain condensers, thus reducing the labour of removing or adding turns to a minimum. Allowance is made at time of resonance adjustment for the slight variations which occur when the coil and associated condenser are impregnated and potted in the filter can.

The send and receive filter characteristics are illustrated in Fig. 20.

Amplifier Detector: The amplifier detector is connected to the output of the receive filter in each channel and serves to reproduce the direct current signals which operate the carrier receive relay. The input to the amplifier detector consists of a 3 decibel stabilising pad followed by a 600/200,000 ohm input transformer. The secondary is terminated in a resistance of 200,000 ohms, the resistance being divided in a logarithmic ratio to permit control of the voltage applied to the grid of the amplifier valve. The input level is thereby adjusted in steps of 1.5 decibel up to a maximum of 15 decibel. The amplifier valve is a 6J7G and the output is applied through an interstage transformer to the grid of a 6V6G valve employed as a detector. The rectified current output of the detector valve passes through the line windings of the carrier receive relay. Through the auxiliary or bias windings of this relay, there is a steady current which holds the tongue of the relay on the spacing contact during the spacing period. On receipt of a marking signal the rectified current takes control and moves the relay tongue to the marking contact. The bias current is derived from the +130 volt supply via a variable potentiometer.

The grid bias voltage of the amplifier valve is normally derived from the voltage drop across a series resistor in the filament circuit, while the bias for the detector valve is obtained from the 24 volt filament supply. In the spacing condition (no drive) the detector valve is biassed to cut off (not greater than 0.5 mA's). In the marking condition the rectified current is normally of the order of 9 milliamps.

The most important feature in the circuit is the inclusion of an A.V.C. feature which holds the detector current substantially constant with line attenuation variations over a range of ± 5 decibel. The circuit constants are such that a normal incoming signal amplified by the first valve makes the grid of the detector valve slightly positive with the result that grid current flows and condenser C.4 becomes charged due to the voltage impressed on it by the flow of current through resistance R4. As a result the normal bias is increased by an amount equal to the voltage drop across R4 and the amplification of the first valve is reduced. The grid bias of the first valve will be reduced as the condenser C4 discharges through resistance R4, but the "time constant" of this combination is sufficiently large to enable condenser C4 to retain its charge for a time greater than the time length of the maximum spacing signal. Although the grid bias of the detector valve is also affected by the flow of grid current through resistance R4, the change in grid bias from the normal value is not large enough to affect appreciably the operating point and thus the output signal is little affected by such change.

If the attenuation of the bearer circuit decreases, the input level increases and the grid bias of the amplifier valve is further increased and the gain is reduced accordingly. On the other hand, if the attenuation of the bearer circuit increases, the input level decreases, and the grid current through R4 is reduced, the condenser C4 discharges and the gain of the amplifier valve is increased. With a proper choice of circuit constants, the output of the detector valve can be held close to the normal value over a working range of at least ± 5 decibel.

The type of automatic level control used on these units needs to take care of only slow variations in line attenuation and not abrupt changes. Abrupt changes are brought about only by fault conditions and need not be guarded against in the automatic level control. On unregulated circuits the line attenuation varies slowly from hour to hour and it is this form of change that needs correction. Therefore, the automatic feature depends on the amount of charge held on condenser C2. It can be seen that if the detector is left without an input for sufficient time for this condenser to discharge, the gain of the amplifier tube will slowly rise. However, on receipt of a signal of such amplitude that it requires correction the condenser quickly charges and the automatic feature operates, but from this it can also be seen that it is desirable at all times to hold the amplifier detector in the marking condition. The rate at which the condenser discharges is such that the bias is not affected when the longest spacing signal used in the 5-unit code is sent.

In order to hold the detector in the marking condition telegraph systems operating over these circuits should be of the type that send "mark" in the repose condition. For normal simplex morse channels, teletypes and teleprinters, the repose condition is "mark" and no change is necessary. In the case of the Multiplex systems, whilst the repose condition is "space," the correction signal is sent once every revolution and, as the signal is transmitted approximately five times every second, this is sufficient to ensure that the detector is always kept in the marking condition.

The production of an amplifier detector unit which, on the one hand incorporates an A.V.C. feature satisfying the stipulated input level variations and on the other hand does not, due to the inclusion of this feature, increase the characteristic distortion of the carrier telegraph channel as a whole, necessitated extensive design work and numerous circuit arrangements, each varying in slight detail, were tested prior to the adoption of the circuit just described. The circuit is of a type which has been employed in voice frequency carrier telegraph systems for a number of years, but the present circuit has an improved performance due mainly to the adoption of special methods of applying the grid bias to both valves. This, coupled with a careful choice of circuit components, has produced an improved performance both in characteristic distortion and constancy of output with varying line attenuation. The tests showed that the limiting circuit element values adopted (C4 — 1 μf and R4 — 10 MΩ) gave optimum results in respect to average distortion on various types of telegraph signals encountered in practice. The inclusion of a limiting feature in an amplifier detector circuit of necessity introduces some additional distortion as compared with an amplifier detector without limiting, but a careful choice of the circuit components and circuit arrangement permits such increased distortion to be reduced to negligible proportions. As mentioned in Part 1, if the telephone bearer circuit is closely regulated (± 0.5 db.), some advantage in total distortion can be secured by eliminating the A.V.C. feature in the amplifier detector units. By employing a circuit of the type described this margin can be reduced to negligible proportions.

The point to be remembered is that the inclusion of an A.V.C. feature is necessary to keep distortion within working limits when the carrier telegraph system is operating over an unregulated telephone bearer circuit. Reference to Table 2, Part 1, will indicate the considerable improvement gained under such operating conditions.

The adoption of a 10 megohm limiting resistance is a disadvantage in some respects in that the electrical components associated with the limiting circuit must have a very high joint I.R. as any slight current leakage will cause a considerable voltage drop across the 10 megohm resistor, thus affecting the bias to both valves with resultant increased distortion. However, as the distortion figures are optimum with this high value of limiting resistance, the solution lies in the adoption of associated circuit components which comply with a severe specification in regard to insulation resistance. Thus the transformers and condenser C4 must normally have I.R. values of the order of 200 megohms. Special precautions in regard to insulation materials and mounting details are also necessary to ensure maintenance of the required I.R. values.

Any difficulties from low I.R. occur in the sub-tropical and tropical climates, and any troubles of this nature have not been in evidence in systems installed in southern States. On the other hand some systems are operating in northern parts of Australia and New Guinea and special attention has been given to the development of high grade tropical finish components. The difficulties surrounding the production of high grade transformers and condensers at the present time are due mainly to the poor class of material available to the manufacturers and in the precautions necessary to prevent the ingress of moisture both during and after manufacture. These difficulties have been overcome and components now available satisfy tropical climate conditions.

The detector valves can also be troublesome if they are low I.R. between grid and cathode. All these valves must meet an I.R. requirement of 500 megohms. This results in the rejection of approximately 40 per cent. of normal supplies for detector purposes, although the majority of the rejected valves can be utilised for other applications.

Another difficulty encountered was the termination of the receive filter. This is normally connected, via a 3 db. pad, to a 600/200,000 ohm input transformer whose output is terminated in 200,000 ohms. The early input transformers had a high leakage reactance which altered the required non reactive 600 ohm termination of the filter with consequent slight shift in the mid band frequency of the filters. This was not serious, in that the channel oscillators could be tuned during line up to the centre point of the filter, but elimination of the condition was necessary for systems operated from existing machine generator supplies. The transformer was therefore redesigned to reduce the leakage reactance.

Send and Receive Amplifiers: A single stage send amplifier, of 600 ohms input and output impedance, employing a 6V6G valve is provided in the transmitting side of the system between the send filter output and the input to the 2-wire/4-wire line equipment panel. The circuit is of the bridge feedback type, i.e., both current and voltage feedback are applied. Optimum component values were chosen to keep the reflection coefficient in the output circuit as low as possible and at the same time obtain a relatively high power handling capacity consistent with reasonable gain. By applying 154 volts (130V. and 24V. combined) to the plate circuit, an output of +26 dbm. was obtained with less than 2 per cent. distortion. At higher levels the distortion rises rapidly. The amplifier has an available gain of 25 db. and the frequency response is within 1 db. over the V.F. range. A 15 db. pad variable in steps of 1 db. is provided for level adjustments, and, in addition, the voltage applied to the grid may be reduced a further 6 db. by means of a tapped resistor across the input transformer.

The output level per channel of a carrier telegraph system must have a value such that the combined peak power from all channels at a point in the bearer circuit corresponding to zero level does not exceed 5 milliwatts. The per channel level is therefore of the order of —26 dbm. so that a send amplifier is rarely required and it is only provided to meet the condition where the carrier telegraph terminal equipment is located some considerable distance from the telephone bearer circuit terminal equipment.

The receive amplifier has input and output impedances of 600 ohms and is of similar design to the send amplifier but employs a 6J7G valve. It is provided in the receive side between the 2-wire/4-wire line equipment panel and the common input to the receive filters. The amplifier has an available gain of 22 db. and the frequency response is within 1 db. over the voice frequency range. At + 10 dbm output, the distortion is less than 2 per cent. The average input level per channel to the amplifier detector input is of the order of —18 db., so that where the send levels are reduced to a value of —26 dbm as previously quoted, the use of a receive amplifier is necessary.

Two-Wire/Four-Wire Line Equipment Panel: This panel serves both the transmitting and receiving sides of the system and provides a ready means of setting up a 2-wire or a 4-wire connection. A special U link connection block provides for a variety of possible conditions, such as connecting send or receive amplifiers in or out of circuit in the 2-wire and 4-wire conditions and avoids the necessity of making wiring alterations each time that a system is applied to a new type bearer circuit of different characteristics to the former circuit. The unit also includes 0-25 db. attenuators in both the transmit and receive 4-wire paths, variable in steps of 1 db. for adjustment of sending and receiving levels.

Test Facilities

In developing the A.P.O. systems considerable thought was given to the provision of adequate testing facilities. The operating margins on carrier telegraph channels, particularly where machine systems are involved, are more critical than on carrier telephone speech channels, and it is therefore essential that the testing facilities provide a ready means of checking the performance of the various channels.

Observation and Monitoring Panel: Observation facilities are required to enable the carrier attendant to observe the signals passing on either the send or receive telegraph loop when any channel is extended to the telegraph office or a channel of another system. The essential requirement is that the observation circuit must not interrupt the message passing over the channel. A two-position M.B.B. key is connected in each send and receive loop and in either the "Observe Send" or "Observe Receive" position connects a 50-0-50 milliameter and monitoring relay in series in the loop. A polarised sounder is connected to the tongue of the monitoring relay so that both audible and visual observation of the signals is possible.

Monitoring facilities are provided to allow the carrier attendant to communicate with the distant terminal. A two-position key is connected in each send and receive loop and in the "Monitor" position connects a double current key to the respective channel static modulator and a polarised sounder to the tongue of the channel carrier receive relay, thus permitting communication between terminals. The remaining position of the Monitoring key is utilised for the purpose of transmitting, on any channel, double current reversals to the distant terminal for "lining up" purposes. A third two-position key connected in each send and receive loop serves to transmit a continuous "mark" or a continuous "space" signal to the distant terminal. This facility is very useful during "line up" of a system and is also of assistance in fault attention.

The key wiring is arranged in such a manner that the send loop from the telegraph office is looped back to its corresponding receive loop in the "Monitor," "Send Revs," "Send Mark," and "Send Space" positions. This feature is of considerable assistance to the telegraph testing officer and also assists in quickly determining if any keys have not been restored to the correct position on completion of tests.

Relay Test Panel: A relay test panel is included in each terminal to facilitate the testing and adjustment of the carrier receive relays. Spare relays are provided with each terminal, but it is necessary to attend to the relays at regular intervals to ensure the satisfactory operation of the system. All relays should be inspected and their contacts cleaned and burnished weekly and then finally checked for adjustment in the relay test set before placing them in operation in the system.

The relay test set provides for accurate contact adjustment, measurement of transit time and a check of the neutrality of the relay. Two sources of supply are employed in the test circuits, viz., the —24 volt filament supply and the normal 17-cycle ringing supply for application to the line windings of the relay. Two meters are mounted on the panel, one being a rectifier instrument, range 0-10 mA, to measure the A.C. current flowing in the line windings of the relay under test during the transit time and neutrality tests. The other meter is a centre zero 10-0-10 mA d.c. type for contact, transit time, and neutrality adjustments. Potentiometers provide for adjustment of the current supplied to the line windings of the relay under test and the balance of the test bridge circuits.

The contact adjustment test is for purposes of refining approximate bench adjustments.

The check of transit time determines the percentage time of one complete cycle, during which the tongue is travelling from one contact to another. The neutrality adjustment ensures that the marking and spacing signals delivered from the relay tongue are free of bias.

Reversal Generator: Although not an integral part of the system, a reversal generator is supplied with terminals to be installed in locations where a suitable source of reversals for testing and "line up" purposes is not available. The frequency of the reversals can be set at any of the following frequencies:—12.5, 17, 25, 33 and 50 cycles per second. The circuit details are shown in Fig. 21. When switch S is operated to the desired frequency setting a circuit is completed to the vibrating relay which operates and furnishes square-topped reversals at the required frequency.

After the relay has been set vibrating and before connection to an external circuit, the neutrality of the output is checked on a centre zero milliameter mounted in the unit. This meter is normally shunted with a 1 ohm resistor so that it will not be damaged when connected to a low resistance circuit. When it is desired to obtain a greater deflection for the purpose of checking the reversals, the 1 ohm shunt is removed by operation of a non-locking key.

Meter Panel: Three meters are provided on this panel, their purpose being as follows:—

Meter M1 is an 0-15 milliammeter and is provided to measure the detected current and the bias current in the windings of the carrier receive relays associated with each amplifier detector. Operation of a non-locking key in the channel concerned to either "Det. Curr." or "Bias Curr." connects the meter in circuit. The channel keys are located on the main jack and key field.

Meter M2 is an 0-1 milliammeter calibrated as a percentage meter for checking plate and filament currents. The meter resistance is built out to 1000 ohms, and the shunt resistors in the plate and filament circuits are so adjusted that when the normal filament current flows through the shunt a current of 0.5 milliamps flows through the 1 milliamp meter. Mid scale on the meter is marked "O" to correspond with the 0.5 mA meter current representing normal conditions. Any deviation from the mid position is read as a high or low percentage. In the earlier systems it was not possible to obtain resistors of sufficient accuracy to give an exact mid scale reading. However, this is not of great importance as the percentage readings for each valve are recorded at the time of installation and subsequent checks compared against the recorded values serve as an indication of the performance of the valves. Later systems employ variable resistors which can be adjusted to give a mid scale reading on the percentage meter at time of installation.

Meter M3 is a combined 0-50V. and 0-150V. voltmeter and is provided to measure the —24V. filament and +130V. anode supplies and the positive and negative 120V. telegraph battery supplies. The necessary connections to the meter are made via keys located on the main jack and key field.

ment of the optimum current values for various types of static modulators, such adjustment being made by including a suitable shunt resistor in the static modulator circuit.

