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AUSTRAL STANDARD CABLES PTY. LTD. – VICTORIAN TELEPHONE CABLE FACTORY

G. T. Alkin, A.M.I.E. (Aust.)

Introduction: Telephone cables were first produced in Australia in 1923 by Metal Manufactures Ltd., at their Port Kembla, N.S.W., factory. These cables were of the paper insulated lead-covered type, suitable only for local distribution in exchange areas. About 1937, however, the production was started of long distance voice frequency (trunk) cables, and, in 1940, these activities were extended to include carrier frequency cables, having a characteristic suitable for carrier band transmissions up to at least 60 kc/s. These cables were all of the paper insulated lead covered type for external use and provision was made to protect them with wire or tape armour from 1937 onwards, double wire armoured cables for river and bay crossings also being manufactured when required. Later the production of textile insulated cables (commonly known as switchboard cables) for internal use was undertaken.

By the end of the last war, therefore, a fairly comprehensive range of telephone cables and insulated conductors was being produced at Port Kembla, but not in sufficient quantity for the growing demand of the country. Therefore, at the request of the P.M.G's Department, Metal Manufactures Ltd. decided to build a new factory at Maribyrnong, a suburb of Melbourne, to produce about the same quantity of local cables as was then being produced at Port Kembla. This project would thus double the local supply of exchange area cables, for which type the demand by the Department was by far the greatest. Economic considerations of raw materials, freights, and transport of finished products to the Southern States naturally influenced the decision to build in Victoria, and as Metal Manufactures Ltd. already had an operating wire drawing factory at Maribyrnong, from which supplies of coiled and spooled copper wire could be supplied, it was logical to build in the vicinity.

Before the building of this factory was actually started, a new company was formed jointly by Metal Manufactures Ltd. and Standard Telephones & Cables Pty. Ltd. to take over the production of all telephone cables and allied lines from Metal Manufactures Ltd. This new Company, Austral Standard Cables Pty. Ltd., came into operation at the beginning of 1948 and took over the existing Port Kembla factory organisation as well as the Maribyrnong project, for which the majority of the plant had been ordered.

As noted above, the new factory was intended originally to produce only local cable, and the layout and equipment had been designed and ordered accordingly, but by the time the new Company was established it became apparent that the demand for all types of cable would increase and that the Port Kembla factory not only could not be enlarged, but the age of its equipment made it difficult to maintain it satisfactorily for the increasing production that was, in fact, being obtained there. It was, therefore, decided that the Maribyrnong factory should be re-arranged and enlarged as far as possible to take care of all developments.

Much of the plant and machinery required for telephone cable production may be classed in the heavy industrial group. Such items as lead presses, stranders, and armouring machines are costly, both to purchase and install, and require considerable foundations. It is therefore obvious that when a new factory, incorporating such equipment, is being considered a very careful study must be made of the trend of telephone cable usage and demand and the effect of new developments upon existing practice assessed in order to ensure, as far as can be foreseen, that all special machinery purchased will have a reasonable economic life before becoming obsolete. This is no easy task in an age when new materials and processes are being developed with amazing rapidity.

At present the cables made are all of the concentric type, but the existing equipment has been designed so that the more modern unit type cable produced in the U.S.A. for the Bell System, and later adopted by the British Post Office, could be produced if required, at least in limited quantities. The cables produced cover the complete range required by the Department in conductor gauges from $6\frac{1}{2}$ lb. to 40 lb. inclusive, and in cable sizes from 1 pair to 1410 pairs. However, by adopting the unit method of construction with 4 lb. conductors, it would be possible to manufacture 1800 pair cables as called for in the British Post Office Specification CW 111, with only minor modification to existing factory equipment. Trial orders for some 4 lb. conductor cable have been placed by the Department and its manufacture is expected to commence shortly.

Maribyrnong Factory: The site available covers 9 acres in area, and on this a main factory building of 50,000 square feet was erected, at the west end of which an additional block was built to house the canteen, cloak room and other employee amenities, as well as the local factory administrative and head office organisations. The main factory building is some 400 feet long and comprises 3 bays, each 40 feet wide, spanned by 10-ton overhead travelling cranes which have been arranged to service approximately half the total factory floor area. Manufacture started in this building in June, 1950, and the first cables were delivered to the Department in August, 1950, although the buildings and services were at this time very far from complete. The production flow is, in general, from west to east down the length of the building.

Manufacturing Process: Of the raw materials used in cable manufacture, a proportion only are of Australian origin. Supplies of copper wire are obtained daily from Metal Manufactures Ltd., and Australian lead and lead alloy is, of course, used. Paper, cotton and textilose string are all obtained from overseas sources, as suitable local supplies are not available, and bulk storage facilities therefore occupy a considerable proportion of factory space; however, these items will shortly be catered for in a separate building. Lead and, of course, galvanised wire for armouring can be stored in the open.

From the raw material flow and process diagram (Fig. 1) it will be seen that cable production commences with the preparation of insulating papers. High grade insulating paper is obtained

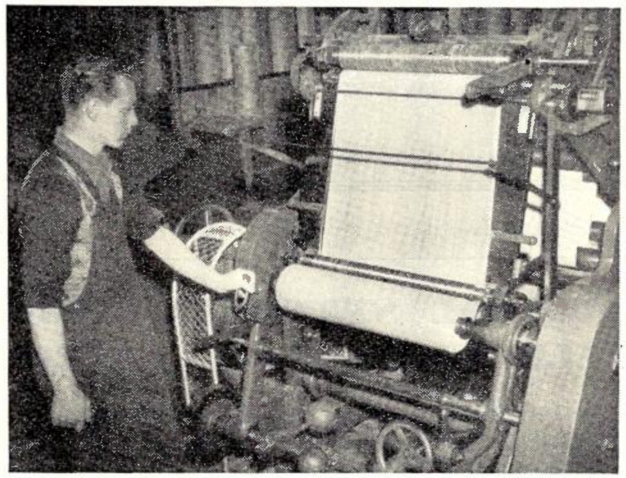

Fig. 2.—Paper cutting machine.

in rolls about 25 inches wide, weighing approximately 300 lbs., and is cut and wound into pads on special paper slitting machines, (see Fig. 2). At the same time, if required, the identifying dye is applied to code mark the paper, by means of special inking rollers. These cut papers vary in width from $^{3}/_{16}$ to $\frac{1}{2}$ inch, and in thickness from .0025 to .005 inch, depending upon the size and type of cable for which they are being prepared.

The cut, and, if necessary, marked paper is taken from these machines to wire insulating machines, where it is wrapped helically round the required copper conductor. Although this wrapping process takes place at high speed, the manner of paper lapping is carefully controlled and a

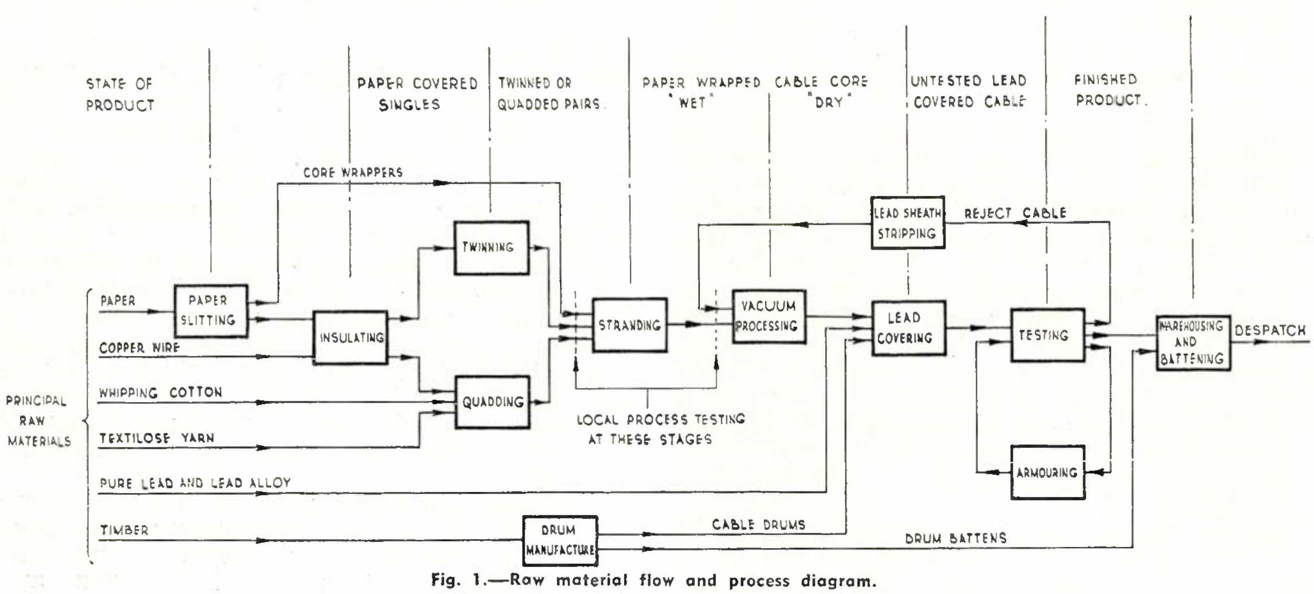

Fig. 1.—Raw material flow and process diagram.

considerable body of air is trapped between the paper and conductor, and represents a fair proportion of the conductor insulant. In the case of trunk and carrier type cables this condition is, in fact, taken a step further, and an open helix of textilose string is wrapped round the conductor beneath the paper to increase the air content. Fig. 3 shows the normal type of high-speed paper insulating machine used for wrapping local type cables.

Fig. 3.—High speed paper insulating machine used for wrapping local type cables.

As shown on the flow and process diagram, this process is followed by the twisting of conductors into either pairs or quads as required. The majority of the twisting equipment at Maribyrnong is designed for star quad construction, which is the type generally required by the department for the bulk of their cables. For this type of quad, four insulated conductors are twisted symmetrically about a centralising string, and the two pairs thus formed are wrapped with an outer helix of coloured flax yarn or cotton, which, apart from holding the quad together, serves the additional purpose of identifying the quad in a built up cable. Typical quadders are shown in Fig. 4.

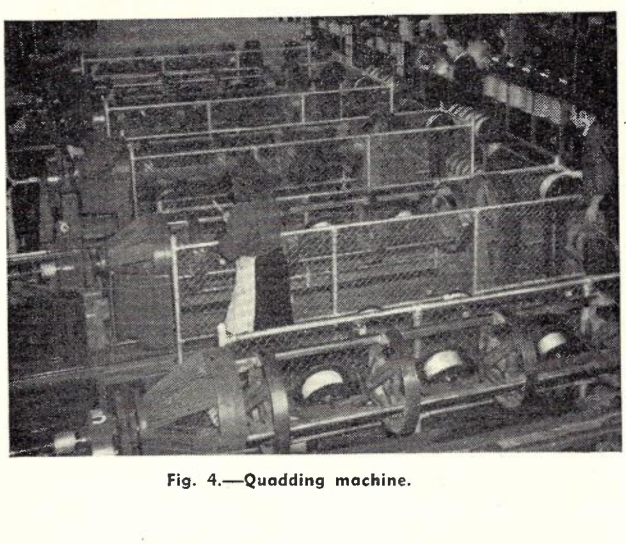

Fig. 4.—Quadding machine.

From such a quad two circuits can be obtained, each from diagonally opposite conductors, having very little coupling between them as they are

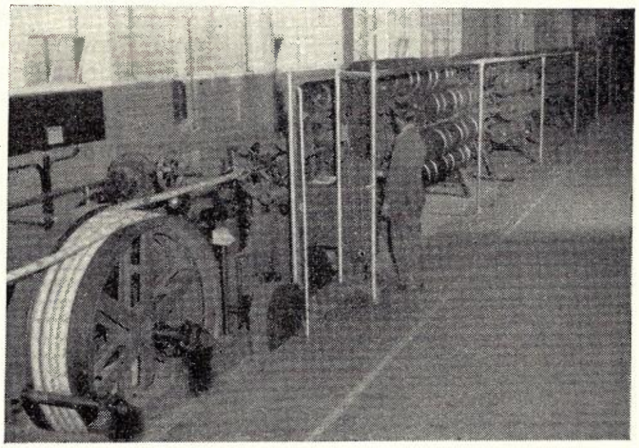

Fig. 5a.—General view of a typical stranding machine.

effectively two circuits maintained continuously 90° out of phase with one another provided that they are uniformly twisted together. Twisting equipment is also provided for the simple twin type construction, and even the multiple twin type can be produced, but since phantom circuits are no longer required to any extent, no special equipment for this type of twisting is provided.

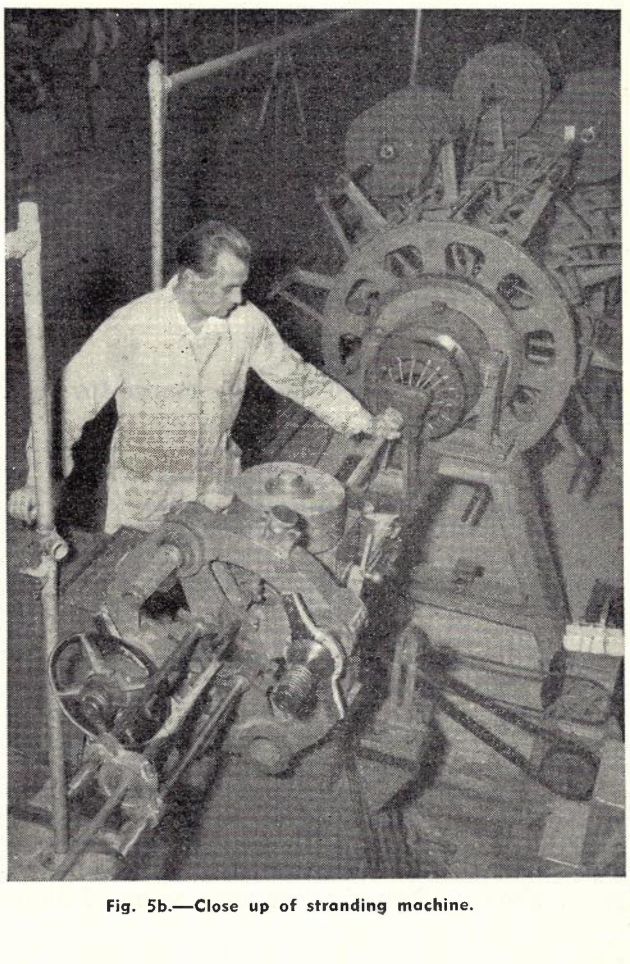

Fig. 5b.—Close up of stranding machine.

The twisted conductors proceed to the stranding machines, where they are stranded to form cables of various sizes, a typical stranding machine for local cables being shown in Fig. 5. The same type of stranding machine can be used for either local quad, twin or switchboard cables, the largest machine being equipped to apply five layers to a core in one operation. It is therefore necessary to pass very large cables through these machines a number of times in order to obtain the necessary layer "build up." A smaller stranding machine is also provided for trunk and carrier type cables, which can also be used for laying up the units for a unit type cable. The units would previously be stranded separately on the local type stranding machines. It might be noted here that the unit type cable, besides providing certain advantages during installation of the cable in the field, also allows the largest cable to be stranded in no more than two

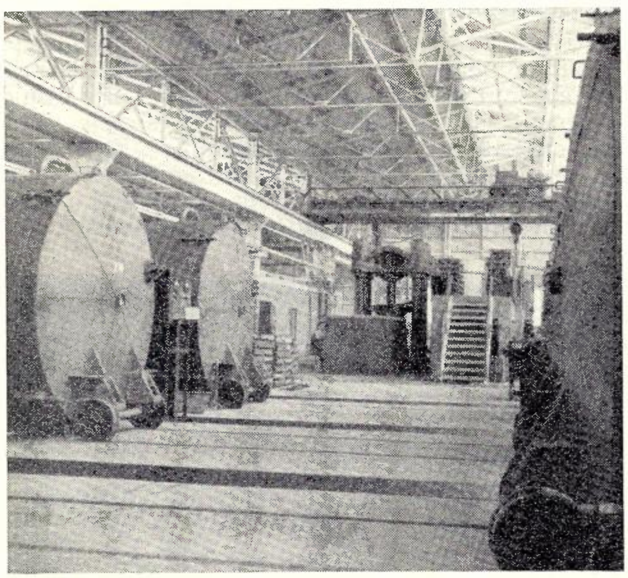

Fig. 6.—Vacuum drying ovens.

operations, which is of some importance for large cables of small conductors.

The stranded layers of conductors are tightly wrapped with one or more layers of overlapping paper strips or, in some cases, calico tapes, the type and number of laps depending upon the customer's requirements. The lapped cable core thus formed progresses to the vacuum drying area, which consists of six large steam heated horizontal cylindrical vacuum tanks or ovens. With these ovens and their associated equipment of vacuum pumps, condensers, etc., the cores may be completely dried before lead covering. The amount of drying is determined by the insulation resistance between the conductors required by the customer, which in Australia, following Continental European practice, is required to be in the order of 5,000 to 15,000 megohms per mile or more. At the time of writing the average cable core is subject to about 24 hours' processing, some 13 hours of which is spent under vacuum. However, D.C. generators have been installed and with these it will be possible to cut this processing time down

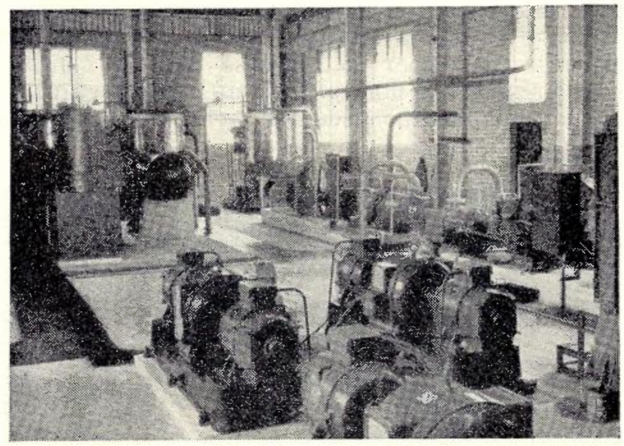

Fig. 7.—Vacuum drying and auxiliary equipment.

to 4 to 6 hours by passing D.C. currents through the cores of such a magnitude as to cause internal heating to the temperature required. Apart from the saving of process time, this process has an additional advantage in that it reduces the artificial ageing of the paper which, to some extent, will accompany its subjection to heat and vacuum

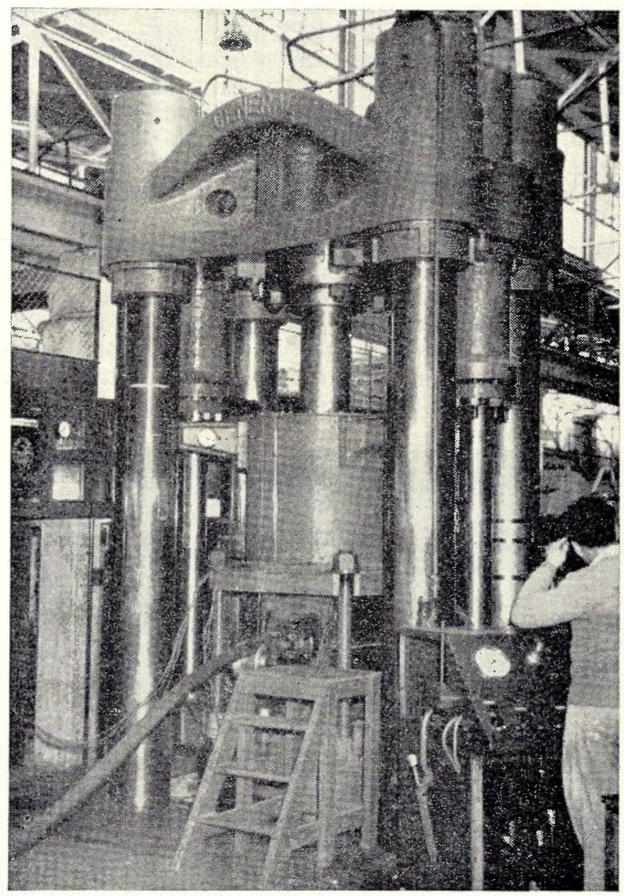

Fig. 8.—3000 ton lead press.

for 24 or more hours. The vacuum pumps for this process consist of one single stage, and one two-stage vacuum pumps. The former is used as a "roughing pump" to remove the bulk of air and moisture in the early stages, while the two-stage pump creates and maintains the higher vacuum which is necessary in order to obtain a high insulation condition in the finished cable. The two-stage pump is capable of holding a vacuum of 0.02 inch of barometric reading. The ovens are designed to take two full-size drying cylinders which have an overall diameter of 72 inches. Primary heat to the vacuum ovens and lead presses, etc., is

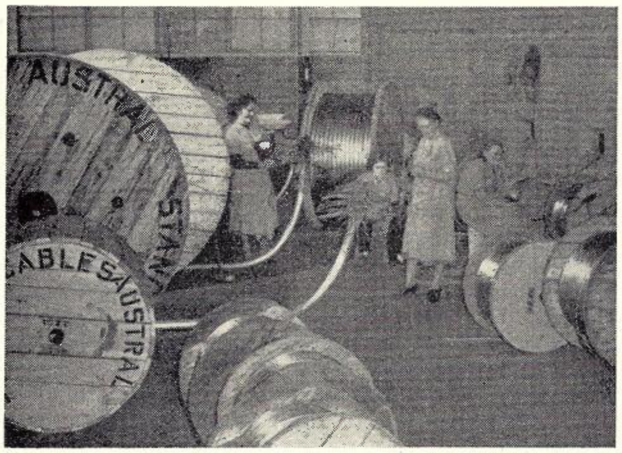

Fig. 9.—Cable drums on test floor.

provided by three oil-fired steam generators which, of course, also provide for the normal factory services. The vacuum ovens are shown in Fig. 6, and the auxiliary equipment in Fig. 7.