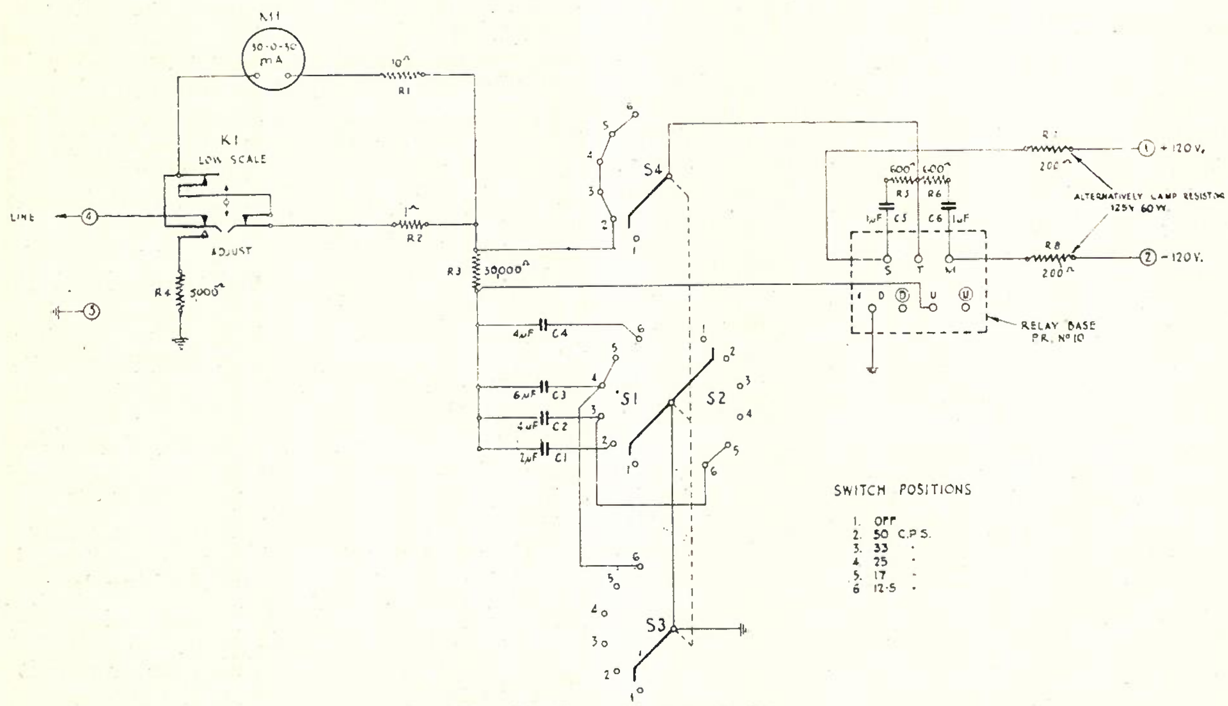


Fig. 21.—Reversal Generator.

Send and Receive Telegraph Loops: The send and receive loops for connection between the carrier terminal equipment and the telegraph office are designed for double current operation. Considerable difficulties in respect to loop arrangements have been experienced in the past due to the diversity of loop arrangements provided in systems obtained from various manufacturers. The lack of uniformity not only introduced difficulties from a maintenance viewpoint, because of differing values of loop current, but also reduced flexibility in the patching of carrier channels. The ideal conditions require a standard value of loop current in any send or receive loop, together with arrangements which permit any two carrier telegraph channels to be patched direct to one another and any terminal set in the telegraph office to be connected to any channel.

With the above factors in mind, the telegraph loop circuit arrangements were designed to cater for the required conditions.

Current Values: A standard current value of 25 mA. (±2 mA.) was adopted in both send and receive loops for the following reasons:—

(a) To permit the operation of teleprinter receive magnets direct in the carrier receive loop. (This method of operation is used at present in a limited number of cases and its use may be further extended.)

(b) Ample margin is provided for the adjustment of the optimum current values for various types of static modulators, such adjustment being made by including a suitable shunt resistor in the static modulator circuit.

(c) Where 215 A. sending relays are used in the carrier system, this current value is required to ensure satisfactory relay operation.

Location of Current Limiting Resistors: In each case the current limiting resistor is located at the earthed end of the circuit to meet the following requirements:—

(a) Correct current value when the circuit is terminated in the telegraph office or extended to another carrier telegraph channel at either the telegraph office or carrier terminal.

(b) Where necessary, for emergency or other purposes, no current limitation is applied at any point other than the telegraph office.

(c) Complete protection against current overload is afforded the static modulator.

Loop Circuits: The principle of operating carrier loops over one conductor of a pair with the mate conductor earthed at each terminating point to provide a shield was adopted after consideration of the following factors:—

1. Metallic loop operation with jacks in the forward and return legs was discarded because experience has shown that this method of operation led to the frequent reversal of loops during patching. The insertion of jacks in both forward and return legs also doubles the space required for jack accommodation at both the telegraph office and the carrier terminal.

2. Metallic loop operation with jacks in the forward leg only would introduce maximum inter-

ference between loops when carrier channels were patched to telegraph receive terminating equipment other than that to which they would be connected normally.

The earlier systems were originally designed for metallic loop operation with jacks in the forward and return legs, but for the reasons just mentioned this method has been discarded in favour of single conductor operation with the mate conductor earthed at each terminating point.

Action is now being taken to alter the carrier telegraph loops in all systems in each State to conform to the above-mentioned standard arrangements. In systems in which the optimum current value applied to the static modulator was less than 25 mA's, it is necessary to incorporate a non-inductive shunt resistor of suitable value in the static modulator circuit to limit the current applied to the modulator elements to the correct value.

In order to ensure satisfactory discrimination of static modulator circuits under the various patching conditions, the telegraph potentials applied at the carrier terminals and the telegraph office should be of the same value, the difference to be not greater than 10 per cent.

With the standard arrangements send and receive channels can be patched together at either the telegraph office or the carrier terminals as required. Such patching is only performed at the carrier terminals in cases of emergency.

General Features: The complete terminal equipment of a 9-channel system is mounted on both sides of a 10 ft. 6 in. rack, the details of the layout being as shown in Fig. 22.

The systems operate from 24-volt negative and 130-volt positive and negative batteries. The approximate power drains for each terminal are as shown hereunder:—

Nine-Channel System

Valves and Miscellaneous Circuits

24 V. negative supply	—	6 amps
130 V. positive supply	—	300 milliamps

Telegraph Loops

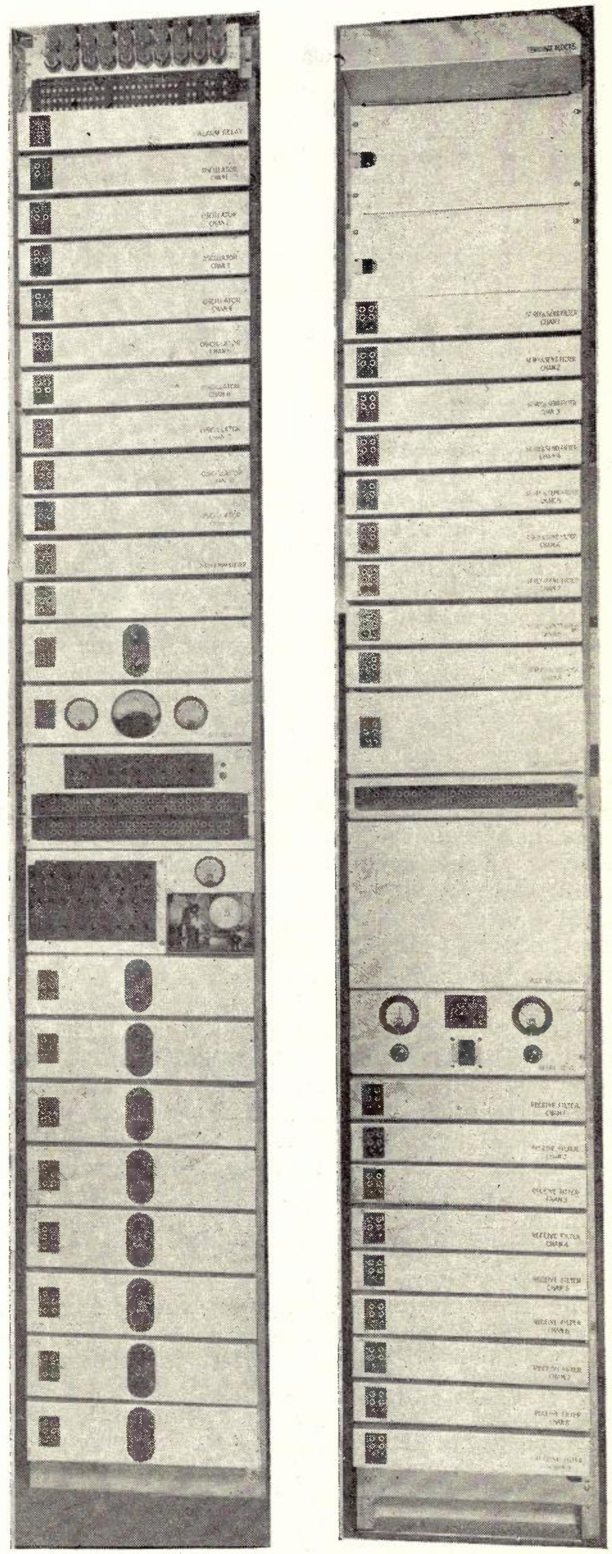
130 V. positive supply	—	250 milliamps
130 V. negative supply	—	250 milliamps

If the send telegraph equipment is to be supplied from the same power supply, an additional drain of 250 milliamps for a 9-channel system on both the 130 V. positive and negative telegraph batteries must be allowed.

In addition to the test equipment previously described, each terminal includes patching and test jacks, whilst the usual alarm relays and lamps are provided to indicate battery supply and valve failures.

Two types of Australian-made valve are employed in the A.P.O. systems, the 6J7G valve in all oscillator and amplifier circuits, with the exception of the send amplifier which employs a 6V6G valve. This latter valve is also used as a detector in the amplifier detector units.

In addition to the 9-channel systems, a number



Front Rear
Fig. 22.—Nine-channel A.P.O. V.F. System.

of 4-channel systems were manufactured and mounted on short 5 ft. 3 in. racks for special purposes. The frequency allocation of these systems is shown in Table 4:—

Channel Number	"A" Terminal		"B" Terminal	
	Transmitting Frequency	Receiving Frequency	Transmitting Frequency	Receiving Frequency
1	1740 c.p.s.	540 c.p.s.	540 c.p.s.	1740 c.p.s.
2	1980 c.p.s.	780 c.p.s.	780 c.p.s.	1980 c.p.s.
3	2220 c.p.s.	1020 c.p.s.	1020 c.p.s.	2220 c.p.s.
4	2460 c.p.s.	1260 c.p.s.	1260 c.p.s.	2460 c.p.s.

TABLE 4—"Frequency Allocation—A.P.O. 4-channel V.F. Systems"

It will be noted that two of these 4-channel systems can be coupled together to form an 8-channel system by associating an A and B terminal together at each end of the circuit.

In addition to the normal voice frequency and Type "R" systems, a number of other systems have been developed, or are in course of development, for certain special circuit applications, and their general features may be of interest.

Unidirectional Systems: The systems previously described provide for duo directional simplex operation on each channel. Some special 4-channel and 9-channel systems were also required for the purpose of remote keying of radio equipment, and in this application a unidirectional simplex channel only is required. In order to avoid extensive redesign of the normal 4- and 9-channel systems, the unidirectional systems conform to the normal layout, the unwanted panels being deleted but main form wiring and common equipment left unchanged, so that later conversion to a normal type system is a relatively simple matter.

Radio Link Systems: Consideration has been given to the possibility of operating M.C.V.F. systems over short-wave radio links. The problem is entirely different to operation over wire lines due to the greater variations in received signal strength, the decrement due to fading being fast compared with the slow variations in attenuation encountered on unregulated telephone bearer circuits referred to previously. In addition, selective fading over the transmitted frequency band is a further problem which has to be overcome.

The normal method of operating the carrier receive relay against a fixed current in the bias winding is unsatisfactory and it is necessary to resort to "two tone" working. In this method two normal voice frequency channels are combined to permit the derivation of one channel by transmitting one tone to line for the marking intelligence, and the other tone for the spacing intelligence. With this method no bias winding is required, the carrier receive relay can be connected in a sensitive bridge circuit, and the current through the line winding of the relay in either the marking or spacing condition may vary over a wide range without introducing bias.

It will be appreciated that the adoption of two tone working for radio link operation effectively halves the permissible number of channels that can be obtained from a M.C.V.F. system. Where selective fading is in evidence it may be necessary to adopt multiple two tone working to obtain satisfactory transmission, and in such a case as many as four frequencies can be transmitted simultaneously for both the marking and spacing conditions. Usually, under the most severe conditions of selective fading, at least one of the four frequencies will be received at sufficient strength to satisfactorily operate the carrier receive relay.

In addition to the special method of working used with the carrier telegraph terminal equipment, special equipment is associated with the radio transmitters and receivers, and diversity reception can be employed to minimise the effects of selective fading.

For the purpose of radio link trials, a number of additional facilities were included in modified A.P.O. 9-channel carrier telegraph systems in order to provide a ready means of setting up the two tone circuit arrangements which are required to minimise the effects of varying signal strength over the radio link due to fading. The alterations mainly consist of additional wiring and supplementary jack fields so that channels can be grouped together in both the transmitting and the receiving directions so as to provide two tone operation. The arrangements permit any two channels to be grouped together to give one two-tone channel so that up to a maximum of four two-tone channels can be operated simultaneously. It is also possible to group four channels or eight channels to provide either two or one grouped channel respectively when propagation conditions are unsatisfactory for normal two-tone operation.

In the grouping a total of four both-way channels can be operated simultaneously. Normally, adjacent channels are associated for two-tone working, the lowest number channel being selected as the controlling channel. However, if necessary, because of selective fading, it is possible to group any two channels of numbers two to nine. The first channel is not employed for grouped working and, therefore, it is not wired out to the special group channel jack field.

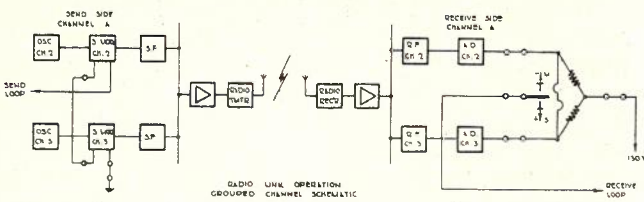


Fig. 23.

If transmission conditions are unsuitable for the operation of four grouped channels, the connections can be readily changed to provide two or one grouped channel. In the latter conditions four normal channels are employed to convey the marking intelligence and four the spacing intelligence.

Fig. 23 shows a block schematic diagram of the circuit arrangements.

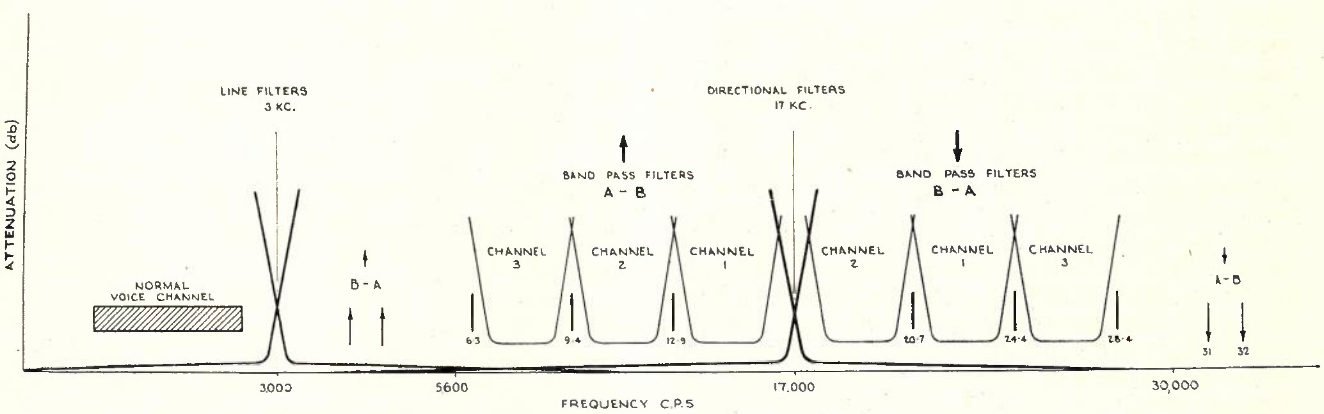
Receiving Relay Connections: Two types of relay connection may be employed for grouped working, viz., "bridge" connection and "differential" connection. For purposes of experimental trials on the first systems, four bridge circuits and one differential circuit were provided. The bridge and differential units are mounted on a separate panel from the normal PR.10 receiving relay panel. Type 209FA relays are provided for the bridge and differential circuits.