Press equipment for lead sheathing comprises one 1000 ton and one 3000 ton press. Both are of the reciprocating vertical type, having moving die blocks and are operated by oil as the hydraulic medium. The press die blocks are thermostatically controlled to give an extrusion temperature to suit either pure lead or lead alloy as required. Pig lead is melted in special electric melting pots, again thermostatically controlled, and fed into the press containers as required. The 3000-ton press, with some of its associated equipment is shown in Fig. 8. The dried cable core on its steel factory drum is taken from a steam-heated holding oven to the back of the press and, as the paper covered core passes through the press block, the semi-plastic lead sheath is extruded round it and the cable is then taken up on its shipping drum. The existing equipment at Maribyrnong will sheath any of the normal range of cables having overall diameters between 0.25 and 3.0 inches. Both the thickness and diameter need to be very carefully controlled, the former mainly to conserve the lead, but also to avoid eccentricity, and the latter to maintain uniform electrical quality in the finished cable length.

After lead covering, the cables are taken to the test floor shown in Fig. 9 and subjected to stringent testing as well as which their A.C. and D.C. characteristics are obtained. The test room is situated on the eastern end of the southern side of the building, where it is naturally less exposed to

Fig. 10.—View of test equipment showing D.C. reflecting galvanometers.

temperature variations. This is desirable, as variations of humidity in particular upset the calibration of some of the test instruments used. The D.C. equipment comprises two reflecting galvanometer insulation resistance sets, which can be calibrated to cover the range of from 100 to 100,000 megohms, and a normal type of wheatstone bridge for conductor resistance measurements. One of the galvanometer insulation resistance sets is also arranged for capacity testing by the capacity discharge method. The A.C. equipment comprises two screened test sets supplied by Standard Telephones and Cables Pty. Ltd., of their own design, and arranged for the routine testing of all capacity unbalance combinations, and also mutual pair and phantom capacities as

Fig. 11.—View of test equipment showing capacity unbalance set.

required. With this equipment are, of course, associated oscillators, amplifiers, etc. The testing is carried out generally to the requirements of the P.M.G's Department. There are, in addition, ringing out and fault locating test sets provided both in the factory for process inspection and on the test floor. Views of the test room and equipment are shown in Figs. 10 and 11.

In the event of a fault occurring after lead sheathing, or of a cable failing to register the minimum acceptable insulation resistance, a lead stripping machine has been provided for the removal of the sheath and exposure of the core for correction (if required) and re-processing. This machine, shown in Fig. 12, is merely an arrangement of horizontal knives, held in a guide, through which the cable is passed. Motorised rollers remove and cut into short lengths the slit lead sheath which is of course reclaimed, and the paper covered core is wound on to a take-up drum without sustaining damage. If a fault is involved, it is then rectified and the cable core is again routed through the vacuum drying process for lead covering as shown on the flow and process diagram.

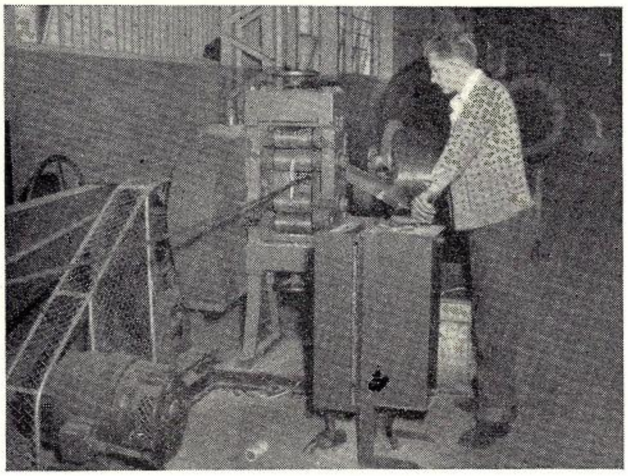

Fig. 12.—Cable sheath stripping machine.

Drum Making: It was originally intended that the wooden drums, on which the cable is despatched to the customer, should be made in the main factory building, but to provide a better arrangement for the other equipment, and also to permit more flexible expansion of the main factory areas if required, it was decided to house the drum making unit in a separate building. The timber supply for this process occupies the extreme south-eastern end of the site, and is arranged to feed directly into the drum-making shop, which in turn feeds into the lead press, or armouring areas where the drums are used to take up the finished product, subject only to satisfactory testing. The drum-making equipment is mostly standard for such a process, and consists of docking saws, a rip saw, band saws, special drills for spindle holes, etc., and a thicknesser and moulder for shaping the barrel laggs. A general view is shown in Fig. 13.

The supply of large quantities of suitable timbers for cable drum manufacture has proved extremely difficult in Victoria, and most drums are made of a double type of construction, having inner flanges and barrel of softwood (South Australian Pinus Insignis), and the outer flanges and outside lagging of specially selected hardwood. Apart from their basic characteristics of grain strength, etc., timbers have to be considered from two other aspects if they come into close contact with the lead sheath of a finished cable. They are the amount of free acetic acid in the timber, as catalytic action can be started thereby and destroy or render porous the cable sheath, and freedom from borer infestation and susceptibility to borers. Several species of borer, among them the common Lyctus Brunnus, are quite capable of boring through an $\frac{1}{8}''$ lead sheath if it happens to be in their way when they emerge from their flight hole.

Armouring: Soon after building operations on the original factory layout had commenced, the P.M.G's Department indicated that they would probably be requiring an increased amount of armoured cable, that is, cables having a protection of steel tape or wire over the lead sheath with the usual bitumen impregnated jute beddings and servings. Armouring machines to perform the process are large and heavy and require an extensive floor area, and although today, with modern bitumens, fume troubles are not so great, the operation is still a comparatively dirty one. The fire danger with molten bitumen is also greater than that associated with the other processes of cable production, and from every point of view therefore there is a strong argument in favour of establishing such a process in a separate building, and that provided at Maribyrnong to house three machines is about 240 feet x 60 feet and has, therefore, a floor area of approximately 14,000 square feet.

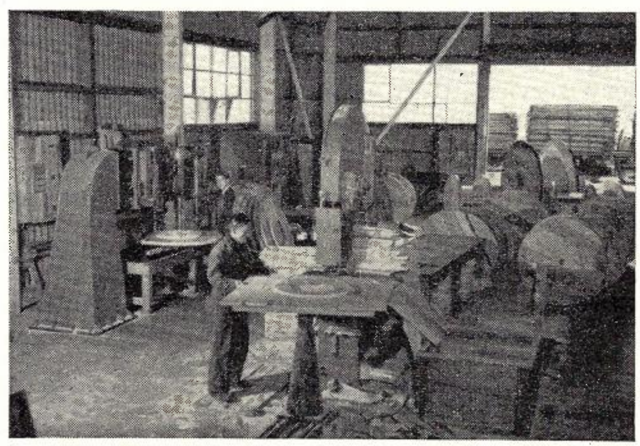

Fig. 13.—General view of drum making unit.

At the time of writing this article, two machines only are in operation, they are a large composite machine capable of applying either a wire or steel armouring with double jute bedding or serving as required, and a steel tape machine to apply steel tape armouring only. The third machine, for wire armouring only, is rapidly being installed and will probably be in production by the time this article is published. Fig. 14 shows the composite wire and tape machine at work. With this plant the lead covered cables produced in the main factory can be covered with any of the normal armourings required for land cables or comparatively short water crossings. Large submarine cables could not, of course, be handled with existing machines except perhaps with extensive improvisation. The auxiliary equipment associated with this process, all housed in the same building, comprises bitumen melting and mixing

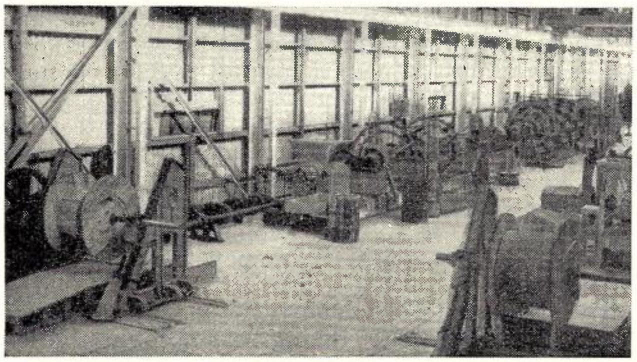

Fig. 14.—General view of complete wire and tape armouring machine.

equipment, jute impregnating equipment, and steel wire and tape processing equipment.

Internal Cables and Wires: It was not originally intended to produce internal cables and wires at Maribyrnong, but the requirements of the Department were so great that at their instigation it was decided to arrange for some production in Victoria, and the scheme entailed the erection of another building to house the textile and possibly plastic covering machines. Unfortunately, due to many conditions which beset the building industry today, the erection of this building has been considerably delayed. However, as most of the equipment to commence operations had already been received, it was decided to install some of it temporarily in the main factory building, and a considerable output of switchboard type cables has been achieved under difficult temporary conditions. When the new building is available, and the complete plant correctly installed for balanced production, a much larger output can be expected and the range of products will be increased. The cables produced so far are of the textile insulated conductor type, protected either by paper lapping and textile braiding or by a lead sheath, and being for internal use they are impregnated with a suitable compound as a protection against moisture when exposed. Eventually, it is proposed to produce plastic insulated and protected cables as far as experience proves their suitability for internal use.

Bulk Stores: As already noted, the majority of non-metallic components of a telephone cable are of overseas origin, and it is therefore necessary to carry large stocks of insulants and other stores to maintain consistent production. Originally it was intended to house bulk stocks within the main building, but various programmes of expansion have dictated the provision of a separate bulk store building.

Trunk Cables: By the removal of the bulk stores from the south-western end of the main factory, it has been possible to re-arrange the paper cutting area to provide sufficient space for equipment to produce trunk and carrier cable in moderate quantities. This development, again not originally intended, was brought about by the growth of demand for trunk and carrier cables and by the fact that the Port Kembla equipment has for many years, been working under strain and in conditions which will not permit further expansion there. This change is not yet complete, and will eventually involve some further increase in both the lead covering and testing departments for which arrangements are already in hand.

Co-axial Cable: This type of cable has not yet been used in Australia for long distance telephone circuits, although it is well established both in the Bell System of the United States and in the long distance trunk network of the British Post Office. Under these circumstances, consideration has been given to the manufacture of such cables at Maribyrnong. Plant for the production of small quantities of co-axial units as supplied to the British Post Office can be housed in the main building when the switchboard cable building and new bulk store are completed, but arrangements have been made to extend the main building along the whole of the south side should this type of cable be required in large quantities in Australia.

Emergency Power: In order to ensure that the output of the factory will not be abnormally affected by power failures it has been decided to install two diesel engine alternator sets of 170 kw capacity adjacent to the auxiliary service equipment, where they can be readily connected to the main factory distribution system.

Conclusion: If and when full equipment is installed for the maintenance of co-axial cables it will be seen that with the completion of the present programme at Maribyrnong it will be possible to manufacture there a complete range of all cables and wires required in the telecommunication field today (with the exception of flexibles). Together with the output from the Company's Port Kembla factory, this will provide reasonable quantities to satisfy present requirements, and both from the economic and defence aspects will be of considerable advantage to Australia. Moreover, as the requirements of the country expand, the experience gained in the erection, equipping and bringing into operation of the Maribyrnong factory will be of advantage in meeting the requirements of further expansion.

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TYPE J2 AUXILIARY CARRIER REPEATER STATION WITH 420 B POWER PLANT

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Introduction

The general features of the Western Electric type J2 twelve channel open wire carrier system have been described in a previous issue of this Journal (1). The longest system of this type in Australia was installed recently between Brisbane and Townsville, the total route distance covered being 837 miles. The system carries approximately 4 per cent. of all trunk line traffic in Queensland, and extends through a coastal area in which reside approximately 45 per cent. of the population of the State. Where traffic conditions warrant, the type J2 system is particularly suited for such long distance routes, as the cost of providing an equivalent number of channels by physical construction is large in comparison. The carrier circuits are of a high quality, and automatic gain regulating equipment enables stable operation with zero loss equivalents.

The interesting features of the Brisbane-Townsville system include a type of repeater station power plant not used previously in this country. This is designed for use in localities where no commercial power supplies exist, and a description of a repeater station using this type of power plant will form the main subject of this paper.

Location of Intermediate Repeater Stations

The locations of the intermediate repeater stations on a 12-channel open wire carrier route are determined after consideration of many factors, such as wire size, length of trunk entrance or intermediate cables, and the location of existing offices. The attenuation of any open wire line increases with increase of frequency, and for a well transposed 200 lb. hard drawn copper pair is approximately 0.37 db per mile, at a frequency of 150 kc/s under wet weather conditions. As the voice and side-band frequencies progress along the line, their power levels fall because of this attenuation. It is not desirable that the signal power level be allowed to fall too low, as it would eventually equal the line noise. Amplifiers are, therefore, provided at intervals along the line to raise the levels in each direction of transmission. These amplifiers, together with their associated filters, equalisers, etc., are known as repeaters, and the maximum spacing between repeater stations is determined by the point at which the noise in the channels would be just noticeable on a long system.

The maximum level sent from any station is limited, because the most economical amplifiers for this type of system have undistorted power outputs of about 6 to 8 watts. For a 12-channel system using such amplifiers, the maximum transmitting level per channel is + 17 db. With this transmitting level, a 28 db maximum repeater section attenuation under normal conditions is used in America, and is based partly on a further increase in attenuation when icing conditions are experienced. This limit was also adopted in Australia in the absence of accurate information on the line noise conditions prevailing, and corresponds to a maximum spacing of about 70 miles. However, it is now known that satisfactory channel noise can be obtained with longer sections, and a maximum attenuation of 36 to 38 db is now being considered for future systems.

In determining the distance from the attenuation limit, allowance must be made for the attenuation of entrance and intermediate cables. Spiral-four cable has an attenuation of approximately 1.2 db per mile at 150 kc/s, compared with 5.3 db per mile at the same frequency for star quad trunk cable.

The Brisbane-Townsville system was planned using the 28 db limit, taking into account the locations of stations where carrier equipment was installed or would be required in the future. The final repeater spacings chosen vary between 40 and 75 miles, and Table 1 shows the actual distances, together with the types of terminal and intermediate repeater equipment.

Equipment	Station	Spacing in miles
East terminal (S.A.)	Brisbane	
Auxiliary repeater	Nambour	65
Main repeater	Gympie	44
Auxiliary repeater	Maryborough	61
Main repeater to be installed at a later date	Bundaberg	55
Auxiliary repeater with 420B power plant	Miriam Vale	68
Auxiliary repeater	Gladstone	44
Main repeater	Rockhampton	69
Auxiliary repeater with 420B power plant	Marlborough	64
Auxiliary repeater with 420B power plant	Carmila	75
Main repeater	Mackay	62
Auxiliary repeater	Prosperine	76
Main repeater	Bowen	41
Auxiliary repeater	Ayr	70
West terminal	Townsville	43

Table 1.

Pending the provision of additional building accommodation at Bundaberg, the J2 repeater has not been installed at this centre, hence the present section between Maryborough and Miriam Vale is 123 miles long.

General Types of Repeater Station

A "main" repeater is one which is installed at an established carrier station where the normal single and three channel terminals or repeaters operate from the 24 V. filament and 132 V. anode batteries. Under these circumstances, types 328A and 329A tubes, which have indirectly heated cathodes, are employed. These tubes take a considerable time to respond to any changes in applied potential due to the very heavy construction of their heaters. Ballast lamps, types 120A and 121A, are used to provide additional stabilisation for the tube heater currents and thus minimise the effect of battery voltage fluctuations.

The repeater spacing for three channel systems is usually 100 to 200 miles, but as shown previously, the J2 repeaters must be spaced at shorter intervals. Additional intermediate stations, which amplify the J2 system but allow other systems on the route to pass through the station without amplification, are therefore necessary, and are known as "auxiliary" repeaters.

Fig. 1.—Repeater Building.

Under these conditions, energy can be transferred from the output of one auxiliary J2 repeater to the input of the same repeater or to the input of a repeater on another J2 system, if provided, via crosstalk paths involving the wires which are not used for the J system bearers. The cause of this transfer of energy is due to the large difference in transmission level (equal to the attenuation of the repeater section) between the output of one type J2 repeater and the input of the same or another similar repeater. In order to minimise these effects it is necessary that all wires on the route be given special treatment, including a gap in the trunk line, longitudinal retards in all pairs at terminal poles, and when more than one J2 repeater is installed, crosstalk suppression filters in the non J bearers in the repeater station itself.

Auxiliary stations are designed to work for considerable periods without attention and when normal A.C. power supply is available, the equipment is operated from a 152 V. 108 ampere-hour battery under the control of a regulated float rectifier. In the event of a mains failure, the battery supplies the load and when the A.C. supply is restored, the rectifier automatically charges at a constant current of approximately 8 amperes until the battery potential reaches 156 V, after which the rectifier resumes its normal float charge to maintain a constant potential of 152 V. J2 repeaters installed at these stations are fitted with types 310A and 311A tubes whose electrical characteristics are identical with those of the 328A and 329A tubes respectively, but the heater construction and power consumption differ, with the result that the tubes respond more readily to changes in applied voltage. Ballast lamps are not used with the 310A and 311A tubes because of the stabilised battery potential, and in such cases, 116A tapped resistances are used to replace the ballast lamps and enable adjustment of the heater currents.

Where an auxiliary repeater station is at a location not yet included in a regional or local power distribution scheme, dual prime movers and D.C. generators are installed for charging a 152 V. 436 ampere-hour battery, which not only provides power for the J2 equipment, but is also used for lighting, heating, ventilation, D.C.-A.C. converters and other miscellaneous purposes. In this case the tubes and secondary battery incorporate some of the principal features of both main and normal auxiliary stations. Types 328A and 329A tubes, controlled by types 120A and 121A ballast lamps, are used because the battery potential is not kept constant. Automatic control equipment is provided for all such auxiliary repeater stations so that they may be operated as unattended stations if necessary. When the battery voltage falls to a pre-determined value, a petrol engine generator is automatically brought into operation to provide the battery with a regulated charge so that the voltage rises to the required limit after which the charging plant is automatically closed down. Automatic facilities are provided so that each petrol engine generator is operated on a rotational basis with lock-out and change-over facilities should the engine on rotation fail to start, or

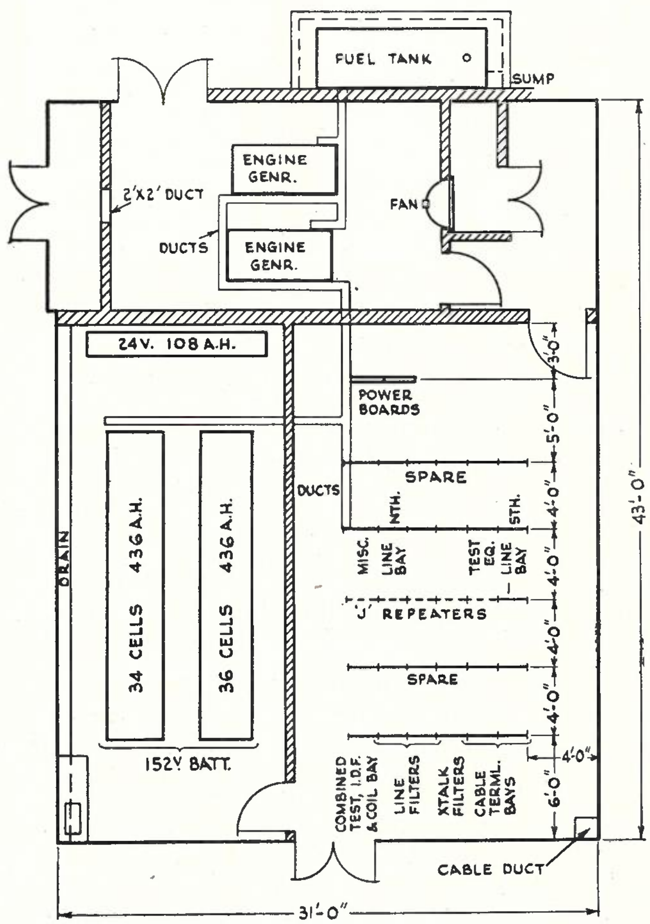


Fig. 2.—Equipment Layout.

alternatively, fail during the course of a charge. Alarms can be extended to the main control station to indicate when charging is commenced and completed. Should either charging set fail to operate, an alarm is automatically extended to the control station.

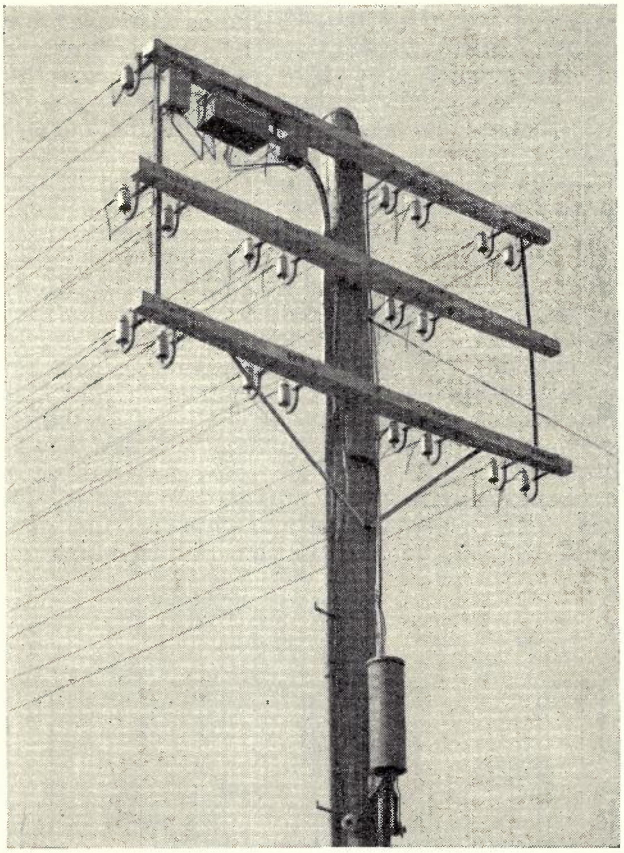


Fig. 3.—South Terminal Pole.

This engine generating equipment, known as the 420B power plant, is installed at Miriam Vale, Marlborough and Carmila. These towns are situated in areas which are subject to cyclones and heavy rainfall. The roads are often impassable during the wet season and train services are not only infrequent, but are also subject to long delays due to flooding. For these reasons, it is problematical whether the repeater stations can be left unattended for extended periods and, pending further experience, a technical officer is employed at each station for maintenance purposes.

Miriam Vale Repeater Station

General: Miriam Vale is a small town with 500 inhabitants, and is situated on the main coastal line about 300 miles north of Brisbane. The repeater building, shown in Fig. 1, is a modern brick and concrete structure with a floor area of just over 1300 square feet. The layout of long line equipment, batteries, engine generators, etc., is shown in Fig. 2.

The gap in the trunk line has been arranged by the provision of south and north terminal poles (see Figs. 3 and 4), which are extended to the repeater building through spiral-four cable and 28 pair 40 lb. star quad entrance cable as indicated in Fig. 5. These cables are brought from the manhole into the building through an external duct and thence into an internal duct which takes the cables into the ceiling. Direct entry into the respective cable terminating bays is made from the ceiling as indicated in Fig. 6.

Type J2 Carrier Telephone Repeater: An overall schematic of the type J2 repeater is shown in Fig. 8, which is applicable to either a main or auxiliary station. As indicated, the incoming high frequency lines from either direction are connected to directional filters which separate the frequency groups for the two directions of transmission. Individual line and regulating amplifiers supply the gains for the two directions, and individual pilot channel equipment controls the regulation in accordance with changing line losses. Amplification of the 12-channel bands to levels of + 17 db is the function of the line amplifiers, both of which are of the negative feedback type, but differ in that the W.–E. (American designation corresponding to B–A in Australia) amplifier has a flat gain characteristic whilst the E.–W. amplifier supplies a fixed portion of the equalisation for this direction. The auxiliary filter and the high cut off filter shown in Fig. 8 serve to augment the loop

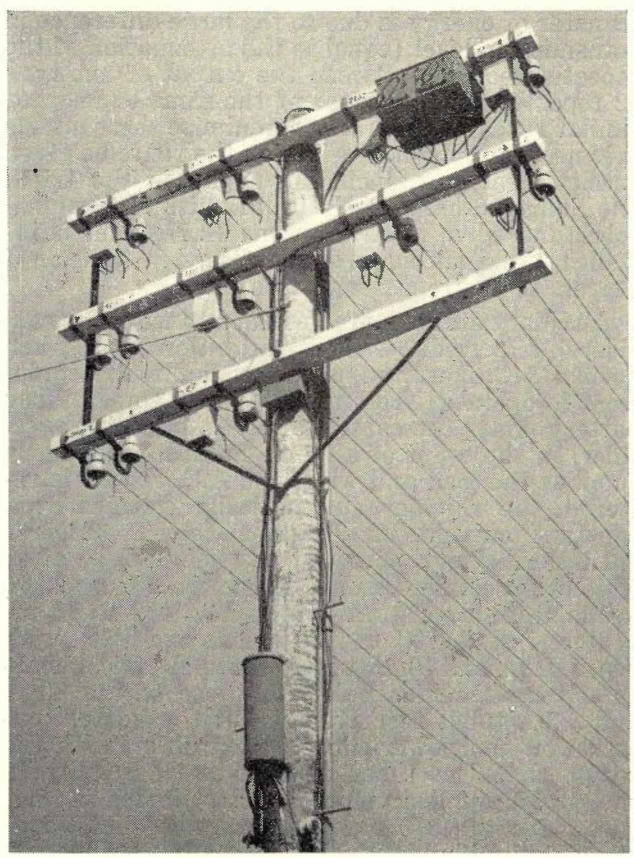


Fig. 4.—North Terminal Pole.

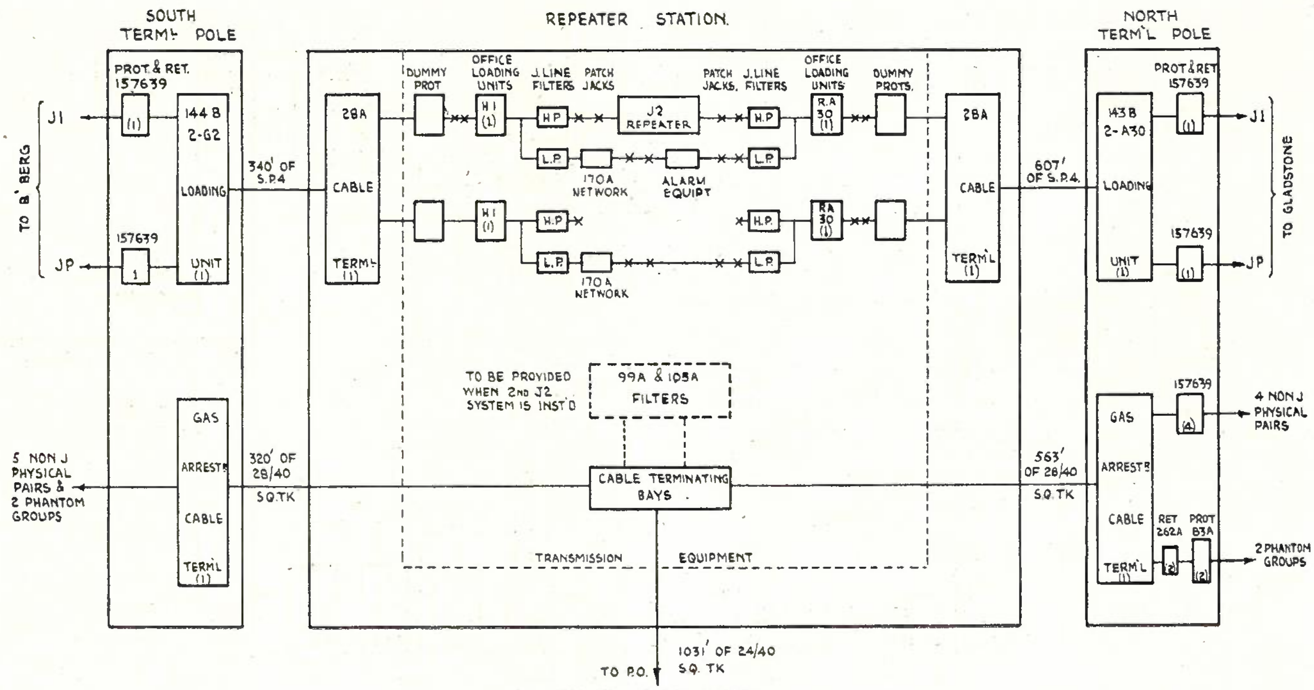


Fig. 5.—Cable Details.

losses around the repeater at frequencies at which the attenuation afforded by the directional filters alone is not sufficient. The E.–W. auxiliary filter also safeguards against overload and modulation difficulties which otherwise might occur during periods when high gains are required. At main stations, the W.–E. auxiliary filter contains a section which introduces loss at 3-channel system

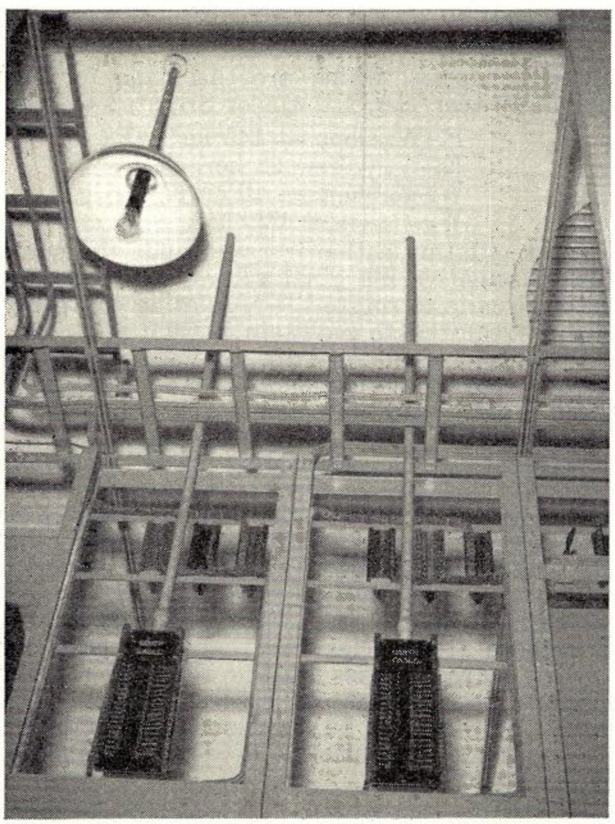


Fig. 6.—South and North Trunk Entrance Cables.

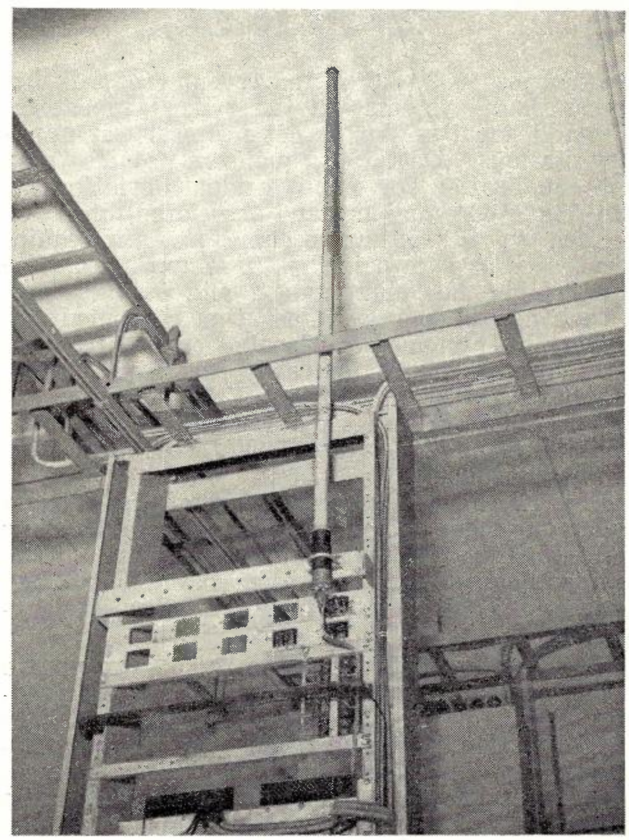


Fig. 7.—Spiral Four—South Entrance Cable.

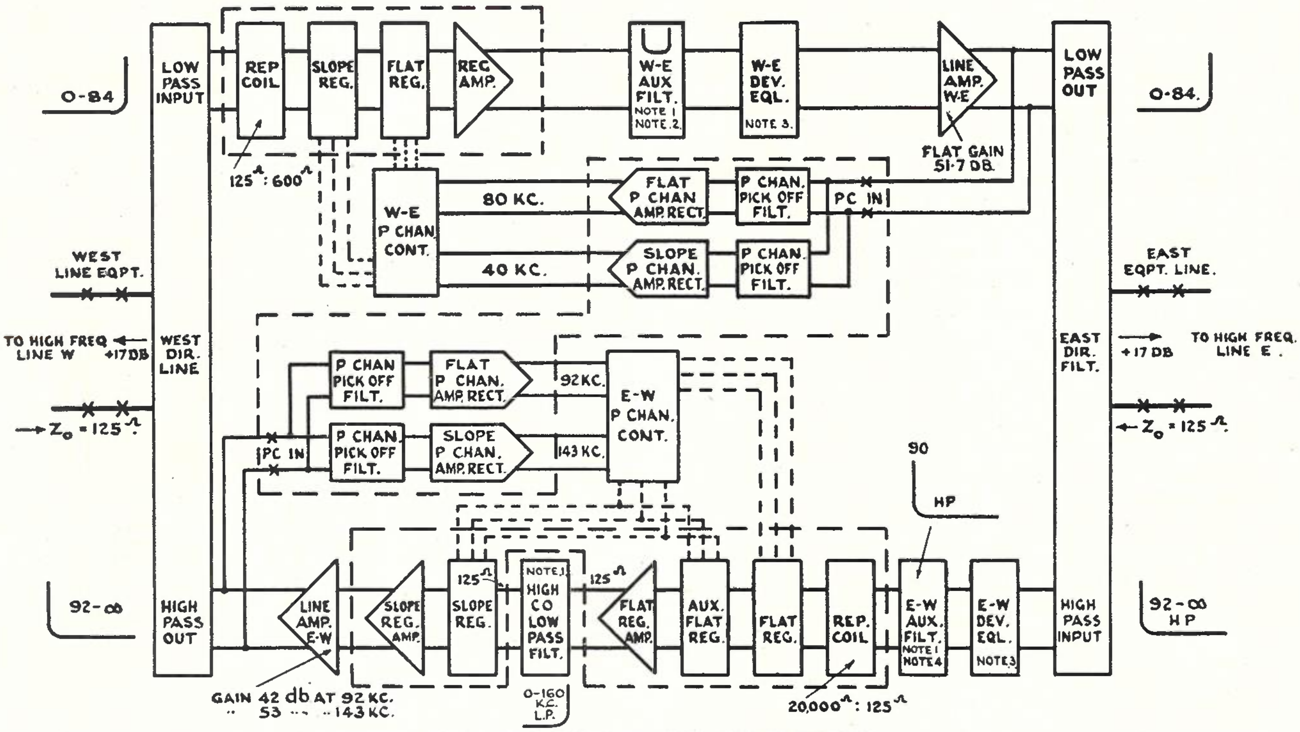


Fig. 8.—Block Schematic of the Type J2 Repeater.

Note 1.—Auxiliary Filters and High Cut-off Low Pass Filters augment the loop losses around the Repeater at frequencies at which the attenuation afforded by the Directional Filters alone is not sufficient.
Note 2.—At Main Stations the W-E Auxiliary Filter contains a section which introduces losses at Type C frequencies to prevent crosstalk between type C systems via type J Repeaters.
Note 3.—Deviation Equalisers in the two branches of the Repeater correct for the distortion introduced by the auxiliary filters and provide "mop-up" equalisation for the Directional Filters and Amplifiers.
Note 4.—The E-W Auxiliary Filter performs functions shown in Note 1 and also safeguards against overload and modulation difficulties which might occur during periods when high gains are required.

frequencies (6–30 kc/s) to prevent crosstalk between these systems via the type J repeaters; this additional section is not necessary at auxiliary stations. Deviation equalisers provide "mop up" equalisation for small residual deviations in the regulated amplifiers and associated filters.