The normal observation and monitoring facilities associated with the controlling channel can be used when channels are connected for group working. A special jack has been provided in each bridge circuit for the purpose of measuring the detected current applied to the bridge relay windings under "marking" and "spacing" conditions.

Grouped Channel Jack Field: Suitable jacking facilities for the send and receive sides of each terminal have been provided on the "grouped channel" jack field to facilitate the choice of the most suitable combination of channels. In order to simplify the patching arrangements and avoid a multiplicity of patch cords, the jack layout has been arranged as far as practicable for connection of normally associated circuits by means of special short circuited twin plugs.

Trials of radio link operation using two-tone working and diversity reception have already shown promise, but the results indicated that further circuit modifications in both the radio and carrier telegraph terminal equipment are necessary, and these aspects are receiving further attention.

The Hilo System: This system derives its name from the fact that it operates below and above a 3-channel carrier telephone system utilising the common transmitting and receiving amplifiers and intermediate repeaters of the telephone system for amplification purposes. The transmitting and receiving amplifiers in 3-channel carrier telephone systems have a satisfactory frequency response above and below the required frequency range of 6.3 to 30 kC/sec., and the unused portions of the frequency spectrum can be utilised for the purpose of deriving additional carrier telegraph channels. The relationship of the Hilo channels to the normal voice frequency speech channel and the channels of the carrier telephone system is shown in Fig. 24.



FREQUENCY ALLOCATION - V.F SPEECH, HILO SYSTEM, AND 3 CHANNEL TELEPHONE SYSTEM

Fig. 24.

The Hilo terminal equipment is similar to the normal carrier telegraph equipment, and the transmitting frequencies are injected into the common transmitting amplifier in the carrier telephone system and selected from the output of the common receiving amplifier at the distant end. The carrier telephone system amplifiers, therefore, carry the currents from the two telegraph channels in addition to the normal speech input currents, but as the injected levels of the telegraph channels are low in comparison to the telephone channel levels, the power handling capacity of the amplifiers is not unduly strained. A typical block schematic of the circuit arrangements for a Hilo terminal is shown in Fig. 25.

It is interesting to note that one of these systems designed in the Transmission Section, Adelaide, is in operation between Adelaide and Port Lincoln and the performance has been very satisfactory. The application of the Hilo principle permits a very economical derivation of two telegraph channels between centres where three-channel carrier telephone systems are installed.

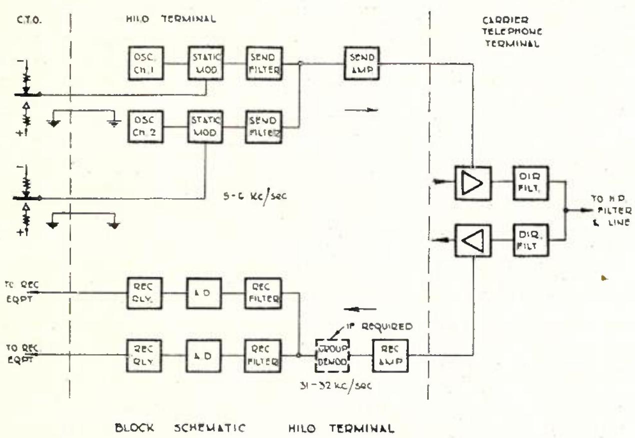


Fig. 25.

Special Wide Band Channels: For special purposes, such as Wheatstone transmission up to speeds of 200 words per minute (160 bauds), a special wide band carrier telegraph channel is required superior from a telegraph transmission viewpoint to the Type B and 240-cycle spacing V.F. channels.

Two methods are under trial, the first being the occupation of the frequency spectrum at present taken up by 2 or 3 channels in an existing 18-channel (120 cycle spacing) V.F. system by replacing the existing filters with special wide band filters. Initial trials indicate that satisfactory transmission at the required speeds is practicable, but some special problems were encountered due to the much greater than normal speeds and it was necessary to re-design the amplifier detector units to obtain increased plate current because, due to the abnormal speeds under which the carrier receive relay is operating, a condition is reached where the magnetic field due to the line winding is inadequate to overcome satisfactorily the magnetic field produced by the polarising permanent magnets.

The second method is an adoption of the Hilo principle previously described, employing one wide band channel in lieu of the two normal 240 cycle spacing channels. Preliminary trials were very satisfactory, and the special wide-band filters have now been finally designed and the production of a suitable system is proceeding.

Telex Units: The manufacturing programme also included the production of Telex units which, in effect, are filterless single channel carrier telegraph systems which provide a means of carrying out teleprinter or teletype communication over a normal telephone circuit as an alternative to telephone communication.

The call is set up by telephone in the normal manner. On agreement to change over to machine telegraph operation, the telephone-teleprint key, which is located near the telephone instrument, is operated to the teleprint position and the telex equipment and associated teleprinter is connected to line in place of the normal telephone apparatus. A diagram of the circuit arrangements is shown in Fig. 26, whilst a typical installation is illustrated in Fig. 27.

An associated power unit provides for operation from 230 volt A.C. mains supply and the complete equipment is normally mounted on the side of a standard teleprinter table. Alternatively, the equipment can be mounted on standard carrier racks. With the addition of a resistance network, the Telex unit can be adapted for operation with teletype machines in lieu of teleprinters.

The equipment provides for duo-directional simplex transmission and at the transmitting end portion of the audio frequency pulses are "bypassed" to operate the local receiver and provide a "home" record of the transmitted message. Due to the absence of narrow band filters, the

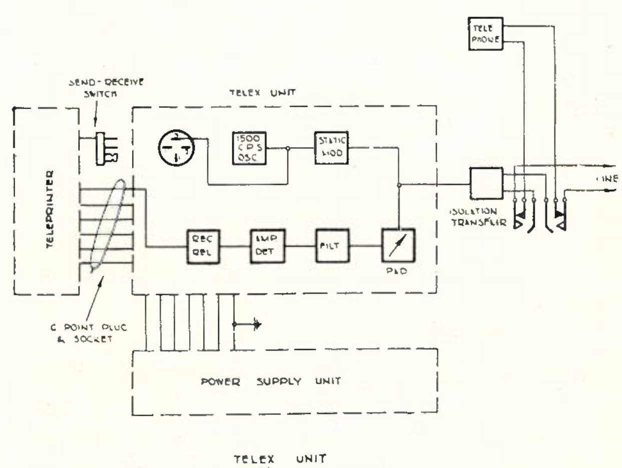


Fig. 26.

transmitted signals are of square topped form and variations in input level of 25 decibel have no effect on the operation of the equipment.

Approximately 50 Telex units have been installed to date and have proved very satisfactory for certain special communication circuits.

The establishment of a "production line" capable of producing the various systems at short notice demanded a considerable expenditure of engineering effort. The numerous electrical components required were exceedingly difficult to obtain on short-term delivery dates, and it was necessary to establish a special material supply section to accurately record all deliveries and maintain close personal contact with the various firms concerned and the various Supply Organisations, such as Ministry of Munitions and Division of Import Procurement. The orders placed for components and panels were distributed between approximately 30 firms in Melbourne and Sydney,

Fig. 27.—Telex. Installation.

comprising approximately 35 contracts and supply orders for 300 different electrical items. It is impossible to recount all the difficulties which arose in material procurement, but due to the necessity, at frequent intervals, to accept items other than those specified, it was necessary to give constant engineering attention to this aspect.

To date, there have been manufactured departmentally a total of 32 systems providing 4, 6 or 9 channels for use over the Department's lines throughout Australia. In addition, there have been manufactured one 9-channel unidirectional carrier system for the use of the R.A.A.F. as a keying system for the remote control of a number of radio transmitters from H.Q. in Melbourne to a radio transmitting centre located 70 miles away in the country, 2 similar 4-channel systems for the Australian Army, and, also for the Army, 4/4 channel V.F. telegraph terminal units for use in New Guinea and 10 complete mobile terminal equipments. These latter communication units are each mounted on a motor truck and include a 3-channel carrier terminal and a 4-channel telegraph carrier unit, together with the necessary power plant, batteries, etc., to provide a complete communication unit, designed to restore communication quickly in the event of damage by enemy bombing to any important distant communication centre.

Considerable assistance was received from the Chief Draftsman's Office in regard to the preparation of the design and assembly drawings, particularly in regard to the manner in which drawings were brought to completion within a very short period of time. When it is considered that more than 120 final drawings were required for production purposes, it will be appreciated that the drafting effort required was a task of considerable magnitude. Already more than 10,000 dyeline prints have been distributed in connection with the manufacture and installation of the equipment produced in the Melbourne Workshops.

Handbooks for the various systems, describing the equipment and furnishing installation and maintenance information, were also prepared, and the copy accompanying each terminal includes the test results obtained during the acceptance tests following completion of manufacture.

The actual production was carried out on a heavy overtime basis due to the urgent need of the various systems, and great credit reflects on the "Radio Section," Melbourne Workshops, where the major portion of the production was undertaken. The production of 25 carrier telegraph systems, 60 Telex units, 10 complete mobile communication units, together with a large number of miscellaneous items, such as trunk test boards, carrier amplifiers, transmission measuring equipment, etc., in a section already occupied with production of special equipment of an even more complex nature, was a particularly fine achievement.

It is not possible within the scope of this article to mention all concerned in a project of the magnitude just detailed, but special credit is due to Mr. S. T. Webster, Telegraph Section, Chief Engineer's Branch, for his assistance in the initial design work, particularly in relation to advice in regard to permissible telegraph distortions and the development of the P.R.10 relay for use as a carrier receive relay; to Mr. E. H. Palfreyman, Research Laboratories, for the filter design and manufacturing technique associated with filter production; to Mr. A. J. McDevitt, Divisional Engineer, and Mr. K. Boyle, Engineer, Transmission Section, Sydney, for the particularly short-term production of six 9-channel systems and suggested circuit improvements, particularly in relation to amplifier detector design; and to Mr. F. P. O'Grady, Supervising Engineer, Transmission Section, Adelaide, for the production of equipment to extend existing Type "B" and Type "R" systems and the design and development of the "Hilo" system.

SWITCHBOARD CB PBX LAMP SIGNALLING CORD TYPE 37-50 VOLTS

J. Silvester

A recently developed lamp signalling non-multiple CB floor pattern switchboard, which is at present being manufactured in the P.M.G.'s Workshops, Melbourne, has many new features in both the construction and the circuits. A front view of the switchboard is shown in Fig. 1. The chief features in the construction are:—

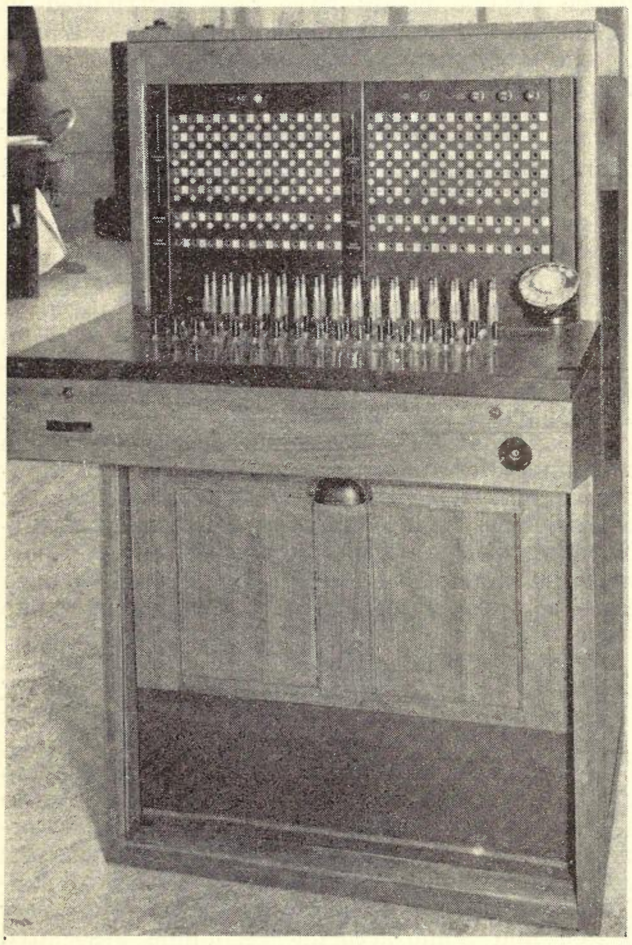


Fig. 1.—Front View showing Face Equipment.

(a) The chassis is an open structure of folded steel, having the top and bottom frame welded to four corner posts which are formed to receive the side panels of wood. The framework is braced down each side with cross members welded to the frame which supports the folded steel channel shelves for the relay sets.

(b) The top panel is of mild steel, the side and rear panels are constructed of wood and each can be removed easily to expose the equipment mounted on and within the chassis.

(c) The relays with their associated condensers and resistances are mounted on jack-in type relay bases, each base accommodating 16 relays. Provision is made for 5 bases with 3 exchange circuits per base, 1 base with 3 tie line circuits per base, 4 bases with 4 cord circuits per base, and 1 10-relay base with the operator's circuit and miscellaneous circuits. The generator is readily detachable by removal of a single locking screw.

(d) Six-volt metal filament lamps with limiting and guarding resistances are used directly in the extension lines, thereby dispensing with the line relay. On exchange and tie lines the locking windings on ring down relays are used as the limiting resistances.

The open construction of the chassis gives both strength and lightness, and, with the removable panels, easy access for maintenance and installation. A rear view showing the panels removed from the back and one side is shown in Fig. 2.

The relays for the various circuits being

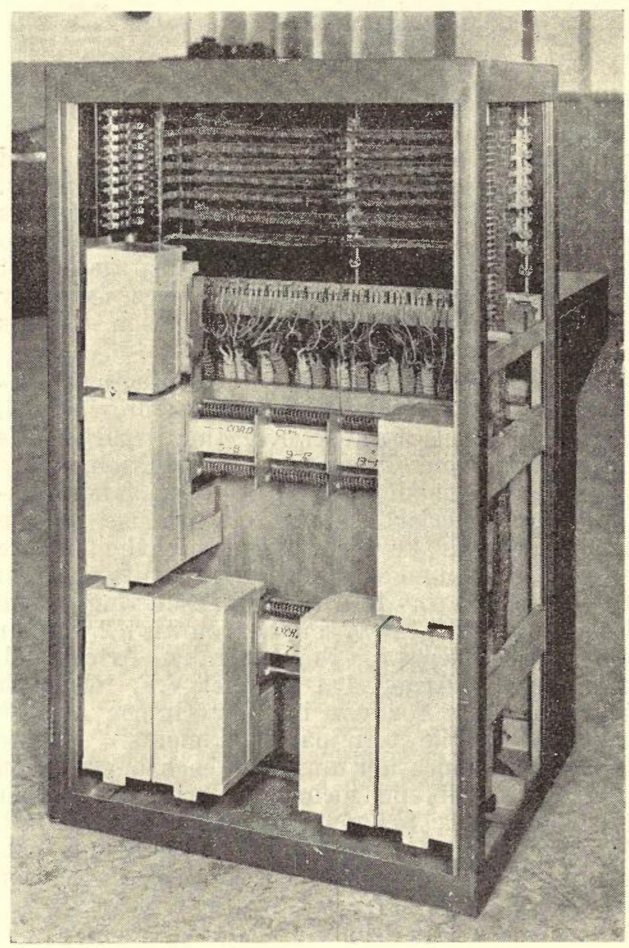


Fig. 2.—Rear View showing Relay Sets' Shelves, with some Relay Sets in position.

mounted on relay bases and jacked-in, simplify maintenance, as the relay sets can be changed or taken out and examined away from the switchboard. The relay sets can be stored and transported separately from the chassis, thereby simplifying lifting on and off vehicles, etc. The capacity of the switchboard can be increased to the full capacity very quickly as required by adding the necessary relay sets, and fitting jack strips, keys and lamps.

The switchboard has been designed for an ultimate capacity of 80 extension lines, 15 exchange lines, 3 tie lines, and 16 cord circuits. The line and lamp jacks are all 10 per strip, the lamp jack being mounted below the related line jack.

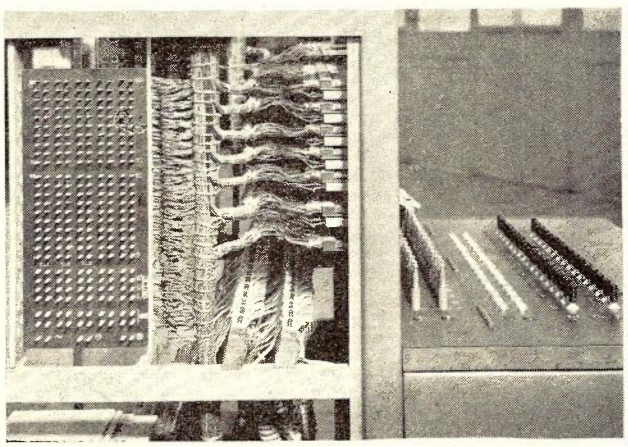


Fig. 3.—Side Panel removed showing Terminal Strip.

The framework and wooden panels are finished brown, the face and stile strips matt black. Each panel is equipped with 40 line jacks with their associated lamp jacks for extension services, 10 line jacks for exchange or tie lines and 10 for night switching. Above these panels provision is made for a "Generator Change-Over Key," a "Battery Cut-Off Key" and a "Night Alarm Key," also a "Fuse Alarm Lamp" and a "Pilot Lamp."

The keyboard is covered with black fibre and equipped with 16 cord circuits, with associated keys, lamps and plugs, 1 coupling key and 1 calling device. The front face of the keyboard shelf and certain portions of the switchboard are covered with timber to prevent the operator making contact with the metal framework.

The limiting resistances in the extension line circuits are mounted on spindles at the top of the switchboard and are readily accessible by removing the top panel. The terminal strip and power distribution panel are mounted on opposite sides of the switchboard behind the jack field. This can be seen in Fig. 2, while a view of the terminal strip is given in Fig. 3.

Provision is made for the installation of cord pulleys if longer cords are required with more than one position. The overall dimensions of the switchboard are,

height 46 inches
width 26¾ inches
depth 35 inches,

keyboard height from floor 29½ inches, depth of keyboard 16 inches.

The facilities given by the switchboard are as follow:—

(a) Lamp signalling with 6-volt lamps for exchange and extension calls.

(b) Lamp signalling with 6-volt lamps for supervising cord circuits.

(c) Audible alarm with key control on exchange and extension call lamps.

(d) Independent battery feed coils with positive lamp supervision each side of cord circuit.

(e) Night switching on all cords with any line.

(f) "Call back" with inward or outward exchange calls.

(g) No electrical interference with dialling or transmission is possible by telephonist on through calls.

(h) No electrical coupling between cord circuits when two speak keys operated at the same time.

(i) Trapping of all follow-on calls (Exchange or tie line).

(j) Provision for holding and transferring inward or outward exchange calls.

(k) V.F. termination during switching to prevent unbalancing of repeater amplifiers when connected to trunk lines.

(l) Provision for tie lines from P.A.B.X. or C.B. or magneto P.B.X.

(m) Tie line (restricted service) relay sets interchangeable with exchange line relay sets in multiples of 3 lines.

(n) Through dialling from extensions with switchhook supervision.

(o) Positive supervision on tie lines.

(p) No battery connected to cords or plugs when cord circuits are normal.

(q) Provides operator's supervision of the progress of an outgoing exchange call during the dialling period.

(r) Prevents connection of an exchange line to another exchange line or to a tie line.

CIRCUIT OPERATION

Exchange line calls—Incoming call—(See Figs. 4 and 5):

Relay L operates to the incoming ring. L1 operates the pilot relay P. L2 locks relay L on its 900 ohm winding in series with the call lamp to earth at the extra springs of the line jack. The telephonist answers the call by plugging into the line jack with the front cord and operating the speak key KS.

The plug operates the extra springs of the line jack, thus releasing relay L and preparing a circuit for relay K, which does not yet operate as it is short circuited by S1.

Key contact unit KS1 completes a circuit to operate relay C on its 1400 ohm winding to earth on the sleeve of the exchange jack. KS2 and KS4 connect the telephonist's circuit to the cord circuit. KS5 and C1 complete a circuit for relay D, which operates and locks via D1 to earth on the sleeve of the exchange jack.

Relay C is slow to operate so that it will saturate and hold whilst its circuit is opened at D7 but closed again at D4 via C7. The reason for opening the circuit of relay C at D7 is to prevent its re-operation via KS1 when the telephonist is supervising calls.

Relay D also disconnects battery and earth from the front cord and connects the two windings of relay A in series across the tip and ring to provide a loop for relay M.

Relays A and M operate in series. M2 loops the exchange line to trip the ring and operate

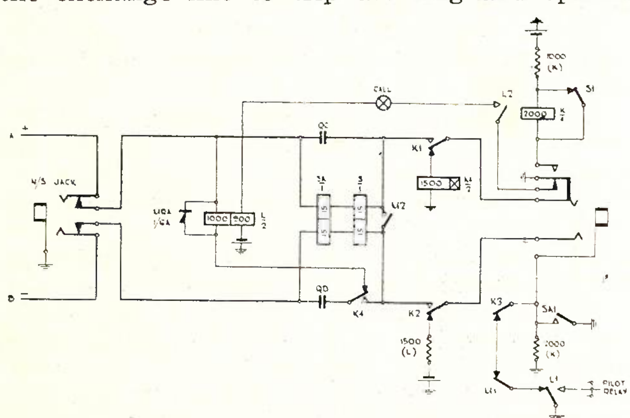


Fig. 4.—Exchange Line or P.A.B.X. Tie Line (with restricted access).

relay S. Relay SA does not operate at this stage because its windings are connected differentially.

Relay K operates when S1 removes the short circuit. K1, K2 and K4 connect the exchange line through to the cord circuit and the telephonist. K4 also disconnects relay L from the line to improve transmission. Relay M releases.

The reason for making relay M slow to operate is to ensure saturation so that it will hold sufficiently long to trip the ringing. Otherwise portion of the ringing current would enter the telephonist's receiver.

The telephonist ascertains the extension required, inserts the rear plug into the extension jack, and rings the extension by operating the rear ringing key KRR. The rear supervisory lamp lights from battery via resistance YB connected to the extra springs of the jack and earth via 150 ohm resistance (D).

When the extension answers, relay B operates on the loop. B1 short circuits the rear supervisory lamp. B2 disconnects the 600 ohm V.F. termination, and B3 opens the circuit of relay C.

If the telephonist restores the speak key KS before the extension answers, the V.F. termination is connected across the cord circuit via KS2, A1 and B2.

When relay C releases, relays A and B are disconnected and the condensers QA and QB are short circuited so that the call is dependent upon

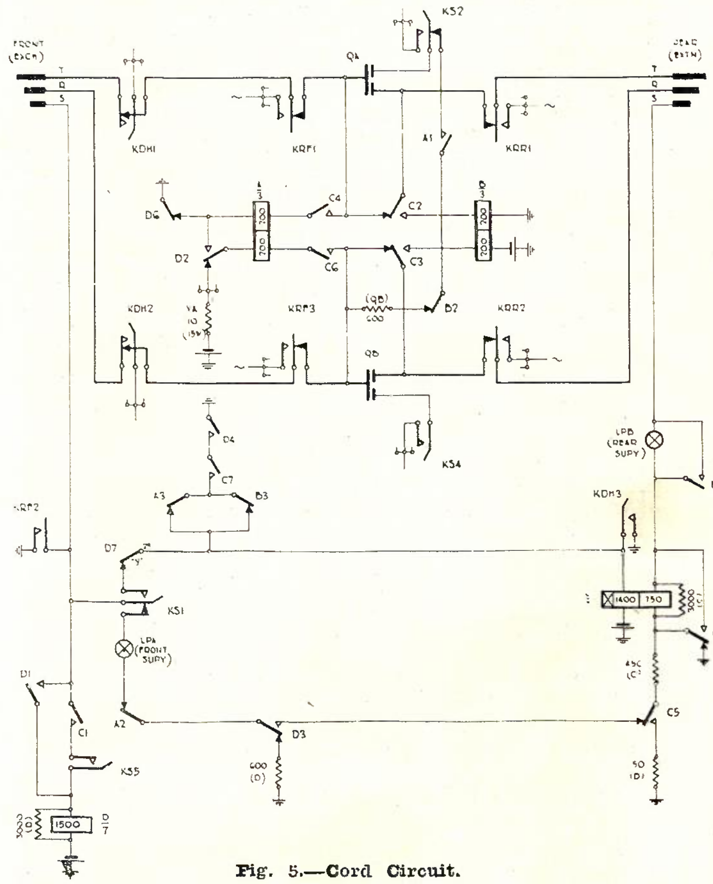


Fig. 5.—Cord Circuit.

the extension loop. C5 connects the front and rear supervisory lamps in series but they do not light as relay K is operated and the circuit is via 2000 ohm resistance (K) which is also the holding circuit for relay D. Upon completion of the call the extension clears and relay S in the exchange line circuit releases. S1 short circuits relay K which also releases. K1 and K2 disconnect the cord circuit from the exchange line. K3 lights both supervisory lamps by short circuiting 2000 ohm resistance (K).

Removal of the front plug restores relay D and the 3000 ohm resistance (D) is connected across the coil to absorb the inductive discharge and prevent the possibility of a mild electric shock from contact with the sleeve of the plug. Relay C is similarly treated.

Recall: Provision is made for the recall of the telephonist on outgoing exchange line calls without releasing the exchange connection. This is accomplished by means of a special press button fitted on each extension telephone. The button is pressed intermittently and when operated places an earth on the tip side of the extension line. This earth increases the current on one side of the connection and unbalances relay SA which, therefore, operates. SA1 short circuits 2000 ohm resistance (K) and flashes both supervisory lamps. The telephonist answers by operating the speak key KS and the hold key KDH, the latter to re-operate relay C which connects relay A across the cord circuit in case the exchange line is to be transferred to another extension.

After plug is withdrawn from extension line the hold key is restored. Relay A operates and holds the exchange line until the new extension answers. When this occurs the rear supervisory lamp is extinguished by B1, and relay C is released by B3 as described previously.

Where recall buttons are not provided on the extension telephones the telephonist can be recalled on incoming exchange calls and on extension to extension calls by intermittently operating the switchhook.

Trapping Circuit: If another exchange call is received before the connection is taken down by the telephonist the incoming ring will operate relay L which cannot lock, however, as its holding coil circuit is open at the jack springs. Relay L responds to the ringing pulses and at

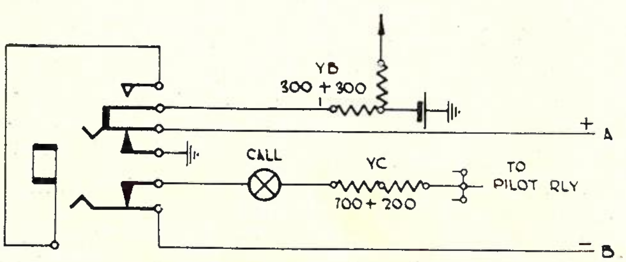


Fig. 6.—Extension Line Circuit.

L1 intermittently removes the short circuit from the 2000 ohm resistance (K), thus causing both supervisory lamps to flash.

The telephonist answers by operating the speak and hold keys and then disconnects the rear plug from the extension jack. The object of operating the hold key is to secure the re-operation of relays C and A as previously mentioned. The telephonist can, however, speak to the exchange line with the hold key operated via the supervisory induction coil No. 14 in the telephonist's circuit.

Extension to Extension Calls (See Fig. 6): The calling extension lights the line lamp in series with the extension loop. The lamp is extinguished when the telephonist answers by plugging the rear cord in the extension jack. Relay C operates on its 750 ohm winding in series with the rear supervisory lamp from earth at D5 to battery on the sleeve of the jack. The operation of relay C connects both feed coils (relays A and B) to the cord circuit. Relay B operates immediately and B1 shunts out the rear supervisory lamp.

Having ascertained the required extension the telephonist plugs in the front cord and rings the extension by operating the front ringing key KRF. This key is the reverse side of the speak key KS so that KS1 completes the front supervisory lamp circuit from earth via 600 ohm resistance (D) to battery on the sleeve of the jack.

When the extension answers, relay A operates and A2 disconnects the supervisory lamp. Upon completion of the call relays A and B release as each extension clears, and the corresponding supervisory lamp lights.

Extension to Exchange Calls: The telephonist answers the extension with the rear cord and the circuit operation is the same as an extension to extension call until the front cord is plugged into the exchange line jack and relay D operates. Relay M operates in series with relay A or on the dial loop if the dial key KDH is already operated. M2 loops the exchange line and relay S operates. If line is connected to a manual exchange, S will not operate in series with line relay at exchange. K therefore remains unoperated, leaving M1 to keep supervisory lamps extinguished until exchange operator answers, thus obviating a false clearing signal.

Relay K operates when the short circuit at S1 is removed and the exchange line is connected to the cord circuit. Relay M releases.

The telephonist listens for dial tone via the dialling key and dials the number required. Also this listening circuit enables the progress of the call to be checked at the end of each digit. If desired the speak key KS may be restored whilst dialling is in progress in order to answer or supervise another call. The telephonist can also speak to the called subscriber via KDH before the key is restored to connect the line through to the extension.

When the extension clears, both supervisory lamps light and the exchange line is connected to the trapping circuit.

If the extension wishes to dial the number, the telephonist does not operate the dial key KDH but plugs the front cord in the exchange jack, whereupon the extension may immediately commence dialling. Since the telephonist's circuit is connected to the cord circuit via condensers QA and QB, the operated speak key KS does not interfere with dialling and the condenser capacity has no appreciable effect on dialling impulses.

The speak key may be restored at any stage or reoperated in order to supervise the call without electrical interference to the circuit. As previously mentioned this is the reason for opening the operating circuit of relay C at D7. If it is desired to transfer the exchange line to another extension the hold key KDH is operated to provide a holding circuit for the exchange line before removing the rear plug from the extension line.

Tie Lines—Incoming Calls — (See Fig. 7): The incoming ring operates relay TA which locks to earth at TE2 via the lamp and TA1. The pilot relay circuit is closed via TA3 to operate the pilot lamp and the audible alarm if the latter is switched on. The telephonist answers the call with the front cord and operates the speak key KS. When the plug is inserted the extra springs of the jack disconnect the pilot relay circuit and operate relay TE which connects the line through to the jack springs at TE1 and TE3. TE2 releases relay TA and prepares an operating circuit for relay TD.

When the speak key KS is operated a circuit is completed for relay TC from battery via the 1400 ohm winding of relay C, D7, KS1, sleeve of the cord and jack, relay TC 10+2000 ohms to earth. Relay TC operates but relay C does not. TC1 operates relay TD, and TD1 connects relay TB across the tip and ring. TD3 short circuits the 2000 ohm winding of relay TC, and the lowered resistance of the sleeve circuit allows relay C in the cord circuit to operate. Relay TC holds on its 10 ohm winding.