Each type J2 repeater occupies an entire equipment rack as shown in Fig. 9. Mountings are of the "single side maintenance and wiring" type. All wiring, tubes, relays and other equipment requiring maintenance are located on the front of the mounting plates for ready access. Fig. 10 is a photograph of the Miriam Vale repeater bay, but sections of the rack above the W.–E. directional filter and below the E.–W. directional filter are not included.

Fig. 11 shows a general view of the Miriam Vale equipment room, and Figs. 12 and 13 show close-up front and rear views respectively, of the J miscellaneous bay and the north J line bay (with the 17B oscillator mounted below its jackfield).

Equalisation and Regulation: To compensate for frequency distortion produced by the preceding section of line, equalisation is necessary in each direction of transmission at a repeater. Regulation is controlled by two pilot frequencies in each direction of transmission and automatic adjustment of equalisation and gain is provided for a wide range of line attenuation changes. The pilot frequencies, which are the same for each type of system, NA, NB, SA or SB, are:—

E.–W. slope — 143 kc/s.
E.–W. flat — 92 kc/s.
W.–E. slope — 40 kc/s.
W.–E. flat — 80 kc/s.

The regulating action is based upon the operation of sensitive marginal relays, which actuate motor circuits to rotate the regulating controls as may be required to maintain normal pilot levels at the output of the repeater. One of the two pilot channel control mechanisms operates a regulator which varies the flat gain of the regulating amplifier while the other governs the slope of its gain-frequency characteristic, providing a continuously variable equalisation adjustment. The two pilots are located at the opposite ends of the transmitted frequency band so that when gain and slope adjustments have resulted in normal output level at the two pilot frequencies, correctly proportioned losses or gains are provided for intermediate frequencies in the band. Gain frequency characteristics of the regulating amplifiers are proportioned over successive parts of the regulating ranges to be complementary to the line attenuation characteristics of dry, wet and ice-coated lines.

Main Secondary Batteries: The main secondary battery and its associated distribution circuit in-

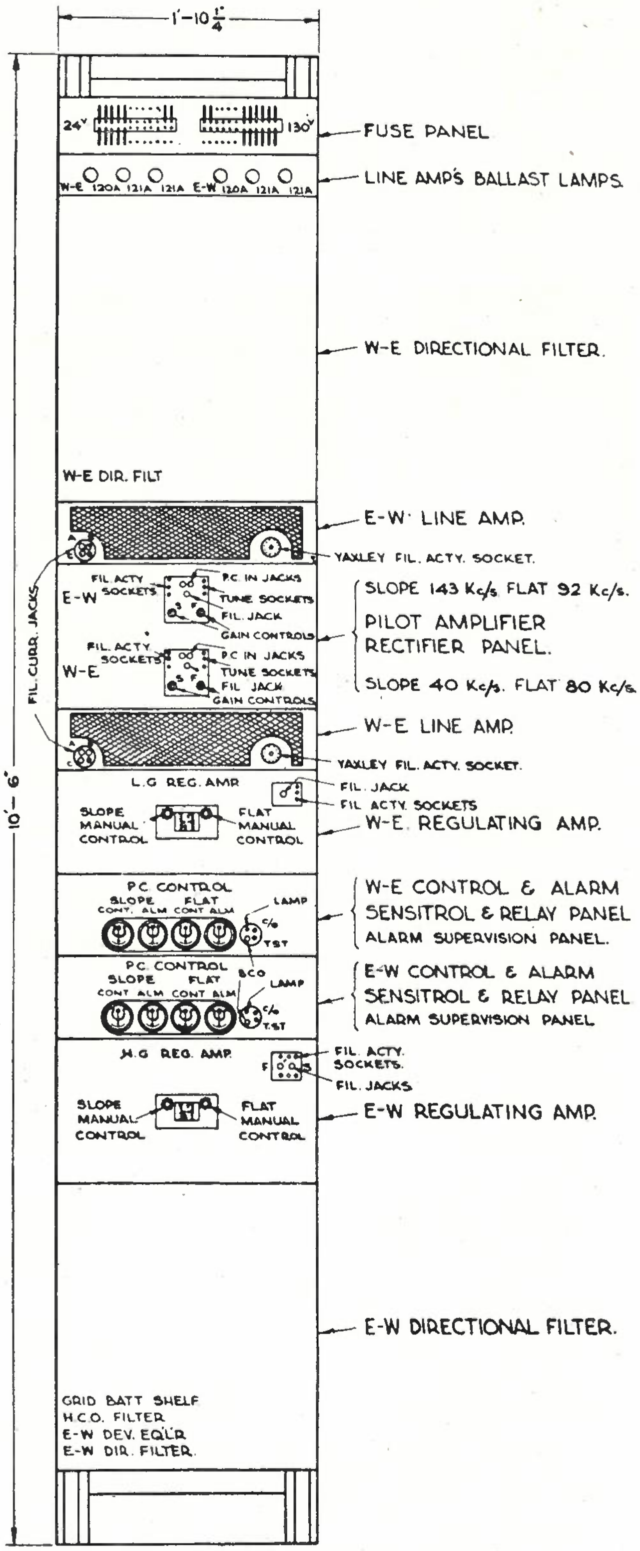


Fig. 9.—J2 Repeater—Layout of Rack Equipment.

stalled at Miriam Vale is of similar design to the type employed at auxiliary stations with commercial power supply, but the battery capacity is necessarily much greater because it has to supply power for the operation of the J repeaters plus

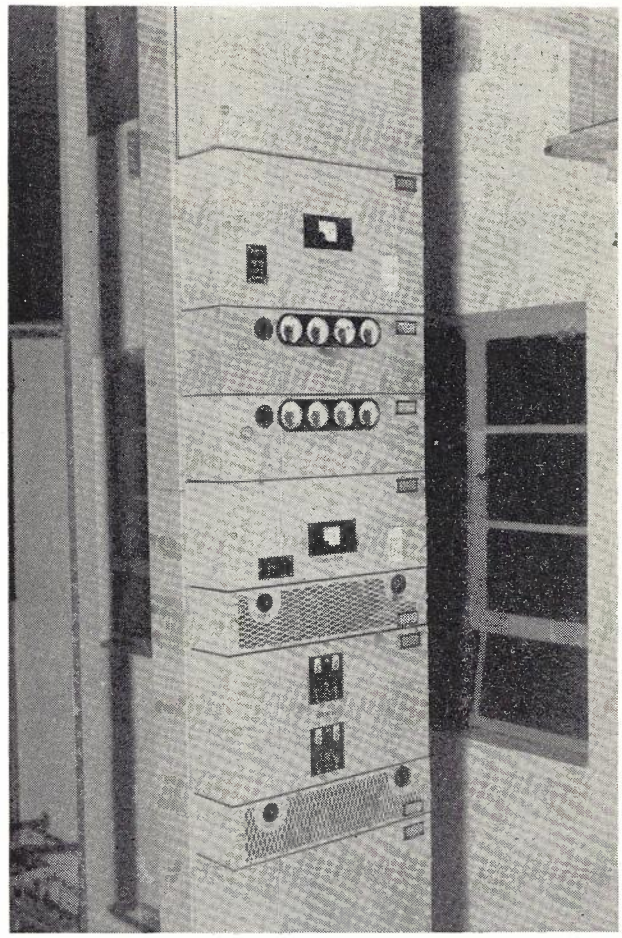


Fig. 10.—Photo of J2 Repeater.

any miscellaneous services. It consists of 70 Tudor type J12 cells connected in series. The negative end is earthed and the battery is tapped at every tenth cell to provide seven sections each having a nominal value of 21.7 volts. The full potential of 151.9 V. is used for the anode supply and the battery has a capacity of 436 ampere hours as against

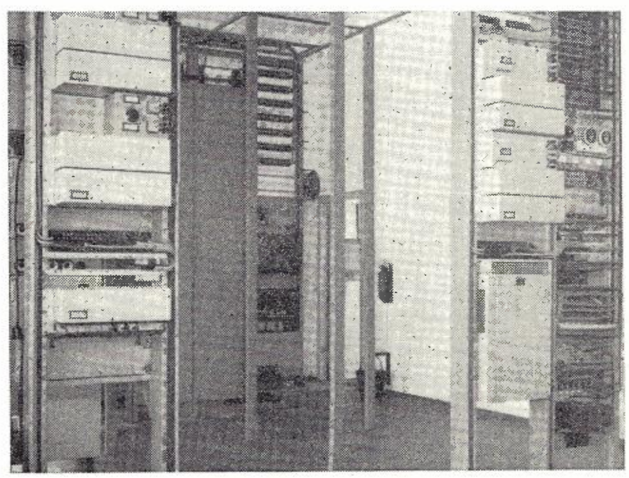


Fig. 11.—Equipment Room.

108 ampere-hours for auxiliary stations with commercial A.C. supply.

Although this description refers specially to repeater stations of the type used at Miriam Vale, Marlborough and Carmila, it is also applicable, with slight modifications, to any auxiliary repeater with normal A.C. supply. These modifications include the use of 310A and 311A tubes, different values of dummy load resistance and different battery capacity.

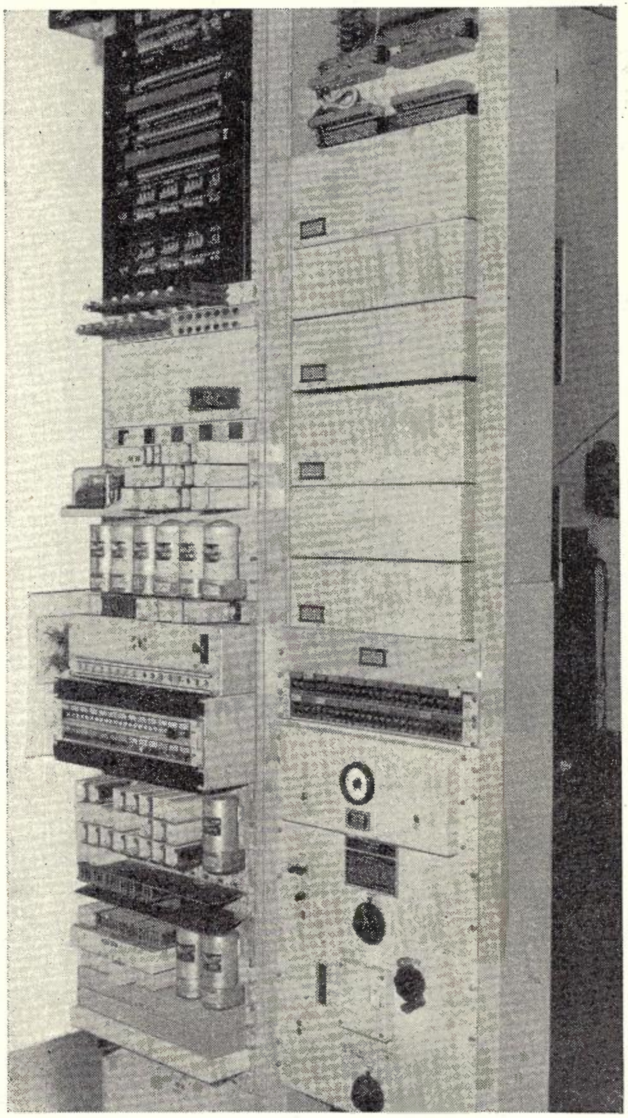


Fig. 12.—Front view Miscellaneous and North "J" Line Bays.

Heater drains of the J2 repeater are distributed over the seven tapped sections of the battery so that each supplies one 121 A ballast lamp and two 329A tubes in series, or two 120A ballast lamps and four 328A tubes in series parallel per repeater. This arrangement provides for an equalised battery drain with the exception of a 120A ballast lamp and a single pair of 328A tubes in series in the E.-W. pilot channel amplifier rectifier. For the first repeater installed in any station, this drain is derived from the 130.2-151.9V. section of the battery, and equivalent dummy loads of 61.8 ohms each are connected across the other six sections. This particular value of resistance is intended for use with the normal auxiliary repeater station which uses types 310A and 311A tubes. Resistors of this type were supplied by the Western Electric Co. for use at Miriam Vale, Marlborough and Carmila, but the correct value to compensate for the 0.425 ampere drain of the E.-W. pilot channel amplifier rectifier should have been approximately 51 ohms. When the installation of these stations was in progress it was decided to use the 61.8 ohms resistors supplied by the company, the final adjustment being made on the variable rheostats to obtain the correct overall values.

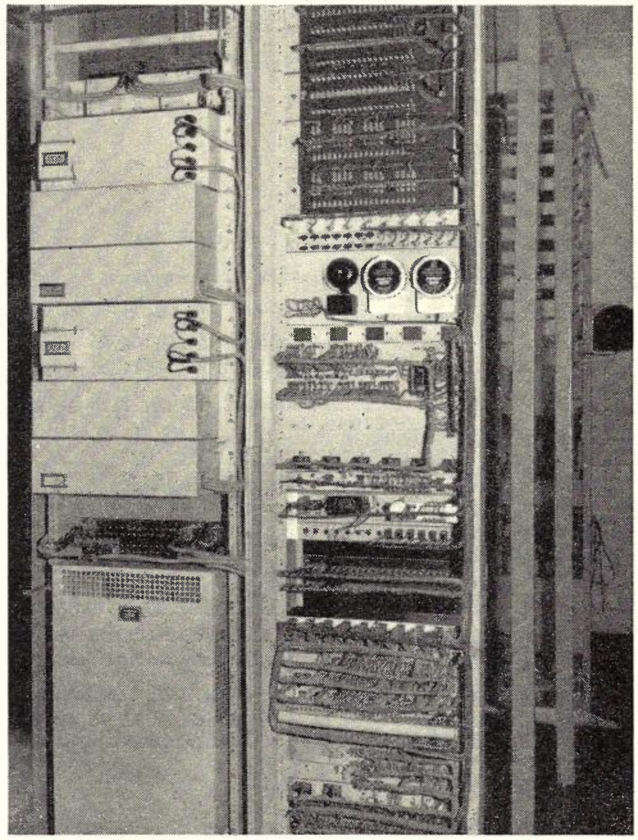


Fig. 13.—Rear View, Miscellaneous and North "J" Line Bays.

As additional repeaters are installed, successively lower battery sections are employed for their E.-W. pilot channel amplifier rectifiers and the corresponding dummy loads are removed. To compensate for small differences in the drains from the various battery sections, an adjustable load rheostat which can be varied between 100 ohms and 2800 ohms is provided across each section. Six of these rheostats can be seen in the top portion of Fig. 14.

The 152V. battery is used to supply both plate and heater currents together with all alarm trunk

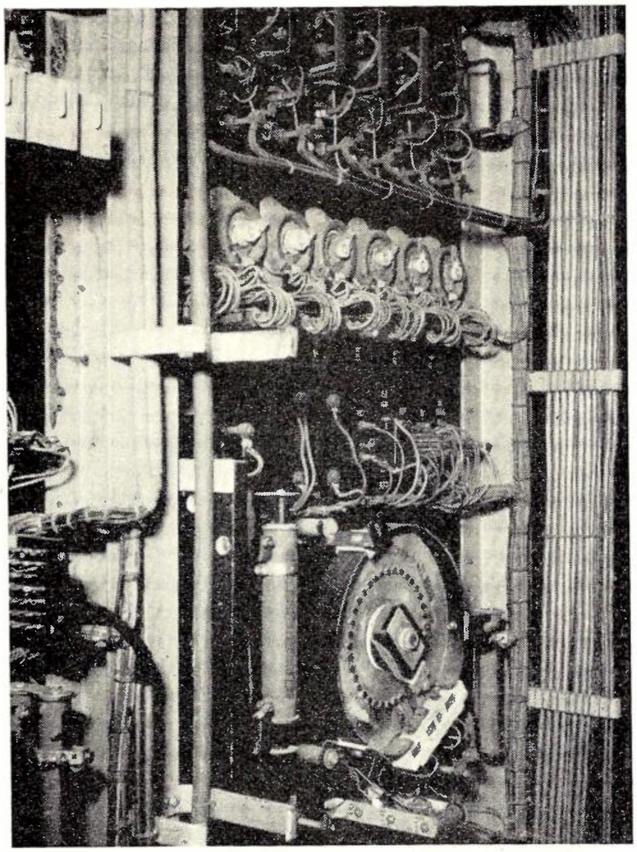


Fig. 14.—Adjustable Load Rheostats.

supplies. The repeater drain, which is distributed uniformly over its seven sections, amounts to 0.85 ampere per repeater, plus a fixed drain of 0.425 ampere for any or all of the seven repeaters. A simplified schematic circuit of the 152V. battery and the circuits connected to its various sections is shown in Fig. 15. When the second repeater is installed, the fuse is removed from the 61.8 ohms dummy load resistance connected across the 108.5-130.2 V. section. As succeeding repeaters are installed, similar action is taken with the dummy load resistors across successive lower sections of the tapped battery, the final adjustment being made by means of the variable rheostats.

Out of service resistors can also be connected across any section of the tapped battery by throwing suitable switches. These are provided so that the drain across the various sections can be equalised should any repeater be removed from the load. For simplicity, these out of service resistors are not shown in Fig. 15.

The anode drain per repeater is 0.352 ampere. The alarm trunk circuit is also extended from the 152 V. battery and requires a maximum instantaneous drain of 1.0 ampere and a continuous drain of 0.12 ampere. The total drain from the 152 V. battery is approximately 1.747 amperes for the first repeater, and for each succeeding repeater up to a total of seven, the additional drain is 1.2 amperes.

The installation of the 152 V. battery presented some unusual problems due to the considerable number of leads that were required between the

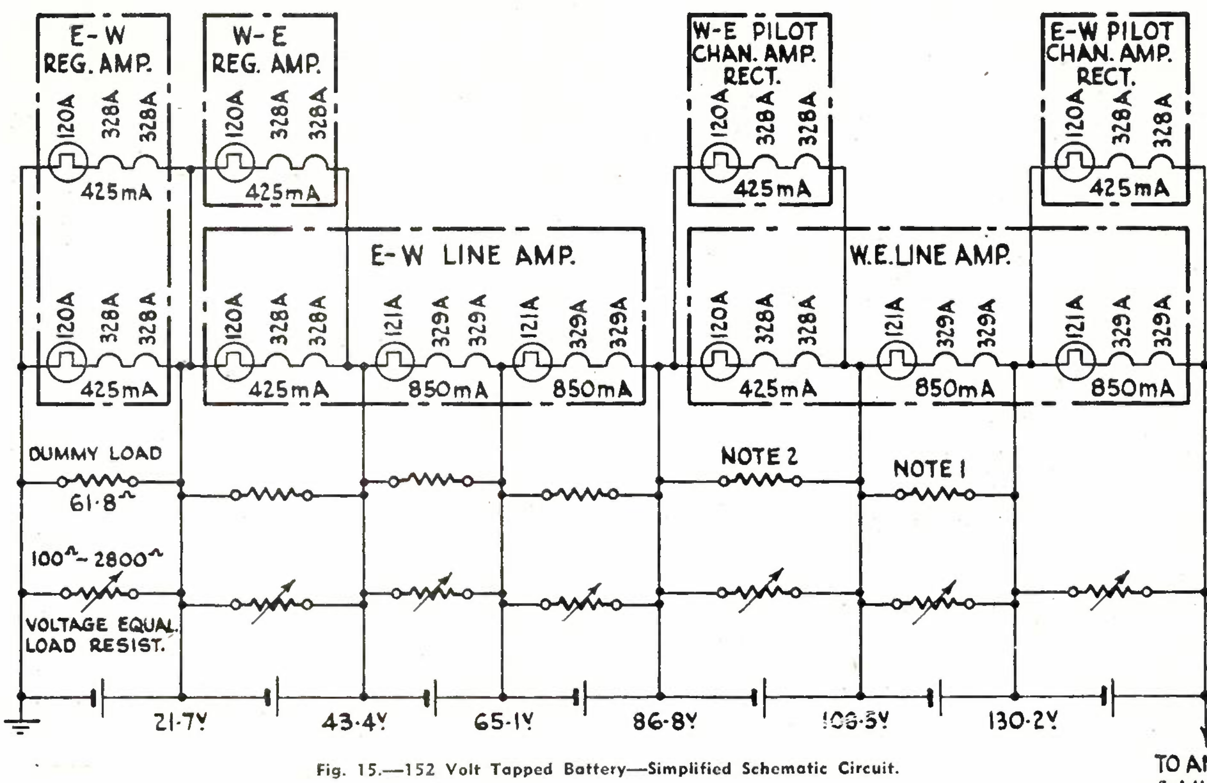


Fig. 15.—152 Volt Tapped Battery—Simplified Schematic Circuit.

Note 1.—Remove when 2nd Repeater is installed.
Note 2.—Remove when 3rd Repeater is installed.

battery and the power board. Each of the two main charging leads consists of 19/.052 conductors and, in addition, there are two 3/.029 leads

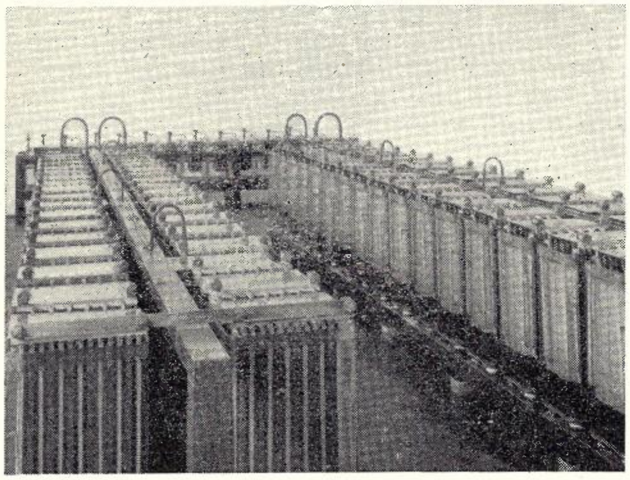


Fig. 16.—Battery Room.

for operation of the contact voltmeter and eight 7/.044 discharge leads for the seven tapped sections of the battery. Lead covered V.I.R. cable is used in all cases.

The cells are installed on comparatively low stillages, the tops of which are about 6 inches above floor level. The battery was divided into two sections of 36 and 34 cells respectively, each section comprising two parallel rows of cells with a space of approximately 3 feet between sections. A wooden framework was erected along the centre of each section, the 3 x 2 inch horizontal bearer being level with the tops of the glass jars. This is clearly indicated in the left-hand section of Fig. 16, which is a general view of the Miriam Vale battery room.

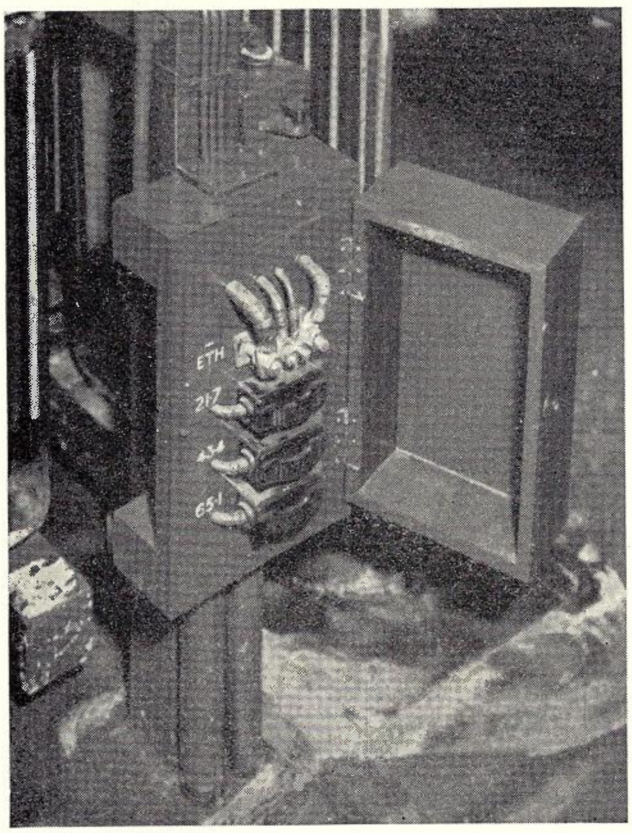


Fig. 17.—Battery Fuse Box (Lid open).

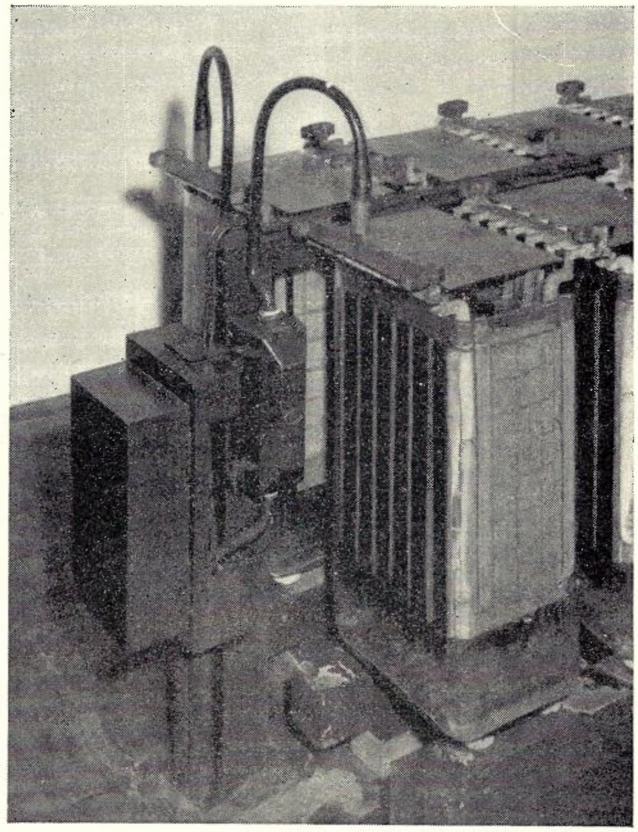


Fig. 18.—Battery Fuse Box, showing 100 amp. Intersection Fuse.

Four vertical supports, each 3 x 3 inches, were grouted into the concrete floor to a depth of 3 inches and sealed to the bitumastic floor covering with sealing compound. This framework is used to carry the cables from the tapped sections (see the loops and cables in Fig. 16), and it also provides a rigid support for the battery fuse box. One of these boxes, at the low potential end of the battery, includes three 30 ampere discharge fuses and a busbar with four brass studs for common earths. Fig. 17 shows this fuse box with the lid open, and Fig. 18 is a view of the same box with its covering lid in position. The 100 ampere iron-clad fuse between the first and second sections of the battery is clearly indicated in the latter photograph.

The main charge, discharge and voltmeter leads connected to the earthed end of the battery are not fused. The second fuse box, at the high potential end of the battery, has five 30 ampere fuses mounted internally and the 100 ampere charging fuse mounted externally. Fig. 19 shows the schematic circuit of these battery leads. The lead

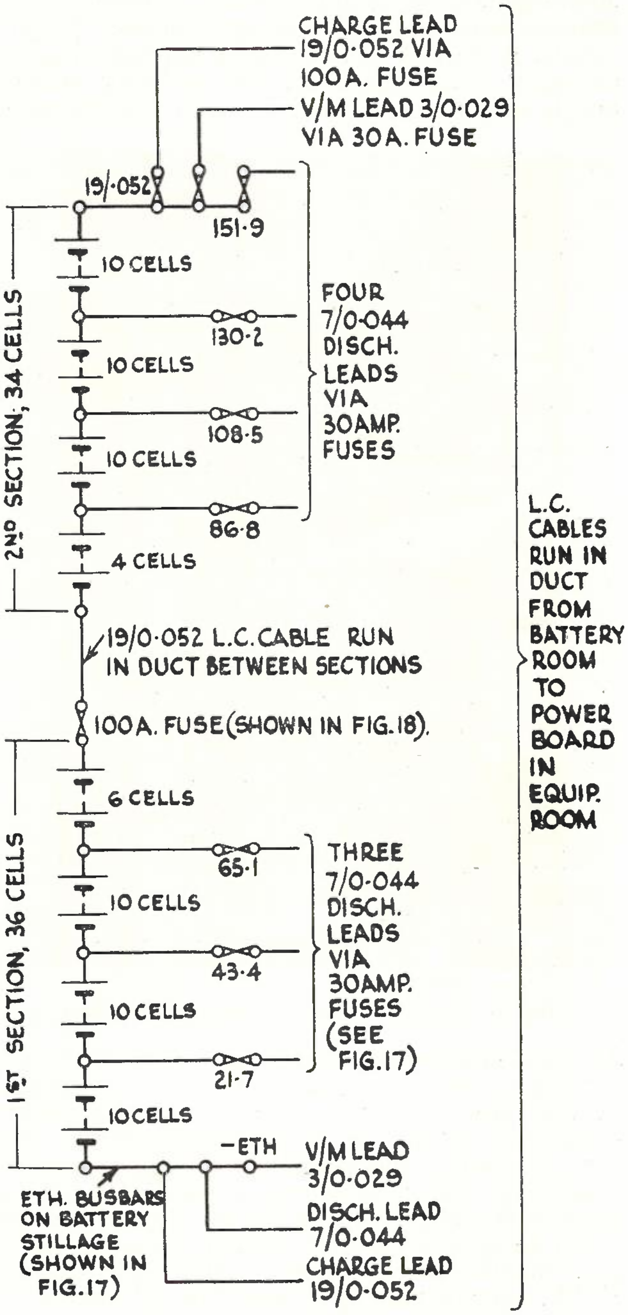


Fig. 19.—Battery Leads—Schematic Circuit.

covered cables between the power board and battery and also between the two sections of the 152 V. battery, were laid in a floor duct which was filled with sand and then covered with about 1 inch of cement. Protection for the leads from floor to fuse box was provided by lead-antimony sheathing.

Miscellaneous Batteries: A 24 V. supply, consisting of 12 Clyde type P7 cells of 108 ampere hour capacity, is used for the pilot channel relay control and other miscellaneous circuits, due to the fact that the current drain is intermittent and cannot be uniformly spaced over the 152 V. battery. The 24 V. battery is connected across the 152 V. battery in series with a resistance which is adjusted to deliver uniform current over the 24 hours both to supply the load and to maintain the battery. Fig. 20 shows a general view of portion of the 24 V. battery. The normal average current drain on the 24 V. signalling battery for the pilot control relays is estimated at 0.02 ampere per repeater, and for conditions that obtain during line failures, the current drain is 0.50 ampere.

The E.-W. line amplifier requires two 22.5 V. batteries and one 4.5 V. battery for the grid and varistor biases of the 329A output tubes. The W.-E. amplifier which has no varistor, requires only one 22.5 V. battery for the bias of its output tubes. A container for the dry cell batteries of both line amplifiers is mounted on the bottom of the J2 repeater bay.

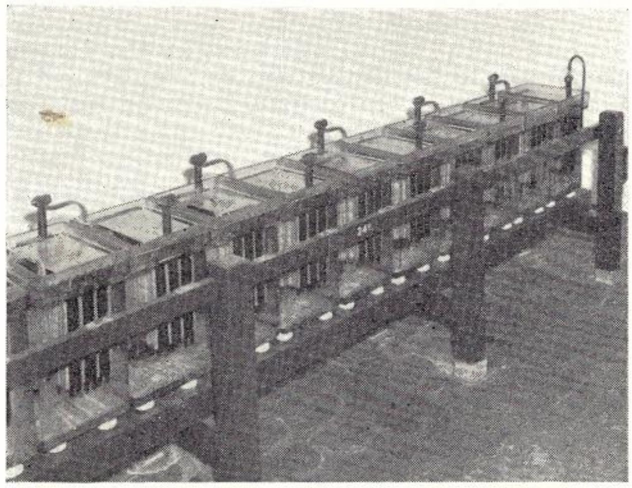


Fig. 20.—24 Volt Signalling Battery.

Miscellaneous Power Supplies: The Telechron driving motors for the variable condensers in the regulating amplifiers are supplied from a 55 V. A.C. source. A step down transformer, 115 V. to 55 V., is mounted on the miscellaneous bay and supplies each system through separate fuses on the adjacent fuse panel. This is shown in Fig. 21. Each tapping is fused with a 1-1/3 ampere fuse, and a fuse alarm circuit, which employs a copper oxide rectifier assembly to rectify the A.C. for operation of the alarm relay, is provided. A no-voltage alarm is also provided.

Two 152 V. D.C. to 115 V. A.C. converters, each rated at 0.75 KVA, supply the 115 V. A.C. for the operation of the 17B oscillator and 55 V. A.C. for the Telechron motors. Power for the motors is obtained from the charging leads of the 152 V. battery. These converters, which are shown in Fig. 22, are designed for continuous operation, and under these conditions the second set is provided for maintenance purposes.

At the three Queensland auxiliary J repeaters with 420B power plants, the circuit was modified so that a converter operates only under the control of start stop contacts and associated relays in the regulator circuit of the repeater. Automatic transfer from the regular to the emergency converter takes place in the event of failure of the A.C. output from the regular converter. A manual switch connected in parallel with the start stop circuit is used to connect the 115 V. A.C. to the 17B oscillator.

The station lighting is also provided from the 152 V. battery through suitable fuses and switch gear. The distribution throughout the building is in accordance with normal lighting practice. The lighting points in the engine room and equipment room have been adapted to use commercial 115 V. 40 W. lamps, by including in series, 60 ohm 20 W. I.R.C. resistors, which are fitted with a bayonet plug at one end and a bayonet socket at the other end. The lamp plugs into one end of the resistor, the other end of which fits into the normal lighting socket. The arrangement is shown in Fig. 6. To avoid corrosion, bulkhead type lights, also rated at 115 V. 40 W., are used in the battery room, but the dropping resistors are enclosed in junction boxes in the conduit. Dropping resistors are used in the leads of electric irons to permit the use of standard 115 V. equipment.

At J2 auxiliary stations fitted with 420B power plants, a separate A.C. source is required for the

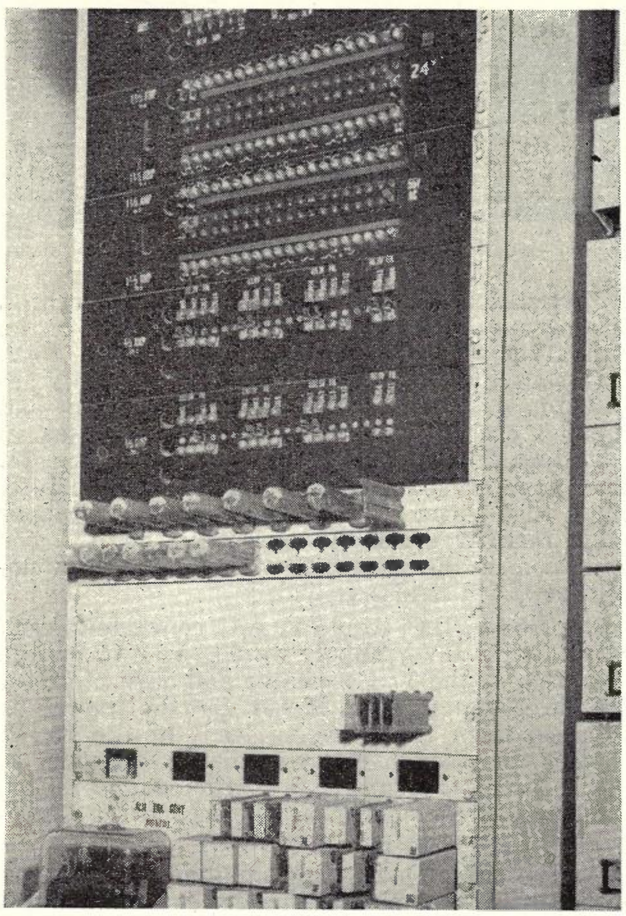


Fig. 21.—Fuse Distribution—Miscellaneous Rack.

operation of the timing devices, Counter E.M.F. control unit and engine-room louvres (if provided). A D.C.-A.C. converter is started when the charging motor-generator set is being cranked and is operated continuously until approximately

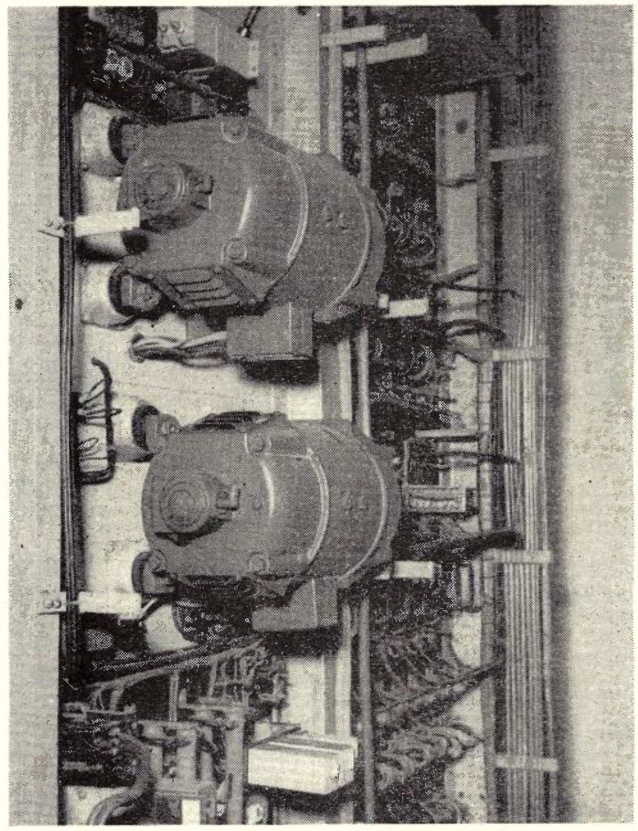


Fig. 22.—Two 152 volt D.C.-115 volt A.C. Converters.

3½ minutes after the charge ceases. D.C. for the driving motor is supplied from the "noisy" output of the motor generator set in use, via control relay contacts and an adjustable rheostat. The current drain is approximately 1.6 amperes at 160 volts. The alternator, which is rated at 0.1 KVA, supplies 60 volts-60 c/s to the six timers, and 230 volts through a suitable step-up transformer to the "mains" transformer of whichever Counter E.M.F. control unit is in use. Fig. 23 shows the converter at Miriam Vale.

The 420B power plant was designed for American conditions and provision is made for opening and closing intake and exhaust louvres in the engine-room under the control of 230 V. motors, one of which is provided for each adjustable louvre. These motors receive their A.C. from the converter through individual 60 V.-230 V. transformers, but adjustable louvres were not required at any of the auxiliary J repeater stations in Queensland, because extreme variations in temperature are not experienced.