Relay TD and TE are made slow to operate to allow relay TC to fully operate via its 2000 ohm winding when the plug is inserted with the speak key operated. The operation of relay C connects relay D to the sleeve circuit via C1 and KS5. Relay D operates and locks to the sleeve circuit via D1. D7 disconnects relay C from the sleeve circuit, but relay C holds to the locking circuit at D4 via C7. Relay TB in the tie line circuit operates when D2 connects both coils of relay A in series across the cord circuit. TB3 disconnects the short circuit across the 2000 ohm winding of relay TC.

It is necessary to keep relay TB connected as shown in the circuit to prevent it operating when relay C operates to prepare the circuit for relay D. Relay D will not operate if relay TB operates prematurely to increase the sleeve circuit resistance by 2000 ohms. When relay TB operates, TB2 connects the 600 ohm winding of relay TA across the line to trip the incoming ring if it is automatic and provide a loop for supervision at the distant end. TB2 is made an "x" (early make) contact so that the ringing will be tripped before TB1 connects the negative line through to the cord circuit.

The telephonist ascertains the extension required and plugs up with the rear cord. The cord circuit functions as on an exchange call and relay TB supplies talking battery for the extensions. When the extension clears relay TB releases. TB2 opens the circuit of relay TA to give supervision at the distant end. TA2 short circuits the 2000 ohm winding of relay TC and lights both supervisory lamps in series via the 10 ohm winding of TC. If the tie line is magneto, relay TA does not remain operative during conversation and the cord circuit supervisory lamps are lit by TB3 as soon as relay TB releases.

Follow-On Calls: When relay TB releases, TB1 opens the negative line from the jack springs and connects relay TA in series with condenser QF across the line. The incoming ring operates relay TA which causes the supervisory lamps to

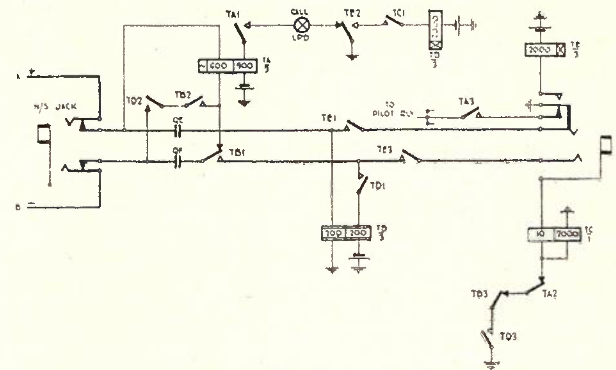


Fig. 7.—Tie Line C.B. or Magneto (with restricted access).

flash by removing short circuit across 2000 ohms winding of TC via TA2 at each ringing impulse. The telephonist answers the follow-on call by operating both the hold and the speak keys as in the case of a follow-on exchange call—KDH3 operates relay C which completes a circuit for relays A and TB. The latter relay trips the ringing as previously described.

Having ascertained the required extension the telephonist plugs in the rear cord and rings. When the extension answers relay B operates and releases relay C. Subsequent circuit action is the same as on a normal incoming call.

Outgoing Calls to Tie Line: Provision is made in the cord circuit to remove all apparatus from across the tie line whilst ringing. When the front ringing key KRF is operated the sleeve of the cord is connected to earth at KRF2, thus short circuiting relay TC in the line circuit. Relay TC releases followed by relay TD which at TD1 disconnects relay TB from the ring side of the line. KRF1 connects battery via the 1000 ohm resistance YE in the ringing circuit to the tip side of the line to operate relay TB on its d-e winding. The operation of relay TB disconnects relay TA from the line at TB1 and this provides a clear line for ringing.

OPERATING PROCEDURE

1. Front cord is always used for answering or calling exchange or tie lines.
2. Extension calls are answered with rear cord.
3. When exchange or tie lines are connected to extensions the connection is completed before restoring the speak key.
4. When exchange calls are transferred from one extension to another, the hold key is operated before the first extension is disconnected. The new extension required is then connected and the hold key is restored. Supervisory lamp will glow until extension answers.

5. When trapping circuit on repeat calls is answered both hold and speak keys are operated before releasing extension connection. The required extension is then connected and hold and speak keys are restored.

6. When calling tie line, speak key is operated before ringing.

7. To prevent overhearing by caller when transferring calls, the dial is held in the off normal position.

8. To night-switch an exchange to an extension line the front cord of any cord circuit is connected to exchange night-switching jack, the rear cord to extension jack. The B.C.O. (battery cut off) key is then switched to the "off" position.

9. To night-switch whilst normal calls are still in progress on the switchboard the lines to be night-switched are connected and the key KS is momentarily operated on each connection. When the normal calls are completed the B.C.O. key is switched to the "off" position.

THE SELECTOR REPEATER

O. C. Ryan

The final selector repeater employed with line finder P.A.B.X. equipment in a 2-figure system, providing services up to 89 extension lines, was described in Volume 4, No. 4, page 223, of this Journal. In this system extension calls can be completed by dialling 2 digits, while access to the public exchange is given by dialling one digit (O) only.

Where more than 89 extension lines are required, a second rank of bimotional switches, additional line finders and racks for mounting these switches are necessary. Each line finder is tied to a selector repeater in lieu of a final selector repeater, as in the 2-figure system. The outlets from working levels of the selector repeater banks, with exception of the exchange level (O), are connected to standard final selectors instead of final selector repeaters. By utilizing the selector repeater, which is described in this article, inter-extension calls are completed by dialling 3 digits, while access to the public exchange is given by dialling one digit (O) only. The advantages of combining the functions of the selector and the repeater in one switch in lieu of providing additional repeater relay sets are the increase in flexibility which is afforded by being able to increase the outgoing exchange lines (within the limit of the number of selector repeaters provided) without having to provide additional repeater relay sets, and the saving in rack space which is of particular importance for small automatic units.

The circuit diagram of a typical selector repeater pre-2000 type, equipped with 3000 type relays and barred out-service facility, is shown in Fig. 1. The switch functions as a group selector on levels 1 to 9 and as a combined group selector and repeater on level O.

Extension to Exchange Calls: When the selector repeater is used for exchange calls digit (O) is prefixed to the call number listed in the directory, in that outgoing exchange lines are trunked from the (O) level of the switch bank.

On seizure, relay A operates, A 2-3 closes the circuit to relay B, while A 21-22 repeats impulses which function is described later. The guarding relay B operates, B 1-2 grounds the P trunk from the line finder switch to maintain the busy and hold conditions, B 3-4 prepares a circuit for relay E, B 6-7 prepares a circuit for the vertical magnet and C relay, at B 21-22 the ring start circuit is closed, while B 24-25 connects dial tone to the positive calling line via H 6-8, S 6-7 and 200 ohm winding of A. Relay CH operates to earth at B 2-1 and CH 1-2 closes a section of the chain relay circuit to provide busy when all switches are engaged.

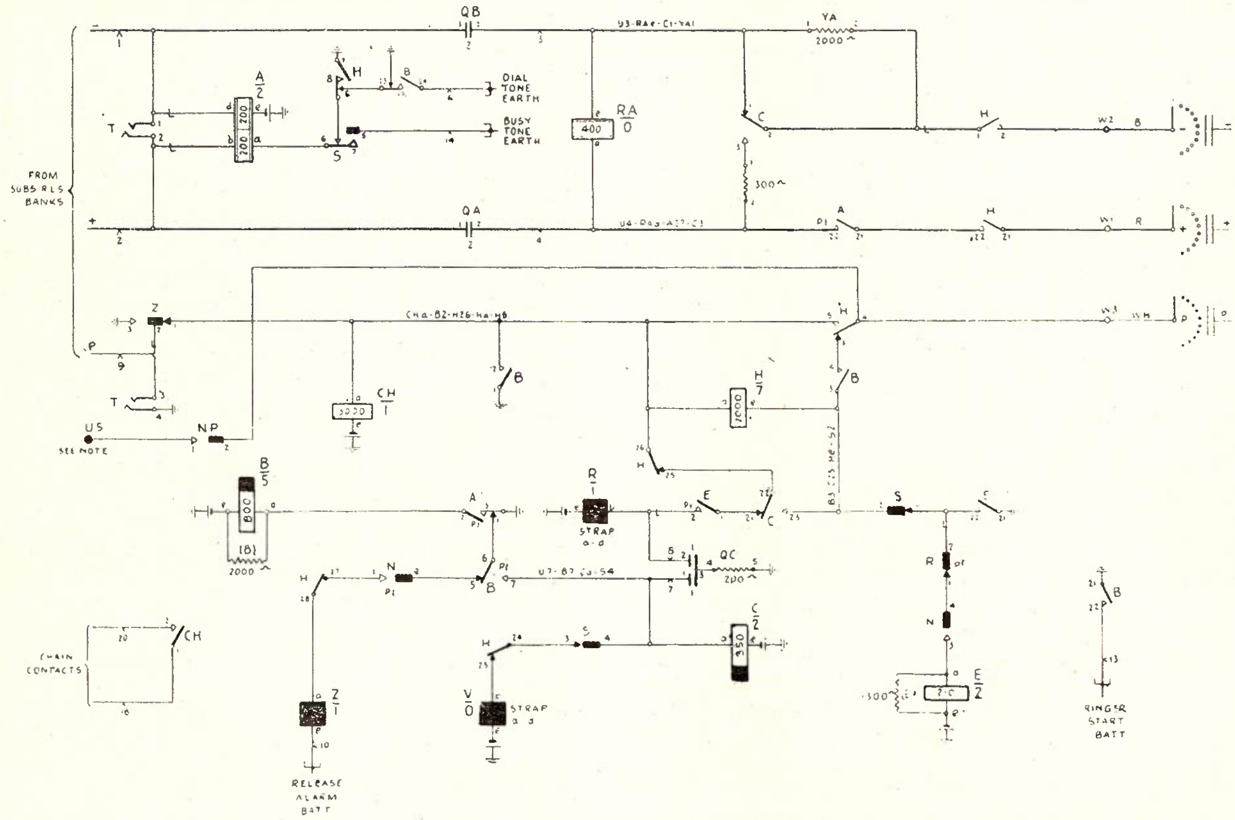
On receipt of the first impulse, relay A restores, closing the vertical magnet (V) circuit via H 23-24, S 3-4, B 7-6 to ground at A 1-3. The magnet operates and raises the wipers to the first level, where the off-normal spring set N is operated. N 1-2 prepares a circuit for the release magnet Z and N 3-4 prepares a circuit for relay E. Relay C operates in parallel with V. C 1-2-3 are not required at this stage, but C 22-23 closes the circuit of E via N 3-4, R 1-2, S 1-2, C 23-22, H 25-26 to ground at B 2-1. Relay C is slow releasing and remains operated during the vertical impulse train. Relay E operates, and E1-2 prepares the rotary magnet (R) circuit, while E 21-22 provides a locking circuit for relay E. The impulses received in the first train cause V to raise the shaft and wipers to the O level, where the normal post spring-set NP is operated by the shaft. NP 1-2 operates and functions as described under "barred extensions." At the end of the first train of impulses, C, after its release lag period, restores and closes the rotary magnet circuit via E 2-1, C 21-22, H 25-26, to ground at B 2-1. The rotary magnet (R) operates and steps the wipers to the first bank contact. At R 1-2 the circuit for E is opened, E restores and opens the rotary magnet circuit at E 1-2.

If the first private bank contact is engaged (i.e., the private bank contact grounded by B 1-2 of a similar switch on a multiple contact) relay E re-operates from battery, E210 ohm winding, N 3-4, R 1-2, S 1-2, B 3-4, H 3-4, private wiper, to ground at the private bank contact. E 1-2 closes the circuit of the rotary magnet and the wipers are moved to the second contact. The interaction between E and R continues until a disengaged trunk is reached or all trunks have been tested busy. On testing a free trunk, the short circuit on relay H, provided by the ground on the private bank contact, is removed. H operates in series with E from battery, E 210, N 3-4, R 1-2, S 1-2, H 2000, to ground at B 2-1, but relay E, however, does not operate when connected in series with H. H 1-2, 21-22, and 4-5 switches the negative, positive and private conductors through to the exchange bank contacts, replaces dial tone earth by a direct earth on the positive calling line at H 7-8, disconnects the vertical magnet at H 23-24 and the release magnet at H 27-28, and at H 25-26 prevents the short circuiting of relay H during subsequent trains of impulses. A loop for the exchange line is provided by RA 400. Further trains of impulses are repeated, via line, positive wiper, H 21-22, A 21-22, 300 ohms NI resistance, C 3-2, H 1-2 to negative wiper and line. The 300 ohms non-inductive resistance is included in the impulsing circuit to reduce impulse distortion on short exchange lines, working into circuits equipped with 3000 type relays. The 2000 ohm resistance YA across C 1-2 is provided to prevent the possibility of false impulses during the transit period of C2. Battery is fed to the calling subscriber via the 200/200 ohm A relay, and speech takes place via condensers QA and QB.

When all trunks are busy, the wipers are stepped to the 11th contact and the 11th rotary step springs S are operated. S 1-2 opens the H relay circuit through E, S 3-4 opens the vertical magnet circuit to prevent further vertical operation and S 5-7 connects busy tone to the calling line.

Extension to Extension Calls: When used for local calls, the switch functions as a group selector. The vertical stepping of the switch is as described for an extension to exchange call but, as the shaft is not raised to the "O" level, the normal post spring-set NP does not operate. On relay C restoring, the rotary magnet steps the wipers to the first bank contact and R and E rotate the wipers, until a free trunk is found as described under "Extension to Exchange Calls." Relay H operates in series with E and switches the negative, positive and private conductors through to the switch ahead, the A relay of which operates via line, positive wiper, H 21-22, A 21-22, RA 400, C 1-2, H 1-2 to negative wiper and line. Further trains of impulses are repeated via A 21-22.

Barred Extension Lines: Selector repeaters in general use are fitted with a relay M having a winding of 6 ohms and a "make" spring unit. The coil is connected in series with the P wire at Z1. M is normally short circuited by the normal post springs, NP 1-2 (see Fig. 2). Where an



On an extension barred out service, U5 is connected to a grounded line finder private bank contact or a uniselector meter bank contact the wiper of which has been grounded.

Fig. 1.

extension line connected with line finder equipment is barred exchange access, the bank contact associated with wipers 7 and 8 is connected to battery. The selector repeater shaft on reaching the (O) level operates NP 1-2, removing the short circuit from M, which operates to battery in the line finder circuit. M 1-2 bridges H 4-5 and completes the E relay circuit. E operates and closes the circuit for the rotary magnet and interaction between E and R continues until the wipers reach the 11th contact, where the circuit for E is opened. Busy tone is fed to the calling line via S 5-7 and A 200.

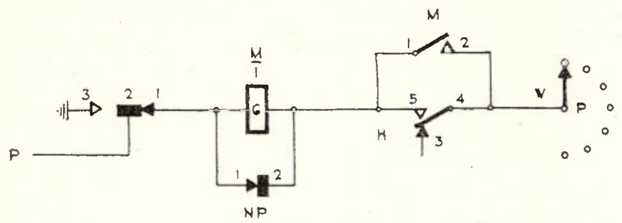


Fig. 2.

Where rotary type uniselectors have been installed for P.A.B.X's., a 1300 ohms resistance has been connected across the B.C.O. relay winding in the line circuit for each line barred exchange access. When a selector repeater shaft steps to the (O) level a marginal relay M, in series with the P wire, operates due to the increased current in the P wire. Relay E operates as explained previously and the wipers are rotated to the 11th contact.