The engine rooms at Miriam Vale, Marlborough and Carmila are ventilated by a thermostatically controlled cooling fan which forces air through fixed intake and exhaust louvres, one set of which can be seen just above the double doors at the right-hand side of the entrance lobby in Fig. 24.

420B Power Plant: This power plant is used to provide a charging source for the 152 V. station battery. Two petrol-driven motor generator sets are used alternately, to keep the battery voltage between certain limits on a charge-discharge cycle basis. The processes of starting a generating set, stopping it at the end of a charge period, starting the second set for the next period, are entirely automatic, and in normal operation the sets will work alternately as long as fuel remains in the 440 gallon tank provided. When the petrol level in the tank is low, an alarm is extended to the distant control station or to the local maintenance technician. A simplified block diagram of the plant is given in Fig. 25.

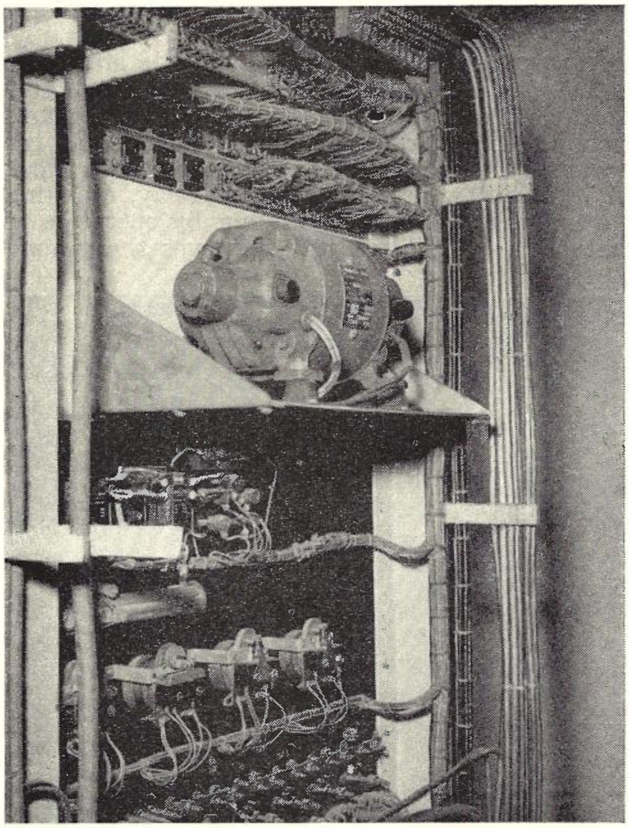


Fig. 23.—152 volt D.C.-60 volt A.C. Converters.

VR1 and VR2 are contact making voltmeters shunted permanently across the 152V. battery. VR1 is adjusted so that the moving arm touches the "low" contact at 141 V. and the "high" contact at 157 V. The corresponding operating voltages for VR2 are 139 V. and 162 V. Supposing that no previous automatic control has taken place, when the battery has discharged until its voltage has reached 141 V., VR1 causes the operation of relays in the control circuit (marked "CON"), which, in turn, energises the "start" relay (ST) in block "A" of the first motor generator set. Closing of the ST contacts connects battery to the series field of generator, Gen. 1. The

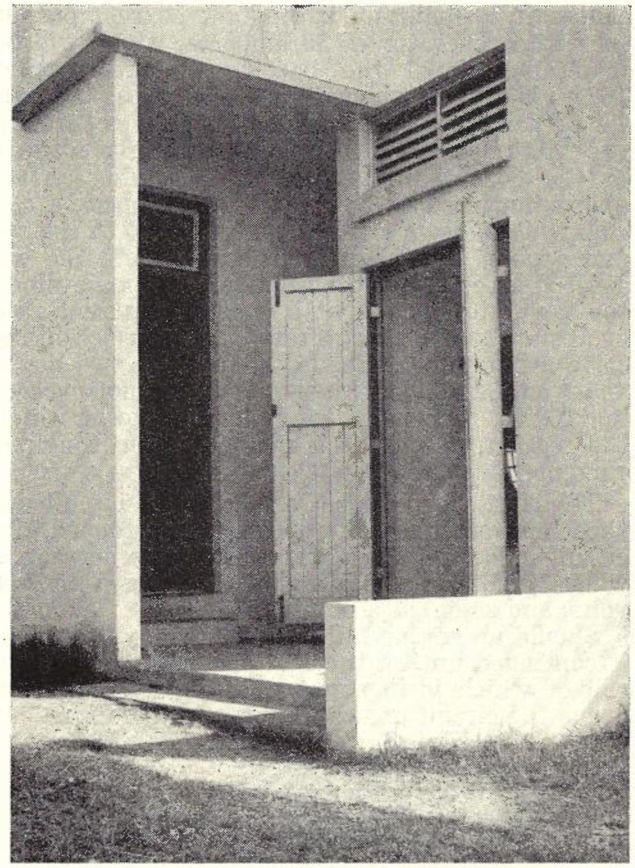


Fig. 24.—Entrance Lobby, showing Fixed Louvres.

engine is cranked by the generator acting as a series-wound motor. As soon as the generator voltage builds up to approximately 3 volts above the battery voltage, a relay in block "A" operates and causes the release of the ST relay, thus disconnecting the series field from the battery. The relay which released ST also causes the operation of a second relay in block "A" which permits the regulator to function. The regulator is adjusted to maintain a constant voltage of 160 V. across the battery. Three minutes after the machine starts, the control relays connect the generator to the battery. The regulating voltage

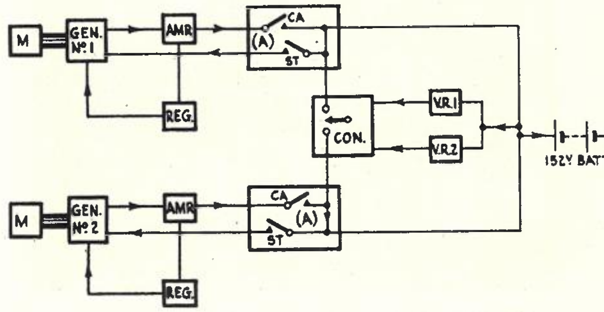


Fig. 25.—420B Power Plant—Block Schematic.

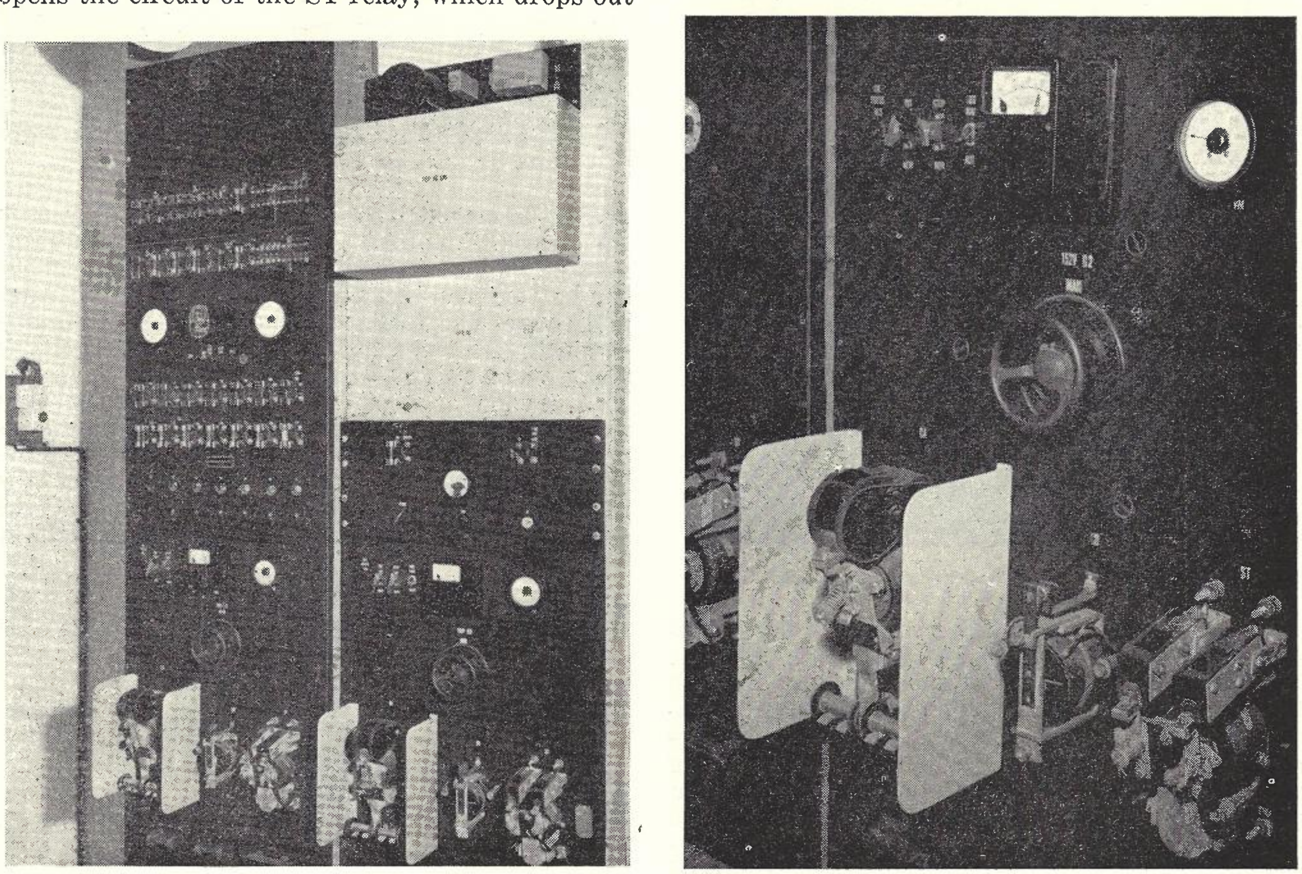
at the commencement of charge will cause the initial charging current to exceed 32 amperes, and a contact-making ammeter completes the circuit which alters the function of the regulator and causes it to maintain a constant current output from the generator of 30 amperes, which will be maintained until the battery voltage reaches 162 V. However, when the voltage across the battery reaches 157 V., a circuit is completed through the "high" contact of VR1 which permits a timer in the control circuit to begin driving. After approximately two hours, the timer opens a circuit which allows a relay in block "A" to release and ground the magneto, thus stopping the engine. Thus, whether the regulator has maintained the generator output at a constant current rate or at a constant voltage rate, the battery will receive a minimum extended charge for two hours at a voltage not less than 157 V. and not exceeding 162 V., the latter being the voltage at which the regulator function is changed from constant current to constant voltage.

The circuit conditions in the control circuit are such that, after motor generator 1 is stopped, the circuit is prepared to start motor generator 2 when the battery has again discharged to 141 volts, and so on, alternately.

Should an engine fail to start readily, cranking is continued until a thermal protection relay, the coil of which is in series with the ST contacts, opens the circuit of the ST relay, which drops out and cranking ceases. Meanwhile, a timer in the control circuit continues to drive. (Normally, the driving circuit of this timer would have been opened when the engine started and the generator delivered full voltage.) After approximately three minutes, the contacts of the timer complete a circuit to perform the following functions:—

(a) Start control is transferred by the control circuit to the other engine which is cranked.
(b) The magneto of the faulty engine is grounded.
(c) A relay in the control circuit is energised, giving an office "engine fail" alarm, and, if required, extends the alarm over the alarm trunk to the distant control station. This relay remains in until an attendant corrects the trouble and manually resets the circuit.
(d) Each time the battery calls for a charge, the engine which has not failed will be started.
(e) With both engines in good order, ground is removed from both magnetos to meet the requirement of (a) above.

Arrangements can also be made to start the engine manually, either at the station, or remotely from the distant control station over the alarm system. The engine is started manually at the station by operation of a key included in block "A". The key energises the ST relay, cranking the engine and at the same time, by operation of another relay in block "A", removes the ground



Figs. 26 and 26a.—Sectional views—Front of Engine Generator Control Boards.

from the magneto. The engine will run as long as the key is operated, thus providing a means of overcharging to restore the batteries to a fully charged condition. Operation of a second key in block "A" stops the engine. A "manual-auto" switch is provided in block "A," which, when operated to "manual", shuts down the generator

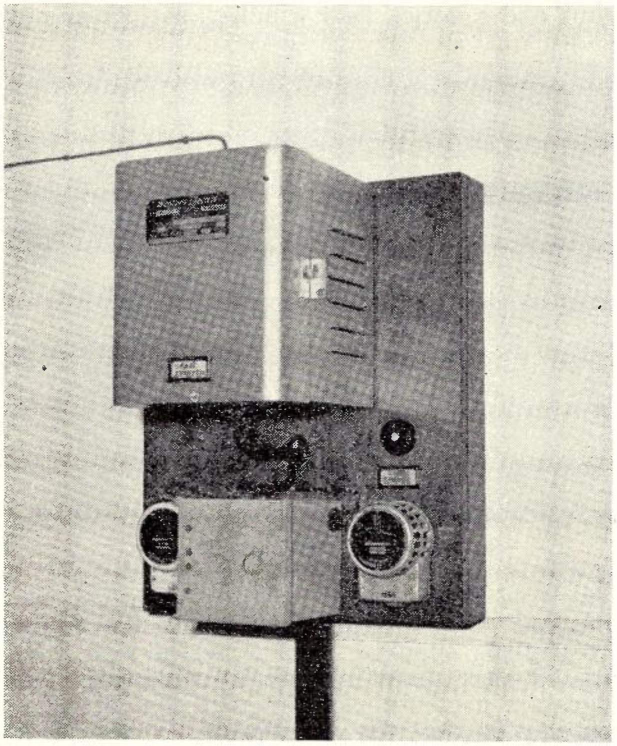


Fig. 27.—Fan Control Equipment.

regulator output, manual regulation being obtained by adjusting a rheostat in the shunt field circuit. Both motor generator sets may be run at the one time under manual control for emergency charging purposes, but only one at any one time may be operated under automatic control.

Fig. 26 is a sectional view of the two engine-generator control boards, and Fig. 26(a) shows in more detail the oil pressure release switch, engine start control keys, regulator auto-manual switch, ammeter with contact for switching to current regulation, charging voltmeter, manual rheostat control and three circuit breakers:—

CA—generator to battery contactor.
CB—reverse current breaker.
ST—series start contactor.

One of the field rheostats can be seen in the lower portion of Fig. 14.

Protective features are provided to guard against overspeed, overheat, low oil pressure and low oil level. In the event of overspeed, overheat or low oil, automatic means provided on the engine will ground the magneto and shut down the set until the attendant corrects the cause of the trouble and manually restores the cut-off button. In the case of low oil pressure, a contact made on the engine energises relays included in block "A", which in turn ground the magneto output to stop the engine. Obviously the engine must be running and the generator charging before this last protective feature becomes operative, otherwise it would be impossible to start the engine. A slow operating relay provides the necessary guard feature in this protective function.

Provision is made for a monthly 12-hour check charge under automatic control. To do this, it is necessary to manually operate an "auto-charge" key at the station. This action starts a timer in the control circuit when the battery voltage reaches 157 V. The timer allows the generator to continue the charge under automatic current or voltage regulation for 12 hours after 157 volts has been reached. When this time has elapsed, the contacts of the timer close and complete a circuit which stops the engine. It is also possible to stop this charge at any time from the distant control station if the alarm trunk facility is provided.

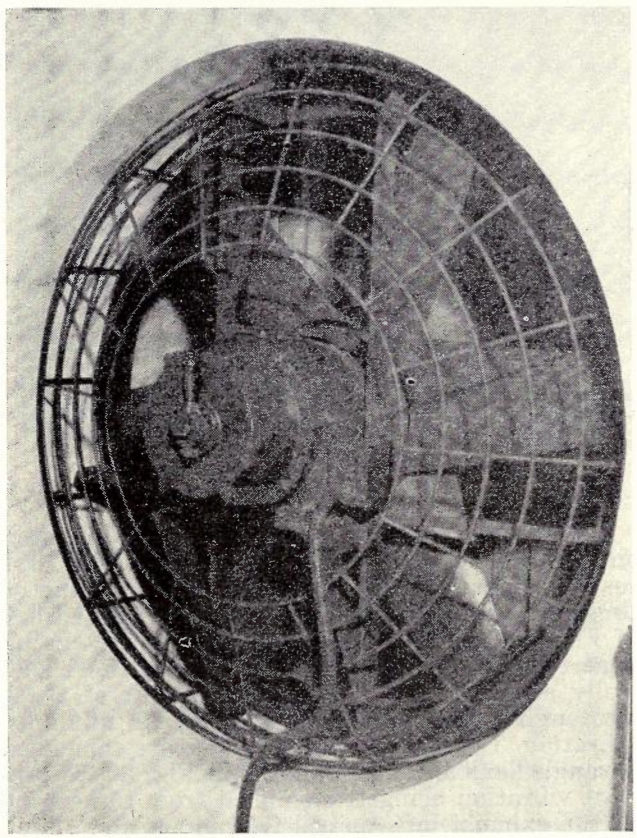


Fig. 28.—Cooling Fan.

A thermostat in the engine room, set at 90°F., operates two relays when the engine room reaches this temperature, and operation of the relays causes power to be supplied to a large exhaust fan which runs until the engine stops or until the engine-room temperature reaches 60°. A second thermostat then operates and releases the above-mentioned relays and stops the fan. The fan control relays, contactors, thermostats, etc., are shown in Fig. 27, and Fig. 28 shows the fan mounted in a 3 ft. 6 in. diameter hole in the wall of the engine-room. A 2 foot square opening is provided in a similar position in the wall at the opposite end of this room.

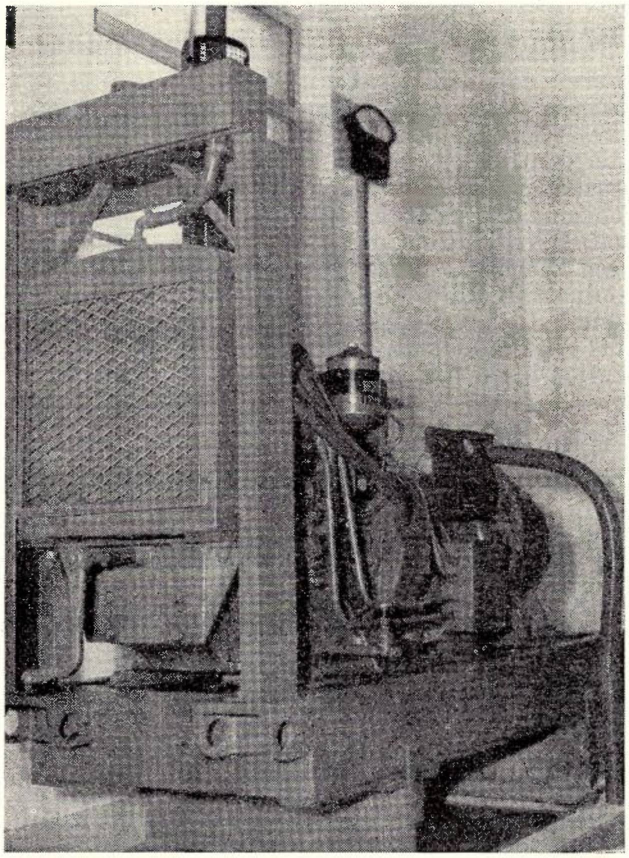


Fig. 29.—Engine Generator.

The two engine generators are rigidly mounted on "I" beams which are not fixed to the floor, but rest on rubber cushions at four points. One of these is shown at the bottom right-hand corner of Fig. 29, which is a general view of one engine generator. The engine-room foundations were specially strengthened to take the weight of these two engine generating sets and also to minimise vibration. The engine exhaust pipes are connected through flexible unions, shown in Fig. 30, to prevent vibration being transmitted from the engine to the exhaust pipe, petrol feed pipes, etc. Each engine generator weighs approximately two tons, and there are no hoists or lifting facilities at any of the stations where they have been installed. The equipment was mounted on to a motor truck at the railway yards, and the truck was backed into a hole dug outside the engine-room doors so that the carrying tray was on the same level as the engine room floor. The engines were then handled without any difficulty and manoeuvred into their final positions.

The prime mover is a 4-cylinder petrol engine of conventional design, using magneto ignition and embodying the several protective features mentioned above. Automatic choking when the engine is being cranked is obtained by means of a relay operated solenoid. Speed is kept constant by means of a governor on the throttle.

The engine is coupled to a generator of 5KVA capacity which is rated to deliver continuously over 30 amperes at 160 volts. It employs a shunt and a series field winding, the latter only

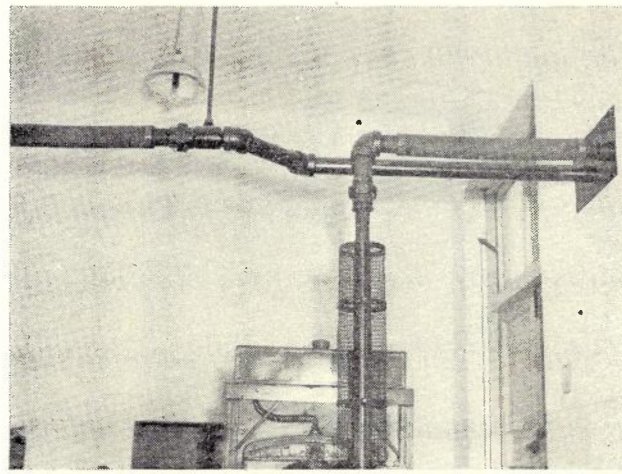


Fig. 30.—Flexible Exhaust Pipe Coupling.

being used to provide the high torque when being "motored" by the battery to crank the engine. The engines supplied from America were fitted with oil filter units for which replacement cartridges are not obtainable in Australia. Investigation showed that the units could be replaced by oil filters manufactured in Australia. Fig. 31 shows the oil filter mounted on one of the two engines at Miriam Vale.

Petrol consumption is at the rate of $\frac{3}{4}$ gallon per hour on full load. More fuel than the engine requires is fed by the petrol pump from the main 440 gallon petrol tank in the well outside the building to a small reservoir tank mounted on the engine. This latter has a capacity of approxi-

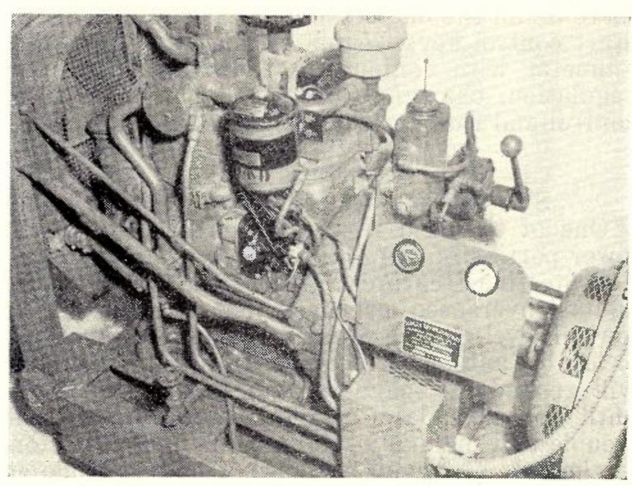


Fig. 31.—Engine, with Oil Filter.

mately 1 pint and can be seen in Fig. 32. The overflow from this reservoir drains back to the main fuel tank. Because there is no tanker service at Miriam Vale, Marlborough or Carmila, all petrol

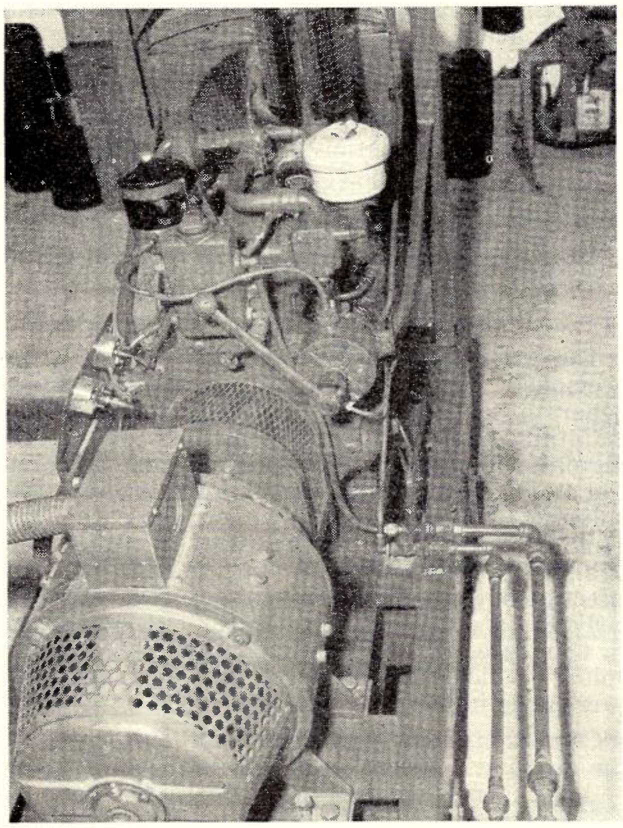


Fig. 32.—Engine Generator, showing Auxiliary Petrol Tank.

supplies must, necessarily, be carried by rail in 44 gallon drums. The main petrol tank is filled from 44 gallon drums through a double-ended hose with special fittings which provide petrol tight seals into the drum and tank filler connection. The tank is anchored in the well by a galvanised iron frame bolted to the side walls, with a wooden saddle, fitted between the frame and the tank, to prevent it from floating during the tropical wet season. This method of anchoring the tank can be seen in Fig. 33. A liquidometer in the engine room indicates the quantity of petrol stored in the main tank. It operates by means of an air column controlled by bellows attached to a float in the tank. The meter, which includes an additional scale calibrated in multiples of 44 imperial gallons, is fitted with adjustable low level alarm contacts. Pumps of the semi-rotary type are used for pumping off any water from inside the tank and also from the tank well.

During the initial charge of the 152 V. 436 ampere-hour battery, the two engine generators were connected in parallel under manual control to obtain the necessary charging rate of 54.5 amperes, as each individual generator has a maximum output of 30 amperes. This arrangement involved temporary alterations to the charging circuits.

A simplified schematic of the regulator, which is capable of producing constant current or constant voltage from the generator, is shown in Fig. 34. Regulation is effected by varying the back E.M.F. generated in the armature of a counter E.M.F. motor which is in series with the main generator shunt field. Thus the voltage across the shunt field is varied and consequently the generator output voltage.

Current regulation obtains during a normal automatic charge, and when required, during a manually controlled charge where the initial charging current is allowed to exceed 32 amperes, at which point the contact making ammeter operates to close the circuit of the AR relay which operates and locks up to ground via the control circuit. This causes a potential of –3V. with respect to ground (obtained from a dry cell) to be applied to the grid of V_1, and approximately –3V. with respect to ground applied to the cathode of V_1. This latter voltage represents the drop across CR_1 resistance and ammeter shunt due to the charging current. The difference between these two voltages is thus applied between the grid and cathode of V_1. Supposing the charging current tends to increase, this increases the drop across CR_1 thus driving the cathode of V_1 more negative and causing the plate current of V_1 to increase. The voltage drop across the plate resistance of V_1

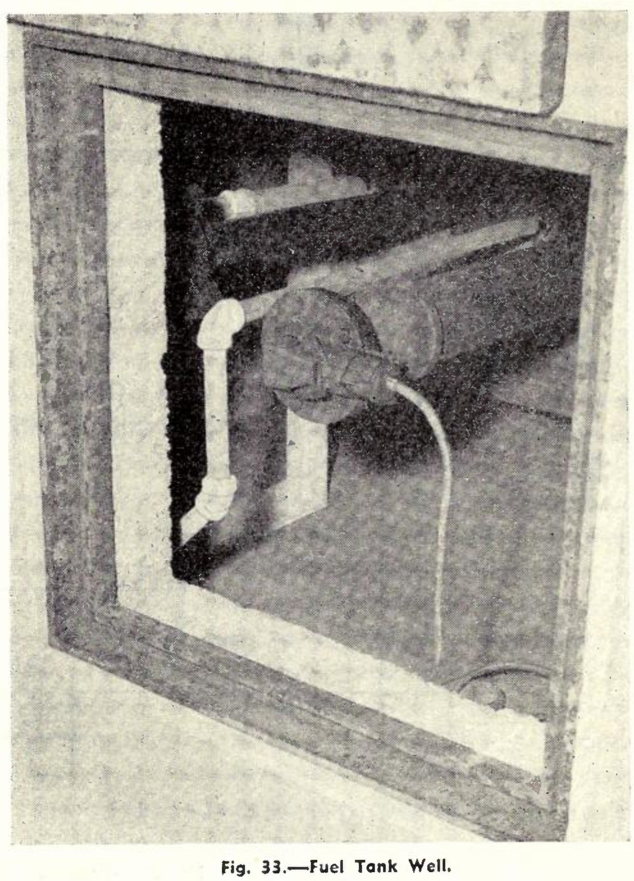


Fig. 33.—Fuel Tank Well.

increases and causes the grid of V_2 to swing more negative, causing the latter to draw less plate current. The cathode of V_2 is in series with the auxiliary winding F_1F_2 of the counter E.M.F. motor and thus the flux due to this winding decreases. F_1F_2 is connected so that its effect opposes that of the main field winding F3–F6 of the counter E.M.F. motor. Hence a decrease in the exciting current of F_1F_2 means a nett increase of flux through the armature of the counter E.M.F. motor and consequently, an increase of the back E.M.F. across this armature. An increase of the drop across this armature reduces the voltage across the main generator shunt winding, thus reducing the output voltage and bringing the charging current to its normal regulated value. A drop in the output voltage of the generator will, of course, have the opposite effect.

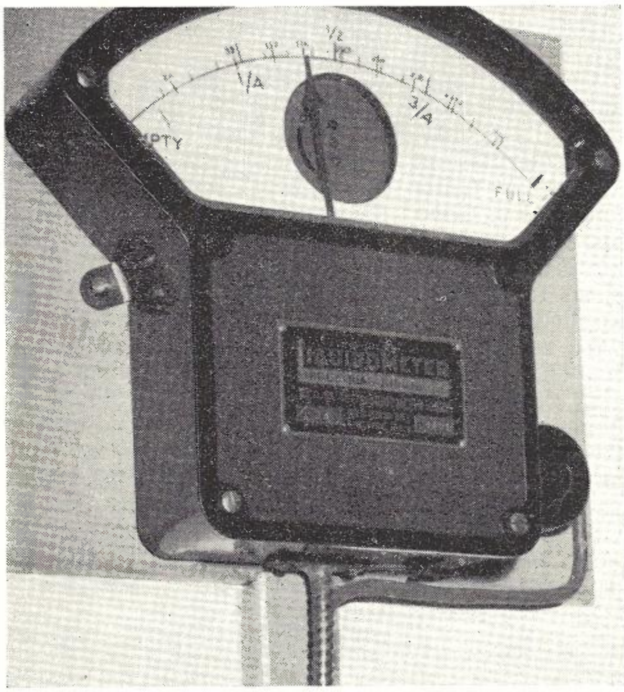


Fig. 34.—Liquidometer.

The voltage regulation is achieved in two ways:

(i) If the initial charging current is not allowed to exceed 32 amperes, the AR relay will remain unoperated; and

(ii) when the battery potential reaches 162V. during a charge, to cause the release of the AR relay.

The generator regulator control tube bias has previously been adjusted to provide an initial generator output voltage of 160V. which will be maintained in the following manner. Where the regulator is operating in this condition, the potential on the grid of V_1 is proportional to the output voltage of the generator whilst the cathode is grounded. An increase of generator output voltage swings VR_1 grid more positive with the same effect as outlined for current regulation, and similarly for a decrease in generator output voltage. In this case, however, it is the generator output voltage which is being held constant and not the current as in the previous case.

Correct timing is an essential requirement for the automatic operation of the 420B power plant, and six synchronous timers operated from the 60V 60 c/s supply, are used in the charge and con-

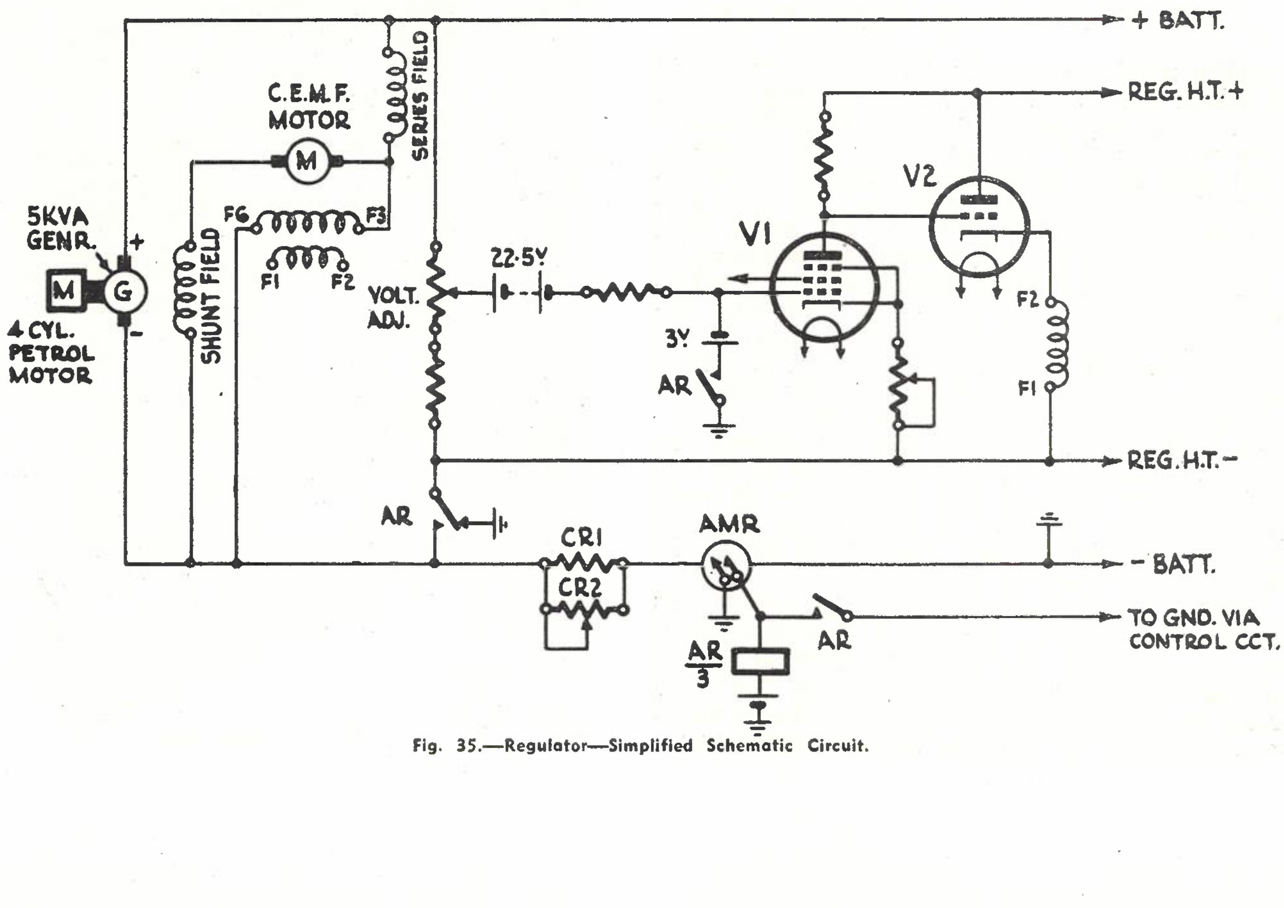


Fig. 35.—Regulator—Simplified Schematic Circuit.

trol circuits. The timers are shown in Fig. 35, and their dimensions are similar to those of the receiver in a telephone handset. They are fitted with changeover spring-set type micro-switches.

The short duration (3 minutes) timers have an external arm which operates the micro-switch after the specified timing period. The arm rotates against the tension of an internal spring and returns to its normal position when the driving power is disconnected. The long duration (2 and 12 hours) timers have similar dimensions, but operate an external cam which requires the continued application of power to restore it to its normal position. Control interlocking relays ensure that the timer continues to operate until the cam completes its rotation after the operation of the micro-switch. A 3-minute timer operates in each of the two charge circuits so that the charging generator, counter E.M.F. and associated D.C. amplifier tubes will reach normal operating speeds and temperatures before the charging generator is connected to the battery. Other 3-minute timers function during any charging operation. Should an engine fail to start, or, alternatively, fail during normal operation, timer ES will function after a delay of three minutes, to lock-out the faulty engine and arrange an automatic transfer of the starting control circuit to the idle engine-generator set. The timer starts its 3-minute delay when the charge is closed down. Its function is to ensure that the 60V. 60 c/s alternator remains in operation to ensure closing of the louvres (if provided), and ensure continued operation of one of the timers associated with an extended charge. During a normal charge, timer CH commences to operate when the battery potential reaches 157 volts. The timer ensures that the battery is given an extended charge for a further period of two hours before the micro-switch operates and the engine-generator is shut down. Timer CG replaces timer CH if the automatic charge button is operated to give the battery a 12-hour extended charge. Its operation is similar to that of the CH timer, except that after the battery potential reaches 157 volts, the charge is continued for 12 hours before the engine-generator set is closed down.

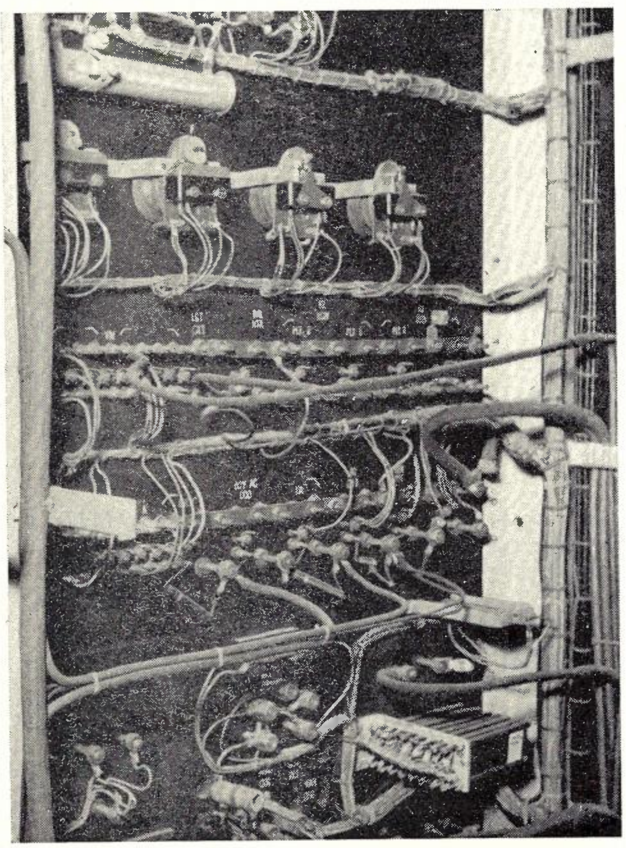


Fig. 36.—Rear View Engine Generator Board, including four timers.