In future installations, where selector repeaters are associated with line finder equipment, circuits between finder banks and selector repeaters will consist of four wires (negative, positive, private and NA—see Fig. 1) in lieu of 3 wires as previously used. On an extension barred exchange access originating a call, ground is extended from the line finder bank via NA wire to NP 1-2 (normally open), H 4-3, B 4-3, S 2-1, R 2-1, N 4-3, to battery via E 210. Relay E operates and E 1-2 closes the circuit for the rotary magnet. Interaction between E and R continues until the wipers reach the 11th rotary contact, where the operation of S 1-2 opens the ground circuit for E. Busy tone is fed to the positive calling line via S 5-7.

Where uniselector units having a separate meter bank level are employed, the M wiper is grounded via a K relay spring unit for extensions barred exchange access. The M level bank contacts are wired to the NP springs of the respective selector repeaters. For other types of uniselector units used for P.A.B.X.'s, the existing practice detailed above for rotary uniselector will continue.

Release: When the calling party opens the lines, A restores, opening the loop to the switch ahead at A 21-22 and the circuit of B at A 2-3. B restores followed by H and CH. The release circuit is closed from release alarm battery, release magnet Z, H 28-27, N 1-2, B 5-6 to earth at A 1-3. Z operates and the switch is restored to normal and release circuit is opened at N 1-2. During release Z 2-3 provides a guarding ground on the P wire to prevent seizure of the trunk by a hunting switch.

THE USE OF MINIATURE CIRCUIT BREAKERS IN AUTOMATIC EXCHANGES

E. J. Bulte, B.Sc.

Protective apparatus associated with A.C. power distribution is continually undergoing modifications as a result of improved design technique and modern manufacturing methods. The basic items of equipment used for this purpose are the switch and fuse, each of which is essential irrespective of the size of the installation. A miniature enclosed type circuit breaker which performs the same functions as a switch-fuse combination is now available, the advantages over the latter being as follows:—

(a) Re-setting of circuit breakers after an overload is quicker and more convenient than replacing fuses.

(b) Greater safety from a personnel point of view, as there are no exposed uninsulated parts.

(c) The material used in the mechanism does not deteriorate with age and consequently the original operating characteristics are maintained indefinitely.

(d) Saving in space.

The principle of operation of the circuit breaker is based on the use of a bi-metallic strip. Due to the different co-efficient of linear expansion of each of the two metals, the strip will bend when heated. The current in the load passes through the strip and furnishes the heat for bending, the amount of which is dependent upon the magnitude of the current. A latch is released by the strip when the latter bends sufficiently, and this latch trips the switch to open the load circuit.

The unit has limited use on D.C., but there are types for single and 3-phase A.C. circuits in various ranges of current capacity.

The elements of a switch of this type are given in Fig. 1. Fig. 2 shows three sketches of the mechanism indicating the "on," "off" and "tripped" positions. The unit is bakelite enclosed and is a combination of a quick make and quick break switch and thermal type circuit breaker. The switch is of the toggle type with an auxiliary arm normally latched under a catch attached to, but electrically insulated from, a U shaped bi-metallic strip. As long as this arm remains latched, the switch functions as an

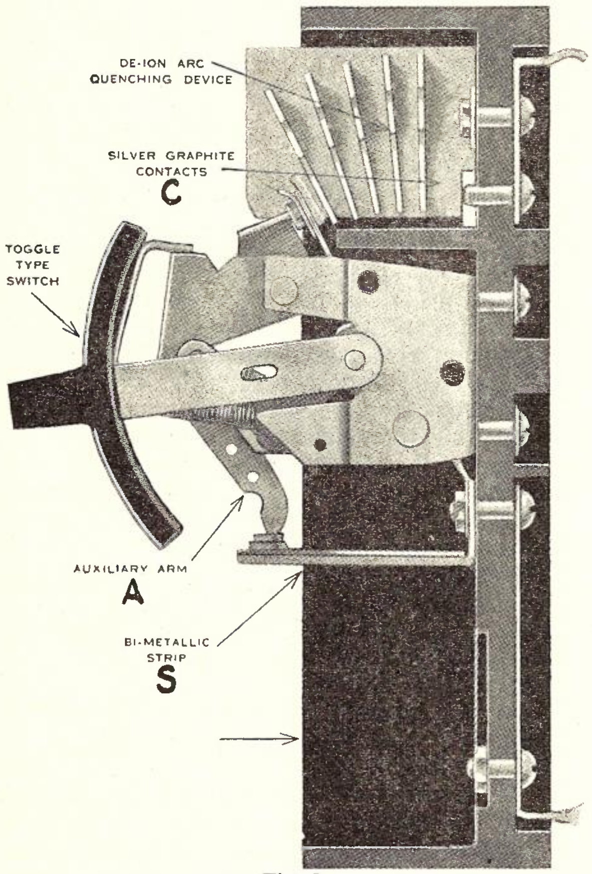


Fig. 1.

ordinary toggle switch, but when the bi-metallic strip bends sufficiently due to a current overload, it unlatches the auxiliary arm, which automatically releases the main toggle mechanism, thus opening the contact. In its tripped position the handle is located midway between "on" and "off," and where several breakers are mounted together it is easy to see which one has been tripped.

A special device to prevent excessive arcing is incorporated in the switch and consists of a series of slotted steel plates insulated from each other and from the contact. When the breaker opens, the arc is drawn into the slots of the plates and is extinguished immediately. The breakers have a rupturing capacity in excess of 3,000 amps at 240 volts A.C. A short-circuit of this magnitude is completely cleared in less than .02 seconds. The contact material is a silver-graphite composition designed not to melt under the severest conditions.

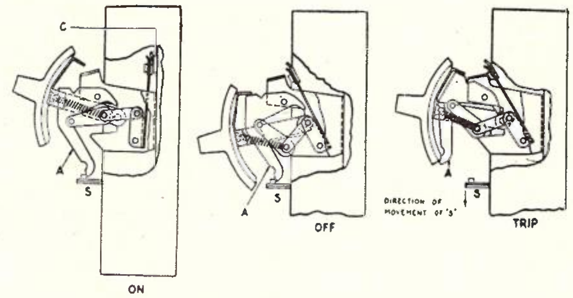


Fig. 2.

In order to restore a tripped breaker, the handle is first operated to the "off" position and then to the "on" position. If overload conditions still apply the breaker will trip out again. Thus, the mechanism cannot be restored to normal until the fault causing the overload is cleared. Fig. 3 shows the three positions of the operating handle.

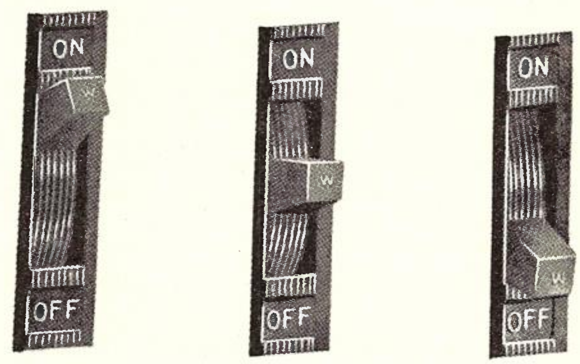


Fig. 3.

Consideration has been given to the design of A.C. power arrangements in automatic exchanges and it has been decided to replace the switch and fuse combination by a miniature enclosed type circuit breaker similar to that described. Apart from other aspects, economy in space is a major factor to be considered in the design of power panels, and some idea of the savings which may be effected will be gained by reference to a typical installation. In this instance it was possible to reduce the number of 5 ft. x 2 ft. power panels used for A.C. equipment from three to two as a result of the provision of miniature circuit breakers in lieu of switch fuse combinations.

INFORMATION SECTION

USE OF OIL ON SECONDARY BATTERIES

In 1933 the use of insulating oil on the electrolyte of secondary batteries was introduced in order to reduce the loss of acid during gassing, and to decrease the consumption of distilled water. The depth of the oil layer was specified as being not less than 1-8th inch for cells up to 2,000 ampere hours capacity, and ¼ inch for cells over 2,000 ampere hours capacity. After about 4 years' experience, its use was almost completely discontinued, the main reasons being:

(i) Difficulty in taking specific gravity readings.

(ii) Prevention of battery inspection, particularly in the case of wooden cells, due to sludging.

(iii) Loss of capacity caused by the oil affecting the negative plates.

However, in Australia and overseas, experiments were continued with a view to determining if oil could be satisfactorily used under favourable conditions. Since the start of the original trials in 1933, a greatly increased number of batteries are now in use in the Commonwealth, and it was considered desirable to reduce the consumption of distilled water, and at the same time the amount of attention required by the maintenance staff, particularly in hot climates, and where difficulties were being experienced with the supply of distilled water. Overseas tests had disclosed that the use of refined paraffin oil affects the negative plates much less than the insulating oil which was originally used for the purpose. Local tests had indicated that by maintaining a very thin film, just sufficient to form a continuous skin on the surface of the electrolyte in lieu of a layer 1-8th inch to ¼ inch thick, the sludging effect was largely eliminated, thereby overcoming difficulties (ii) and (iii) mentioned above.

Consequently, it was decided to combine the results of the abovementioned tests, and to determine the effect of using a thin layer of refined paraffin oil on batteries where local conditions made it desirable. A particular case where difficulties were being experienced with the supply of distilled water was at some of the repeater stations on the north-south Central Australian trunk line route.

This procedure has now been in operation for periods up to 12 months, and from results to date, complete success has been obtained in all instances in eliminating the difficulties which were experienced with the early use of insulating oil. Savings in the use of topping-up water of as much as 75 per cent. have been obtained.—E.J.B.

SOME NOTES ON FREQUENCY MODULATION

The distinction between the method of modulating a carrier known as "amplitude modulation" (abbreviated AM) and the process by which frequency modulation (FM) is accomplished, may be briefly set down as follows:

In AM the carrier **frequency** is held constant; its **amplitude** is varied from the mean value in direct proportion to the modulating voltage and at a rate equal to the modulating frequency.

In FM the carrier **amplitude** is held constant; its **frequency** is varied from the mean value in direct proportion to the modulating voltage, and at a rate equal to the modulating frequency.

Depth of Modulation.—With AM, the amplitude of the carrier is varied about the unmodulated value, maximum modulation (100 per cent.) obtaining when the carrier voltage amplitude varies between zero and twice the unmodulated amplitude, with application of the intelligence signal.

With FM the frequency variation of the carrier determines the modulation depth. If ΔF is the maximum frequency deviation allowed from the unmodulated frequency, then ΔF corresponds to 100 per cent. modulation, $\frac{\Delta F}{2}$ to 50 per cent. modulation, etc.

Modulating Signal Frequency and Sidebands: In AM, if the carrier is modulated with a signal of frequency f, then in addition to the carrier, frequency F say, additional frequencies (sidebands) are generated at $F + f$ and $F - f$, the two sidebands being of equal amplitude and proportional to the amplitude of the modulating signal. At 100 per cent. modulation the amplitude of the sidebands is one-half that of an unmodulated carrier.

In FM, conditions are more complex: if ΔF is the frequency deviation caused by a modulating signal of frequency F, then a large number of sidebands is generated, at frequencies $F \pm f$, $F \pm 2f$, $F \pm 3f$, etc., the amplitudes of the sidebands in general being of negligible amplitude at frequencies greater than ΔF from the unmodulated carrier frequency.

If f = maximum frequency of modulating signal

ΔF = maximum frequency deviation of carrier

Then $\frac{\Delta F}{f}$ is defined as the modulation index, and is an important factor in governing the overall performance of a system.

In the engineering of a complete system (either AM or FM), the band width must be sufficient to transmit all significant sideband frequencies without distortion, so that in AM the band width needed is 2f, and in FM is $2 \Delta F$.

Transmitters: In FM transmitters modulation is usually affected at a relatively low frequency and low power level, a series of frequency multipliers and power amplifiers being used to give the final frequency and output power, e.g., if the carrier desired is 48 megacycles/sec., and the frequency deviation ± 72 kilocycles per sec., a convenient method would be to modulate at 4 mC with frequency deviation ± 6 kC, followed by a 12 times frequency multiplication.

An AM transmitter, when fully modulated (100 per cent.) must deliver a power output equal to four times the unmodulated carrier power. On the other hand, an FM transmitter delivers a constant power output. An output stage of a given power capacity will deliver an average power under FM conditions, approximately 3 db greater than under AM conditions.

Receivers: The receiver of an FM system must be capable of translating a variable frequency input to a variable amplitude output. Any circuit, such as a tuned resonant circuit, which gives variable output for variable frequency input, may be used for the purpose, but it is customary to use a combination of tuned circuits and rectifiers, called a discriminator, to obtain the desired characteristic without undue distortion.

FM receivers have the property of discriminating against noise to a greater extent than is possible with AM receivers for two reasons, (a) an amplitude limiter may be incorporated in the FM receiver to iron out any amplitude variations caused by noise, and (b) the FM discriminator has the inherent characteristic of discriminating against noise. This noise discrimination increases wth increase of the modulaton index $\frac{\Delta F}{f}$, and is a prominent characteristic of an FM system.

The characteristic of noise discrimination obtained with FM is obtained at the expense of increased bandwidth, and added receiver complexity compared to AM.

For a worthwhile improvement in signal to noise ratio over an AM system, an FM system needs to have a large frequency swing. In the broadcasting case the value of $\frac{\Delta F}{f}$ should be of the order of 5, and thus, if $f = 10$ kC, as would be the case for high quality broadcasting, $\Delta F = 50$ kC. The band widths needed are then, for $AM = 2f = 20$ kC; for $FM = 2 \Delta f = 100$ kC.

The gain in signal to noise ratio obtained with FM is obtained only for signals greater than a definite minimum value, called the "Threshold Value." Below this threshold value an AM system would give better results than FM.

General: Band widths of 100 kC are not available in the medium frequency broadcasting band (550-1500 kC), and the only suitable portion of the frequency spectrum available for FM is the very high frequency portion—above 30 megacycles per sec. At the same time, FM increases the usefulness of these high frequencies, where noise is present in the form of amplitude modulated interference.

Wide band FM possesses the disadvantage that where more than one path exists between the transmitter and the receiver, sideband distortion may occur due to wave interference. Reflection of signals by an object such as a hill, cliff, or large city structure may cause the multipath effect, since there could be present at the receiver the signal which reaches after reflection from an object of the type mentioned, as well as the signal received directly from the transmitter.—E.J.S.

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. 2492.—MECHANIC, GRADE 2—TELEPHONE INSTALLATION AND MAINTENANCE

M. A. Bowden

Q. 6.—An open type lead-acid secondary battery is to be taken out of service for nine months. Describe the procedure to be adopted.

A.—Maintenance Circular No. 33, Section 7, prescribes the following procedure. If a periodical freshening charge cannot be given, it is advisable to take a battery entirely out of service, the procedure being as follows. First, fully charge the battery and then discharge it at normal rate until the voltage of each cell has dropped to 1.85. The acid should then be siphoned off—one cell at a time—and then immediately replaced by distilled water. The discharge should then be recommenced at half the normal rate until the voltage has fallen to about 0.5 volt. The terminals of the battery should then be short-circuited and so left for 36 hours. The plates should then be washed thoroughly by spraying water on each element, then soaked in running water for 24 hours, and allowed to dry. The plates may then be stored for an indefinite period. Wood board separators should be removed before the water is finally drawn off, and, if suitable for re-use, stored in acidulated water.

Q. 7.—A subscriber connected to an automatic exchange requires three telephones in parallel. What circuit alterations are needed when installing the telephones, and why is this necessary?

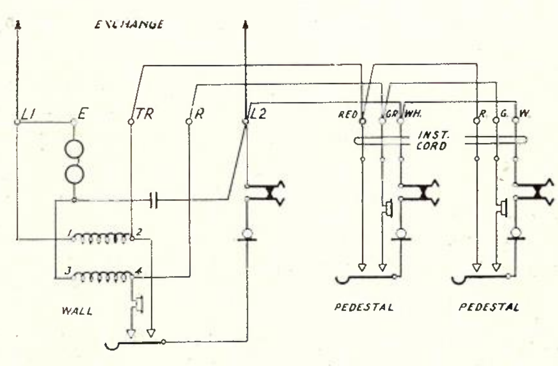
A.—If three telephones be connected in parallel without some circuit alteration, trouble will be experienced because of the added capacity of the condensers of the two additional telephones. The high capacity will cause distortion of the dialled impulses, and, in some exchange areas, the discharge of the condensers at the end of a ringing period may trip the ring before the called subscriber answers. The circuit changes to be made depend on the types of telephones connected. Three combinations will be considered:

(a) Three wall telephones.
(b) One wall telephone and two pedestal telephones, or two handset telephones 162.
(c) Three handset telephones 332.

Combination (a).—Open the bell circuits of two telephones by removing the straps between terminals L1 and E, and change the condensers of all telephones from two microfarads to one microfarad.

Instead of three wall telephones in parallel, it is preferable that two of the telephones should be either pedestal telephones or handset telephones 162.

Combination (b).—A bell set is not necessary with either pedestal or handset telephone, and there is no occasion to change the condenser of the main telephone. A three-wire circuit is run between the wall telephone and the other two instruments, and terminals TR, R, and T (or L2) of the wall telephone, connected to the red, green and white terminations respectively of the instrument cords at the other telephones. Fig. 1 shows the connections for a wall telephone and two pedestal telephones.



DIAL SHUNT SPRINGS NOT SHOWN

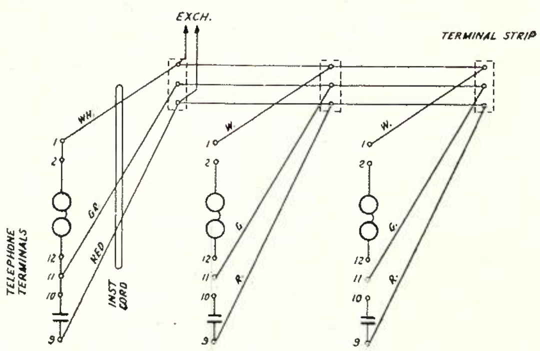
Q. 7, Fig. 1.

Combination (c).—A three-wire circuit is run between the main telephone and the two to be connected in parallel with it. Each telephone 332 is a complete unit, and it is necessary to alter the internal connections of the telephones so that one bell and one condenser only will be left in circuit. The changes to be made are:

(i) **Main Telephone.**—Strap terminals 1 and 2 in the telephone and transfer the green conductor of the instrument cord from terminal 2 to terminal 11.

(ii) **Telephones in Parallel.**—Remove straps from between terminals 10, 11, and 12, and transfer the green conductor of the instrument cord from terminal 2 to terminal 11.

Connect the three telephones in parallel by arranging a three-wire circuit as shown in Fig. 2.



3 TELEPHONES 322 IN PARALLEL
LINE & CORD CONNECTIONS ONLY

Q. 7, Fig. 2.

Q. 8.—What are the main advantages and disadvantages of through calling on a cord type C.B. P.B.X. in an automatic exchange area?

A.—Advantages: (a) Full control of an exchange line by an extension when connected through by means of a normal cord circuit, i.e., after an extension has been switched through to an exchange line, the extension may dial and complete an unlimited number of calls without the intervention of the P.B.X. Telephonist.

(b) Saving in P.B.X. operating time. Where through dialling facilities are not provided, the exchange line is looped by the holding coil which is connected across the exchange line when a plug is in the exchange jack, and the Telephonist must dial every number. Where the facilities are provided, the extensions may dial direct, thus freeing the Telephonist for normal switching duties.

(c) Reduced holding time of exchange apparatus. The switches are released immediately the extension hangs up. Where through dialling facilities are not provided, the switches are held by the exchange line hold coil until the P.B.X. Telephonist takes down the connection.

Disadvantage: After an extension hangs up at the end of the conversation, some time may elapse before the P.B.X. Telephonist disconnects. During this period the exchange line will test clear to an incoming call, and the exchange line indicator circuit at the P.B.X. will be open because of the plug in the jack. If a connection be now established at the exchange, the call will be routed to the extension which was through connected for the previous call. In most cases this will necessitate calling the Telephonist from another extension to have the correct connection made.

Q. 9.—What are the standard tones provided in an automatic exchange, and what purpose does each tone serve?

A.—Dialling Tone: 33 cycles per second. Continuous. The tone indicates to a caller that dialling may commence. It is transmitted from a first selector or equivalent switch after the telephone receiver has been raised, and the circuit of the calling subscriber has been extended to a free switch ahead. The tone continues until the first digit of the wanted number has been dialled.

Ringing Tone: 133 c.p.s. Interrupted, 0.4 sec. on, 0.2 sec. off, 0.4 sec. on, 2 sec. off. The tone is transmitted from the final selector to the calling subscriber to indicate that the call has been set up, and ringing conditions established.

Busy Tone: 400 c.p.s. Interrupted, 0.75 sec. on, 0.75 sec. off. The tone indicates to a caller that the call has not matured. The tone may be transmitted from a final selector when the line of the called subscriber is engaged or from an intermediate switch when all bank outlets are busy.

Number Unobtainable (N.U.) Tone: 400 c.p.s. Continuous. The tone indicates that the connection established is not to a working circuit. Vacant numbers or those not available may be connected to the N.U. Tone Circuit.

Q. 10.—State the functions of a type "C" or "CA" P.A.B.X. Briefly describe the equipment included in this type of P.A.B.X.

A.—Functions: The functions of a "C" type P.A.B.X. are to provide automatic service for a subscriber whose requirements can be met by 4 two-way exchange lines and 25 extension lines. The installation of an extension unit converts the P.A.B.X. to a "CA" type, and provides for 8 two-way exchange lines and 50 extension lines.

The following facilities are provided:

1. Extension to extension calls dialled direct.
2. Calls outgoing to the public exchange dialled direct by prefixing "Y" to the directory number.
3. Any extension may be barred direct access to the public exchange, in which case calls may be routed through the associated manual switchboard.
4. Calls incoming from the public exchange are received on a cordless type manual switchboard, and routed to extensions by the use of key sender equipment. If the extension is busy, the call is completed automatically as soon as it becomes disengaged.
5. Through clearing and automatic release on exchange calls, the exchange equipment is held busy until both calling and called terminations are free.
6. All exchange lines are night-switched to predetermined extensions, but when the lines are free, any extension not barred may call the exchange.
7. Extensions call the manual switchboard by dialling 9.
8. A busy extension may be offered an exchange call; a warning tone is provided to advise the extension that the telephonist is across the line.
9. On exchange calls, the telephonist may speak to either the exchange or extension without the other party hearing.
10. Outgoing exchange calls may be set up by the telephonist and reverted to any extension.
11. Automatic call back and transfer of exchange calls. If an extension telephone is fitted with a non-locking press button (which when depressed grounds

one side of the line), an exchange call may be held and information obtained from any other extension by dialling the relative number. Alternatively, the exchange call may be transferred to the extension number dialled without calling the manual switchboard.

Equipment: All relays are of the 3000 type with the exception of the extension line and cut off (L and K) relays, which are 600 type.

Extension to extension calls are established by means of link circuits, of which there are 4 in the C type unit. Each link circuit has associated with it a 25-point uni-selector as a line finder, and a 100 outlet final selector of the 2000 type. Each of the four both-way exchange line circuits has a 50-point uni-selector as a line finder. The "Level 9" circuit has a 50-point uni-selector. All uni-selectors are non-homing. One call back and transfer circuit is provided, and also one ringing and tone equipment.

For a full description of the C Type P.A.B.X., the reader is referred to Telecommunication Journal, Vol. 2, No. 1, June, 1938, page 21.

EXAMINATION No. 2377.—ENGINEER—TRANSMISSION

J. E. Freeman, B.Sc., A.I.R.E.(Am.).

SECTION 3.—LONG LINE EQUIPMENT

Q. 7.—Show by means of a schematic diagram the circuit of a 2-wire 2-valve (22 type) telephone repeater. Describe briefly its operation. Show in the diagram where the filters are located in the repeater circuit and their usual electrical form. Explain the purpose of these filters. Explain also the importance, in the operation of the repeater, of securing a close balance between the impedance of the lines and of the corresponding networks.

A.—See Telecommunication Journal of Australia, Vol. 4, No. 4, page 255.

Q. 8.—(a) The earlier carrier telephone systems used in Australia employed the system of transmitted carrier. In the later types the carrier is suppressed. Discuss the advantages and disadvantages of the two methods.

(b) The operation of a number of 3-channel carrier systems on the same pole line introduces a severe crosstalk problem. Describe those special features in the apparatus design, the selection of frequencies, frequency grouping and transmission levels used, which are adopted to lessen the crosstalk problem, with brief notes indicating the reason for the adoption of each. (Reference is not required to the use of special transpositions on the open wire lines.)

A.—(a) When a carrier system employs transmitted carrier, it is possible to employ the carrier at the distant end for demodulation. This means that no demodulator oscillator is required at the distant terminal, and there is no possibility of the channel being "out of synchronism" due to oscillator frequency differences. However, in modern carrier systems, the system of suppressed carrier has been adopted for the following reasons:

1. The carrier tone is not transmitted continuously to line, and, therefore, will not cause noise in other systems due to crosstalk.
2. Common amplifiers can be designed with a lower load rating.
3. The overall equivalent of the carrier channel is not affected to such a great degree by the variations in attenuation of the line.

If two identical carrier systems (employing transmitted carrier) are operated on the same pole route, crosstalk will produce a beat note at the distant end, wherever the modulator oscillators at the transmitting terminals are different in frequency. The use of suppressed carrier working removes the possibility of such notes being produced.

If a carrier current (frequency $\frac{p}{2\pi}$ amplitude P) is modulated with a voice frequency tone (frequency $\frac{q}{2\pi}$), the modulation product can be approximately represented as—

$$i = P(1 + k \cos q\,t) \cos pt.$$

This equation can be expanded—

$$i = P \cos pt + Pk \cos q\,t \cos pt$$

$$= P \cos pt + P\frac{k}{2}\left[\cos(p + q)\,t + \cos(p - q)\,t\right]$$

$$= P \cos pt + P\frac{k}{2}\cos(p + q)\,t + P\frac{k}{2}\cos(p - q)\,t.$$

The terms on the right-hand side of the equation are the carrier current, the upper side band and the lower side band respectively. Normally $k < 1$, and it is, therefore, obvious that the major portion of power is being transmitted as carrier current. This requires common transmitting amplifiers with a high overload point, but if the carrier current is suppressed, a lower overload point will give satisfactory service.

Suppose the upper side band $\left[P\frac{k}{2}\cos(p + q)\,t\right]$ is demodulated at the distant terminal with a carrier tone A cos pt. The demodulation product can be approximately represented as—

$$i_1 = A\left[1 + \frac{Pk}{2}\cos(p + q)\,t\right]\cos pt.$$

$$= A \cos pt + A\frac{Pk}{2}\cos(p + q)\,t \cos pt.$$

$$= A \cos pt + \frac{1}{2}.\,A.\,\frac{Pk}{2}\cos qt + \frac{1}{2}A\frac{Pk}{2}\cos(2p + q)\,t.$$

The middle term on the right-hand side of the above equation gives the voice component (the remaining tones are largely removed by means of a low pass filter). In the case of "transmitted carrier" type systems, A cos pt becomes equal to P cos pt (as the demodulating carrier tone is supplied from the transmitting terminal), and, therefore, the voice component is given by:

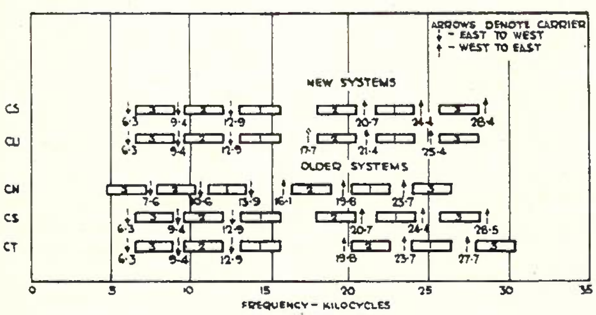
$$\frac{1}{2}.\,P.\,\frac{Pk}{2}\cos qt.$$

Under these circumstances, if the change in line attenuation is such as to increase or decrease the side band current by a given ratio, the carrier current will, in general, also be changed in the same ratio (both P and $\frac{Pk}{2}$ will be affected), and the resultant voice current will be changed by the square of this ratio. In the suppressed carrier system, on the other hand, although the side band is changed as before, the carrier remains practically constant (supplied from a separate oscillator), so that the voice current is less affected in this case.

(b) The effects of near end crosstalk occurring on open wire lines are reduced by the use of different frequency bands for the different directions of transmission (in the case of three-channel systems, a band from 5 to 15 kC/sec. is used for transmission in one direction, and a band from 15 to 30 kC/sec. is used in the other direction). Under these circumstances, any near end crosstalk occurring in spite of the physical separation of the circuits is returned on the disturbed circuit to the output of an amplifier. Since the amplifier is a one-way device, the crosstalk can proceed no farther, and does not reach the terminal of the circuit. Near end crosstalk in such circuits is, therefore, of little importance, except in so far as it may be converted into far end crosstalk by reflection from an impedance irregularity. To avoid this latter effect, it is essential that all circuit impedances be so matched as to eliminate important reflection possibilities.

The effects of far end crosstalk are reduced by arranging that the transmitted currents from various systems pass a given point on the pole route at the same level. It is obvious that if one system is at a much higher level than a second system, the effects of crosstalk from the first system into the second system will be severe. Automatic level control systems assist in reducing crosstalk effects by keeping all systems on a particular pole route at the same relative level.

Fig. 1 gives the frequency allocations as used in American three-channel systems. Staggering of frequencies (as used on the older systems) has been abandoned by American manufacturers, although equipment is available with "staggered" bands as well as inverted channels. The use of channel inversion only (as used on the upper channel of the CS and CU systems) allows one system to be converted into the other with minor alterations to the modulator and demodulator oscillators.



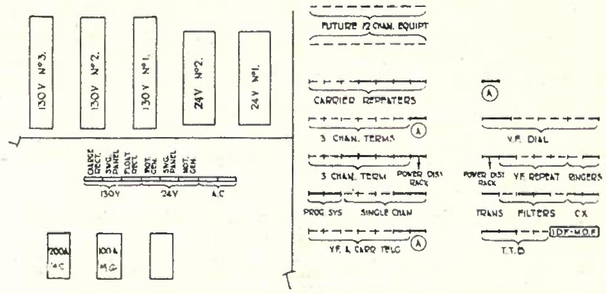
Q. 8, Fig. 1.

The use of channel inversion makes the crosstalk from one system to another unintelligible. Where more than two three-channel systems are operated on a pole route, "staggered" systems may also be necessary if crosstalk conditions are bad.

Q. 9.—A new building to house long line equipment is to be erected at an intermediate station on the trunk line route between two State capitals. At this station there are located, at present, two 3-channel carrier terminals, four 3-channel repeaters, the terminal of a voice frequency telegraph system, and other trunk line equipment, the latter equipment being of types and quantities as usually found at a fairly large country station.

Draw up a floor plan layout of a building to include a battery room, power room, and apparatus room that you would consider suitable to accommodate the equipment, having due regard to economy of space, but providing a reasonable margin for orderly future development. (A sketch plan in outline only is required, and to an approximate scale.)

The plan should show the positions suggested for batteries (24 volt and 130 volt), for power plant (240 volt A.C. motor-generators floating the battery, and a power switchboard), and for the apparatus. The apparatus layout should indicate where you would place the racks carrying the various classes of equipment at such an office, using full lines to show the position of existing apparatus, and dotted lines for future systems or apparatus. Give brief notes indicating the reasons for adopting the sizes and respective locations of the rooms, and for selecting the positions shown for the various types of apparatus.



Q. 9, Fig. 1.

A.—Fig. 1 gives a layout for a new building to house long line equipment at an intermediate station on the trunk line route between two State capitals. Doors are shown in the diagram, but windows have been omitted from the drawing. The toll test boards have been placed to obtain maximum lighting.

The equipment has been provided so that equipment which requires maintenance attention at frequent intervals (e.g., Relays on Carrier Telegraph Systems) is close to the Toll Test Positions. If the equipment has automatic level regulating equipment (e.g., J equipment when installed in the future), the equipment is installed at the back of the equipment room.

The racks marked A are provided with cables which connect to the Distributing Frame. These racks allow new equipment to be wired into the Carrier Room more readily.

The 24-volt batteries have a capacity of 1050 ampere hours, and the 130-volt batteries have a capacity of 108 ampere hours.

The empty block in the power room is provided for future motor generators.

The large space to the right of the Equipment Room has been provided for future carrier-in-cable equipment. Until required, this space will be available for the use of installation mechanics when new equipment is being provided at the station.

EXAMINATION No. 2473.—ENGINEER—TELEGRAPH EQUIPMENT

R. C. Henry.

SECTION 1

Q. 1.—A Teletype point to point service is to be provided in a local network. Type 15 machines are required, and only the machines are to be provided at the subscribers' premises. Draw a schematic sketch of the circuit arrangements and state the essential requirements to be met to provide a satisfactory service.

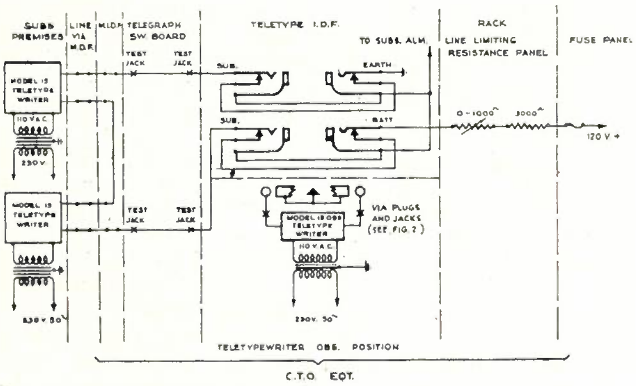
A.—General: The installation of a Model 15 Teletypewriter point to point service requires a minimum of auxiliary apparatus, as the machines can be arranged to operate without their line relays being in circuit, thus dispensing with the necessity of providing signalling battery at the subscribers' premises.

In this regard, each teletypewriter has its transmitter contacts wired in series with its selector magnet, so that a point to point service becomes a simple series circuit with a steady value of line current equal to 60 milliamperes, which is supplied in general, by the telegraph office situated within or near the locality concerned.

Teletypewriter point to point services arranged on the foregoing lines give reliable operation without appreciable loss of margin. By margin is meant the maximum degree of distortion that can be tolerated on the received signals, comprising the code group, consistent with their correct reception and translation into printed characters.

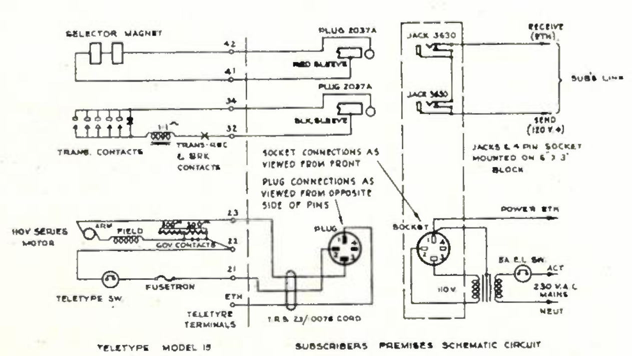
Essential Requirements: The items listed hereunder represent the minimum requirements, assuming, of course, that 230 V. 50-cycle supply mains are available at all stations:

1. A line circuit consisting of cable pairs and/or open wires.
2. Two Model 15 Teletypewriters, each supplied with a double wound step down 230 V.-110 V. mains transformer.



Q. 1, Fig. 1.

3. A source of signalling battery supply.
4. A means whereby the electrical condition of the circuit may be quickly tested.
5. A testing and/or observation teletypewriter, complete with mains transformer.
6. A maintenance schedule that will ensure adequate inspection and routine tests being performed in order to provide a satisfactory service.



Q. 1, Fig. 2.

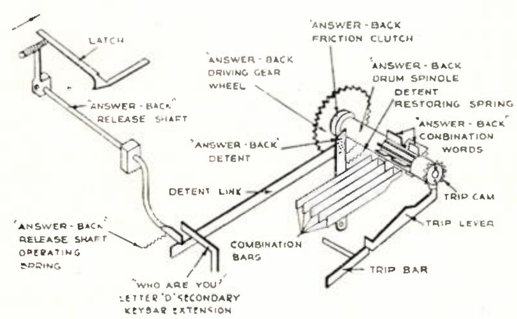
7. A replacement Model 15 Teletypewriter to permit quick restoration of the service in the event of a major machine fault or breakdown.

Circuit Details: Fig. 1 is a schematic diagram of a typical point to point teletypewriter installation, with test and observation facilities. In this regard, the test and observation machine is plug ended at the cord shelf of the Teletype I.D.F. and Jack Field position. Fig. 2 indicates the wiring connections of a typical subscribers' installation.

Q. 2.—What provision is made to enable an operator on a Teleprinter Service to check that the machine at the distant end is functioning?

Explain with the aid of a sketch the operation of this facility.

A.—General: A teleprinter operator can confirm that the mechanism of the distant teleprinter, with which a circuit has been established, is in good mechanical order, by transmitting the "Who Are You?" signal, and thereby bringing into operation the "Answer Back" mechanism of the distant machine, which is arranged to automatically transmit "TPR OK." Thus, in the case of the distant machine being unattended, the home station operator, on transmitting the "Who Are You?" signal before and after the message, is able to confirm, in addition to the mechanical fitness of the distant machine, the satisfactory reception of the sent message upon his machine, correctly receiving "TPR OK" in response to his "Who Are You?" signals. Although the main feature of the "Answer Back" mechanism is to confirm the identity of a distant machine, it is not used in this manner (departmentally) at the present time. However, the following details regarding the operation of the fitment relate to its use in the general sense.



Q. 2, Fig. 1.

The Answer Back Mechanism: The main component of the Model No. 7 Teleprinter A.B. unit is the ward drum, which is mounted concentrically on a spindle, and driven by means of a friction clutch, via reduction gearing from the keyboard unit shaft. The wards, which position the code bars, project radially from the surface of the drum, and are arranged in suitably spaced rows, whose direction is parallel to the spindle axis. Any row of wards represents a group of signal code elements required for the transmission of a character, and in this respect the ward projections and gaps correspond to the "space" and "mark" signal elements respectively. Earlier A.B. units enabled 13 characters to be transmitted, but those of more recent design permit the transmission of 20 characters. In both cases, however, the first two characters to be transmitted are the "letter shift" functions and the third and fourth, "carriage return" and "line feed" respectively, whilst the last character transmitted is invariably the "letter shift" function. The speed at which the A.B. spindle rotates when the unit is brought into operation is 25.5 r.p.m. Other features associated with the unit are discussed hereunder.

Transmission of the "Who Are You?" Signal: The sending operator depresses the "Figures" shift and letter "D" keys in quick succession, thereby transmitting the respective signal code elements to line. In the particular case, however, the letter "D" (secondary) key is held in its operated position until receipt of the first character of the distant machine's A.B. code.

The A.B. mechanisms of the sending and distant teleprinters each provide home records of their respective transmissions; therefore, it is essential that the sending machine A.B. unit should remain quiescent when it transmits the W.R.U. signal. Fig. 1 shows how this is accomplished by the extension of the letter "D" keybar, which, when operated, engages with the detent link and prevents the A.B. spindle detent from disengaging and allowing the ward drum to rotate. Thus, the simultaneous operation of the sending and distant A.B. units is prevented.

Reception of the "Who Are You?" Signal: On the reception of the W.R.U. signal and its conversion into the representative physical condition, the bell crank of the distant machine will move in a direction as indicated by the arrowhead shown by Fig. 1. The A.B. release shaft now moves in such a manner as to permit its operating spring to take control and move the detent from the shoulder of the A.B. spindle slot, thus allowing the friction clutch to rotate the A.B. ward drum.

Transmission of the Answer Back Code: When the A.B. spindle rotates, the code bars of the keyboard unit will be successively positioned in accordance with the physical shape of each row of wards. The signal combination set up by the code bars will, therefore, be transmitted to line as the cam of the A.B. spindle operates the trip bar via the trip link.

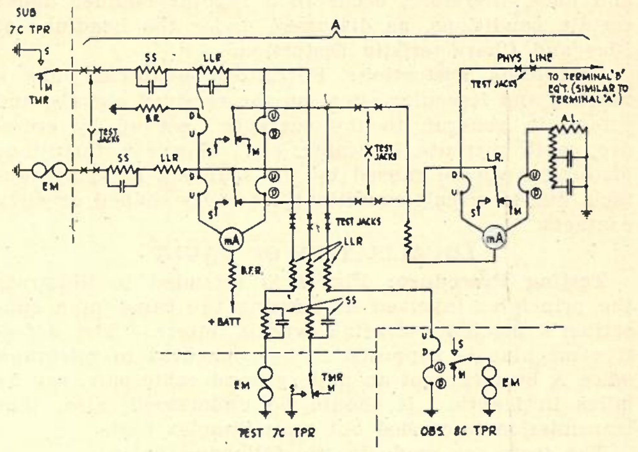
The motion of the A.B. spindle is arrested after one complete revolution, because the restoration of the relative bell crank permits the detent restore spring to take control and engage the detent with the spindle slot shoulder as it moves into its normal (stationary) position, in which case there are no wards fitted to the A.B. drum to impede the free movement of the code bars when the keyboard is used.

Q. 3.—On a long-distance leased Teleprinter Service, operated over a physical channel, the receiving machine is printing wrong letters. Discuss the probable reasons for this and state the tests you would make to locate the cause of the trouble.

A.—General: The usual procedure in cases where a machine prints wrong letters is to ascertain whether the local record of its own transmission is correct. In the following discussion the local record is assumed to be satisfactory. Also, the current values of the teleprinter circuit relay line and bias windings are considered normal, as likewise those flowing in the duplex physical circuit differential relays.

The physical line circuit should, therefore, be relined to ensure that the duplex balance network is correctly adjusted; also, that the line relays (designated L.R. in Fig. 1) are working under optimum bias conditions in order to permit the received signals being repeated correctly.

The electrical constants resistance capacity inductance and leakance of the physical circuit have a distorting effect on the signals as they recede from the transmitters, and as the signal length may be lengthened or shortened, according to circuit conditions, signal distortion is generally expressed as the percentage length of the received signal to that transmitted, which is considered to be of unit length and perfect shape.



Q. 3, Fig. 1.

Before teleprinters are installed for service, they are, in general, subjected to a test, which ensures they are capable of receiving and correctly translating signals of normal speed and current value, that are 35 per cent. early and/or late with respect to the start signal. This means that the machine can correctly receive signals with 70 per cent. distortion, assuming, of course, that their maximum displacement with respect to the start signal does not exceed 35 per cent. The margin of a teleprinter fulfilling the abovementioned requirements would be 35 per cent. With reference to the particular case, distortion which adversely affects the margins of teleprinters, and hence their capacity to cope with mechanical imperfections, such as wear and adjustment of mechanism or incorrect speed differences between itself and the sending station, is as mentioned hereunder:

Bias Distortion: The most common cause of bias distortion is unbalanced spacing and marking battery potentials, the effects of residual magnetism in relay cores and/or armatures or incorrect adjustment of the artificial lines in the duplex circuit. Bias distortion can be positive or negative accordingly as it affects the marking or spacing signal elements. In this respect, if the marking elements are lengthened and the spacing elements correspondingly shortened, the bias is positive. On the other hand, if the spacing elements are lengthened with a corresponding shortening of the marking elements, the bias is negative.

Characteristic Distortion: Characteristic distortion, when considered as remote from bias and fortuitous distortion (discussed later) varies in its effect on the received signal in accordance with the polarity and sequence of the signal elements. Thus, should a teleprinter print wrong letters, the nature and sequence of those letters antecedent to the ones incorrectly printed are of special significance to the testing officer. Characteristic distortion varies, also, with the type of line circuit; i.e., if it be composed of aerial wires and/or cable pairs. However, the effects of characteristic distortion are relatively small when the line consists of open aerial wires, but in the case of long underground cable circuits of high capacity the nature and sequence of the signal code elements on the charge and discharge of the line influences the degree of distortion on the received signals.

Systematic Distortion: Systematic distortion is the combined effects of bias and characteristic distortion, and does, therefore, occur in a regular manner under certain conditions, as discussed under the headings of Bias and Characteristic Distortion.

Fortuitous Distortion: Fortuitous distortion has a varying and irregular effect on the received signals, and refers, in general, to the currents set up by cross-fire, earth currents, lightning, etc. However, fortuitous distortion can be caused by the sparking at relay contacts due to circuit conditions, or badly shaped or dirty contacts.

LOCALISATION OF FAULT

Testing Procedure: Fig. 1 is intended to illustrate the principles involved in locating the cause of a subscriber's machine printing wrong letters. The defective machine is supposed to be connected to telegraph office A by means of an underground cable pair, say 2½ miles in length. It should be understood, also, that transmission is carried out on a Simplex basis.

The tests are made in the following order:

1. The testing officers, at A and B, terminate the duplex physical line on duplex morse test sets at jacks "X" and co-operate in carrying out the normal routine of artificial line adjustment and balance. Both officers also make a check on their relays for neutrality, transit time, and freedom from contact sparking when tested on the panel relay test set, which is supplied with 25 cycle "square" topped reversal current.

2. The duplex test sets are removed from circuit and the A and B test teleprinters connected in circuit. The subscribers' line circuits are opened at jacks "Y," correct current values checked and adjusted, and the margins taken of the duplex line relays LR in the following manner:

Suppose Station A transmits to B, then by means of steadily depressing the letter S key, and by applying pressure with the forefinger of the left hand on the pawl abutment lever to release the pawl of the transmitter, continuous S's are sent to line. The testing officer at Station B now turns the bias adjusting head of the line relay to "space" until correct reception of the letter S fails. When this occurs the bias adjustment is turned to "mark" until the letter S is again incorrectly printed by his test machine. Finally, a setting of the bias is made midway between two points of failure. Any departure of margin from normal "settings" must be investigated and corrected. Station B now transmits S's to Station A, who adjusts the line relay of his duplex circuit in accordance with the methods adopted by the testing officer of Station B.

It will be observed that the letter S represents the nearest approach to "reversals" by the continuous transmission of any single letter.

3. The testing officers of A and B stations now conduct teleprinter trials over the duplex circuit by exchanging signals on a simplex basis, which usually consist of two rows of the letters RYRY, and so on; then, all figures, 1, 2, 3, etc., finishing with "The quick brown fox" etc., test sentence. It is assumed that the trials are satisfactory.

4. The testing officer of Station B now conducts teleprinter trials with the subscriber's machine connected to Station A. It is assumed that correct reception results at both stations. Station B next exchanges signals with the subscriber connected to his station, when again reception is satisfactory in both directions. However, when the subscriber connected to Station B exchanges signals with the distant A subscriber, it is found that his machine continues to print wrong characters when in "Letters" or "Figures." Hence the margins of the receiving mechanism of the teleprinter connected to Station B are not within the prescribed limit, and the fault would be reported to the mechanical section for remedial action.

EDITORIAL NOTE

The late issue of this Journal has been due to causes beyond the control of the Board of Editors. The delay is, however, regretted and an endeavour will be made to catch up the leeway with succeeding issues.

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