Conclusion

The Brisbane-Townsville type J2 twelve-channel carrier telephone system has been in operation since December, 1950, and during this period, the auxiliary repeaters and associated 420B power plant at Miriam Vale, Carmila and Marlborough have operated satisfactorily.

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THE DESIGN OF A VOLTAGE STABILIZED ANODE SUPPLY FOR 230 VOLT D.C. MAINS OPERATION

T. R. Allen, A.M.I.E.E.

Introduction: Consideration was given to the possibility of designing a circuit which would enable 230 volt D.C. town mains to be used for the supply of anode current at 130 volt, for the working of carrier equipment. The circumstances which necessitated the work described herein were as follows:—

(i) The D.C. town mains supply at a country centre was used to drive a DC/AC rotary converter, the output of which was transformed and rectified to provide the 24 volt filament and 130 volt anode supplies. No batteries were used owing to accommodation limitations, and as the D.C. mains supply (nominally 230 volt) was subject to voltage variations of approximately ± 25 volt, the 130 volt anode supply variation was of the order of ± 22%. As the limits for anode supply voltage are 130 volt ± 10%, this condition called for attention.

(ii) Further, as the installation of an additional carrier system was projected, it was necessary to make provision for the additional load on the 24 volt filament and 130 volt anode supply. This could have been drawn from the supply circuit as it existed, but the converter, which was rather optimistically rated in view of its meagre iron circuit, would be called upon to give an undesirably large output.

The desirability of limiting the load on the converter and the necessity of stabilizing the 130 volt supply caused an investigation to be made into the possible methods of achieving the desired result.

Design Considerations: The characteristics of various gaseous discharge voltage regulator tubes were examined, and the type S.130 (Osram) was selected as showing most promise of meeting requirements. The circuit employed for this type of tube is shown in Fig. 1. In order to ascertain

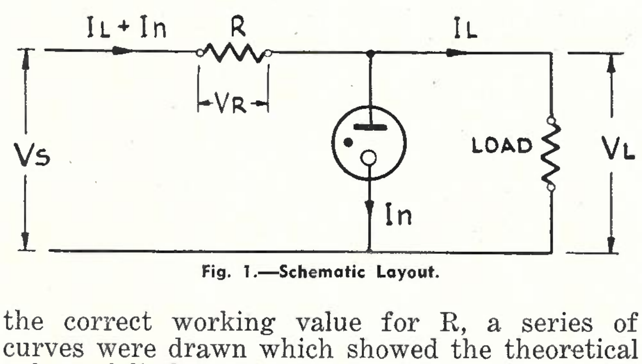

Fig. 1.—Schematic Layout.

the correct working value for R, a series of curves were drawn which showed the theoretical values of discharge tube current for various mains supply voltages (Vs), and various resistance values R. It will be seen from Fig. 1 that the tube current

$$In = \frac{Vs - Vl}{R} - Il \qquad (1)$$

Fixing the load current Il at 240 mA. and the load supply voltage Vl at 130 volt, we have:—

$$In = \frac{Vs - 130}{R} - 0.24 \qquad (1A)$$

Employing this expression the family of curves shown in Fig. 2 were prepared.

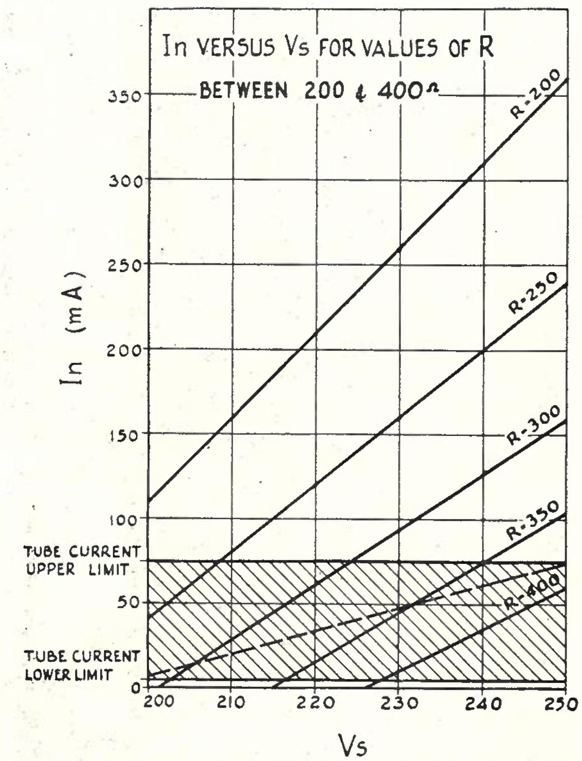

Fig. 2.—Relationship of Tube Current to Mains Voltage.

It was noted that the manufacturer's current limits for the tube S.130 are 5 mA. to 75 mA. Having drawn these limits on the graph it was seen that no one value for R would suffice to cover the range of voltage variations it was desired to stabilize.

Thus, attention was given to the use of some form of non-linear resistor which would vary in resistance according to the current flowing through it. It was also realized that this non-linear resistor would have to dissipate approximately 25 W of power. Furthermore, it was desirable that the item should be robust, should dissipate heat safely and be readily obtainable. Consequently investigation was made of the characteristics of various ballast and resistance lamps and, finally, "Lamp Resistance, 125 Volt 30W" was chosen as being a lamp with characteristics which showed some promise of being employed in a manner indicated above. From the curves in Fig. 2 it can be seen that the required resistance characteristic is such that when the mains voltage (Vs) is 200 volt, the resistance value of R is approximately 280 ohms, and when the mains voltage (Vs) rises to 250, the value of R is approximately 380 ohms. This can be checked by using equation (1). Fig. 3 shows the ideal variation required.

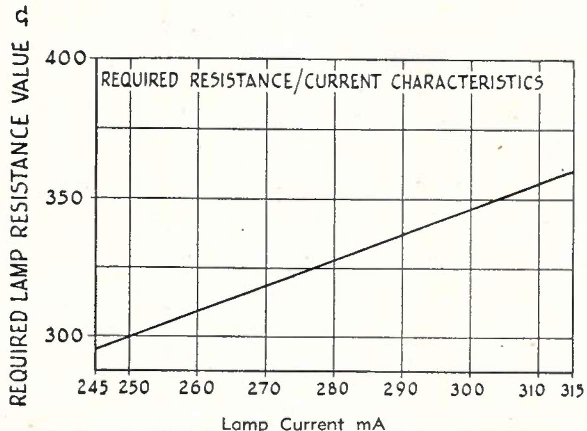

Fig. 3.—Required Lamp Resistance/Current Characteristics.

Smoothing Requirements: In addition to the requirement that the 130 volt anode supply desired from the D.C. mains be stabilized, it must also be filtered to remove generator and extraneous noise. This, therefore, called for a filter of conventional type. A 10 henry choke was included in the filter, and as this had a D.C. resistance of 100 ohms, this had to be taken into account when selecting a lamp combination for use as a non-linear resistor, that is:—

R min – 100 ohms = 186 ohms
R max – 100 ohms = 281 ohms

Choice of Lamps: Fig. 4 shows characteristics of various resistance lamps. It was found by measurements made on batches of lamps from various manufacturers that the most suitable lamps were the 125 volt 30 W lamps produced by Messrs. Siemens Bros., as these showed a steeper and more linear resistance current slope, and more uniformity between lamps. The resistance characteristics of a large batch of these lamps lay within the hatched area shown in Fig. 4.

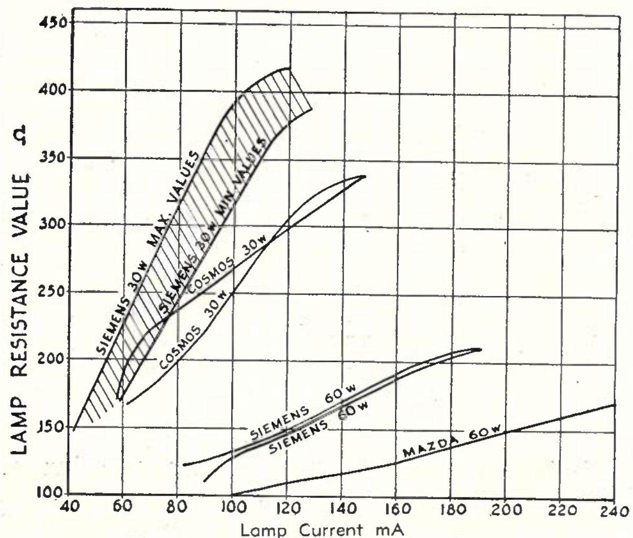

Fig. 4.—Characteristics of Various Lamps.

Examining series parallel arrangements of these lamps it was found that a combination of two series groups of three in parallel gave almost the required theoretical values. Table 1 shows values arrived at, and percentage variation from the calculated value required, for average lamps, lamps on the lower boundary of the hatched area of Fig. 4, and lamps on the upper boundary of the same area.

Table 1.

Total Current (Il + In)	Calculated R value	Average lamps		Low-resistance lamps		High resistance lamps	
		R ohms	% error	R ohms	% error	R ohms	% error
mA	ohms						
245	186	192	+ 3%	170	— 9%	214	+ 15%
315	281	242	— 14%	226	— 20%	268	— 7%

While it is realised that a more intricate series parallel arrangement could be arrived at, giving a closer approach to the calculated resistance/current slope, it was felt that in view of the fact that the discharge tube would tend to correct automatically for any reasonable discrepancy in the resistance value, the additional resistance lamps necessary could hardly be justified in view of the small gain in performance.

Final Design: Fig. 5 shows the final arrangement as installed. It will be seen from this schematic diagram that the power filter was included

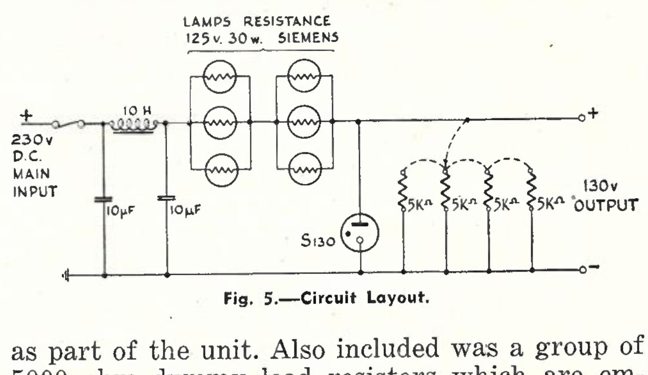

Fig. 5.—Circuit Layout.

as part of the unit. Also included was a group of 5000 ohm dummy load resistors which are employed to build out the load current to the design figure of 240 mA. in order to ensure the correct operation of the circuit.

Performance: Fig. 6 shows a comparison of the input and output voltage variations in service. It will be noted that input variations of some 30 volts cause output variations of less than 3 volts. Fig. 7 shows an input/output comparison for a greater range of input volts, that is 10 volts output variation for an input variation of 60 volts. It will be seen that these figures are well within the specified limits.

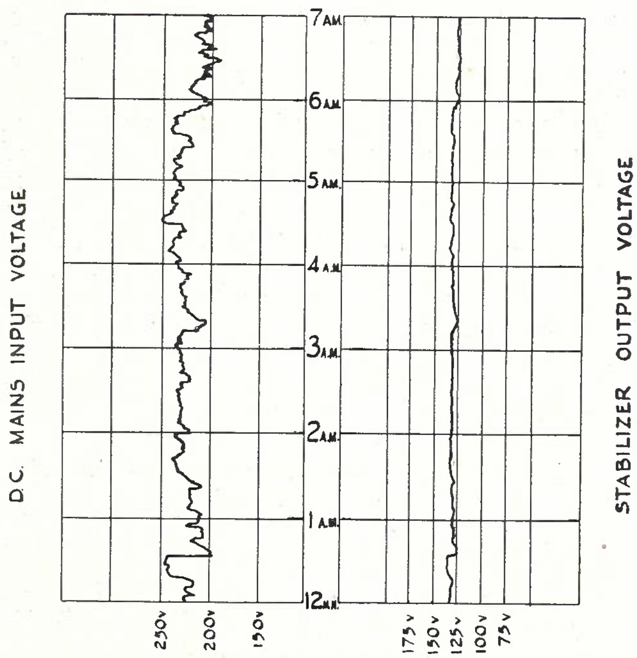

Fig. 6.—Input/Output Characteristics—30 volt Mains Voltage Variation.

Conclusion: The unit described achieved the object desired. It is simple in design and operation and provides a reliable, smoothed and stabilized anode supply for the operation of equipment direct from D.C. mains. The use of the stabilizer is, of course, not limited to direct mains operation and may also be used to reduce any unregulated D.C. supply of approximately 230V. to 130V. stabilized.

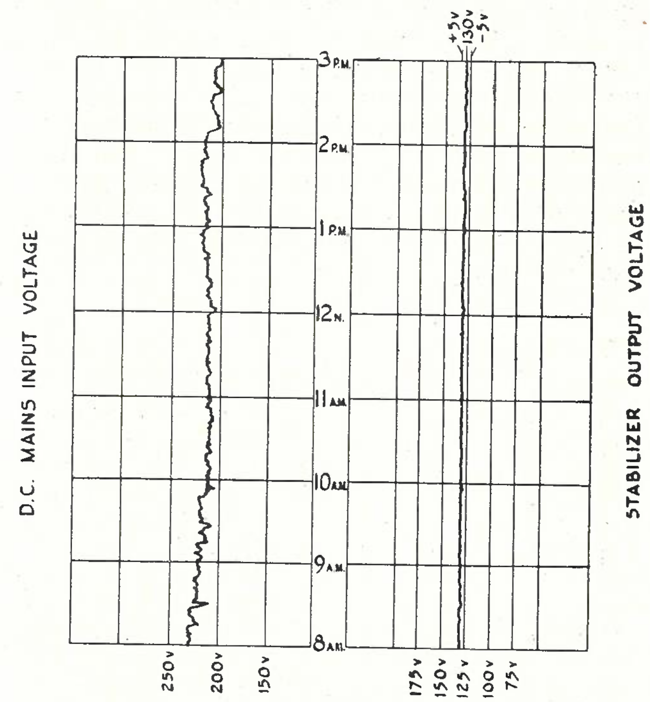

Fig. 7.—Input/Output Voltage Characteristics—60 volt Mains Voltage Variation

MAINTENANCE PROBLEMS IN AUTOMATIC NETWORKS

W. King

Introduction

It is proposed to describe briefly in this paper a number of problems more directly associated with automatic networks in the larger capital cities. Similar problems, however, exist also to a limited extent in the smaller networks. Before dealing with these problems in detail, a brief summary of the types of equipment in use in automatic exchanges in the Commonwealth and the fault incidence of each type of equipment will be given.

Fault Incidence of Equipment

Bimotional switches in use prior to 1938 were Strowger pre-2000 type, and slight differences in mechanical design and circuit conditions existed in the switches supplied by the different manufacturers. Since 1938, most of the exchanges installed have been 2000 type, although it has been necessary to purchase considerable quantities of pre-2000 type equipment to provide for extensions to existing pre-2000 type exchanges. At present, approximately 48 per cent. of the total bimotional switches in the Commonwealth are 2000 type. The quantities are shown in Table 1.

Type of equipment	Pre-2000 Type Switches	2000 Type Switches	Total
Group selectors	89,160	74,433	163,593
Final selectors	32,147	33,627	65,774
Discriminating selector repeaters	9,991	12,468	22,459
Line finders	—	11,664	11,664
Siemens No. 16 switches	10,283	—	10,283
Total bimotional switches	141,581	132,192	273,773

Other equipment	Units in situ
Uniselectors plunger type	68,367
Uniselectors rotary type	390,340
Repeaters	50,077
Subscriber's registers	581,236

Table 1.

In earlier pre-2000 type exchanges, plunger type subscribers' uniselectors were provided. In later exchanges of this type 25 point non-homing uniselectors were used, and later still, the 23-point homing type uniselector. The bimotional switches used in these exchanges have been mainly 100 outlet selectors and 100 line final selectors only, a very limited number of 200 outlet group selectors of the pre-2000 type having been installed. The earlier 2000 type exchanges were of the line finder type, but in later exchanges the 23 point homing type uniselector has been generally used.

With regard to the performance of the different types of equipment, the figures shown in Table 2 will, no doubt, surprise many who have held the opinion that the fault incidence of a 2000 type switch was much higher than that of a similar pre-2000 type switch. It will be seen that there is very little difference in the fault incidence of either type of switch and it must be remembered that 200 outlet 2000 type switches are being compared with 100 outlet pre-2000 type. When the fault incidence of wipers and wiper cords, which accounts for approximately 30 per cent. of all faults on both types of switch, is taken into consideration, a slightly higher figure for the 2000 type selectors is accounted for, and the comparison is more favourable for the 2000 type switch. It must be remembered, however, that a large proportion of the pre-2000 type switches have been in continuous use for over 20 years.

Another point of interest is a comparison of the fault incidence of the various types of equipment over a period of twelve years (1939 to 1951). These figures are shown also in Table 2, and it will be seen that while the faults per switch for pre-2000 type switches have increased, which is accounted for by the ageing equipment, the faults for 2000 type switches, with the exception of D.S.R's, are considerably lower than they were twelve years ago, when very little experience had been gained with this type of equipment.

Type of equipment	Pre 2000 Type Faults per switch per annum		2000 Type Faults per switch per annum	
	1939	1951	1939	1951
Group selectors	0.60	0.73	1.39	0.78
Final selectors	0.76	0.8	1.55	0.71
Discriminating selector repeaters	1.55	1.48	1.46	2.15
Line finders	—	—	1.68	1.03
Uniselectors plunger	0.08	0.1		
Uniselector rotary	0.07	0.09		
Repeaters	0.31	0.34		
Subscriber's registers	0.008	.008		

Table 2.

It is not proposed in this paper to consider in detail the actual fault incidence of the various types of equipment. Taking into consideration the staff position on maintenance, with less than 50 per cent of the staff fully trained, the grade of service is reasonably satisfactory so far as actual equipment faults are concerned. Most of the network troubles at the present time are due to other causes, which include the reduction in the overall grade of service given to subscribers as a result of serious congestion in junction routes, lack of adequate trunking in many exchanges, insufficient number of lines to busy subscribers, and loss of calls due to faults of a special nature brought about mainly by the congested traffic conditions. Special observations taken in the larger networks indicate that during the busy periods approximately 25 per cent. of calls are ineffective due to the following causes:—

Subscribers' busy	7 per cent.
Trunk or junction busy	10 per cent.
Fault of apparatus	8 per cent.

While the loss due to subscriber busy and junction and trunk congestion is serious, and every effort is being made to overcome these problems, it is with the calls lost due to apparatus failures that this paper is concerned. When these losses are analysed further it is found that 2 per cent. are due to actual equipment faults and the remaining 6 per cent. to "stop-on-busy" and no-progress calls. Of the no progress calls, it is probable that quite a large percentage is due to "repeater unguard." It is proposed to discuss these problems at some length later, but before doing so it is stressed that both are largely a result of congested conditions, and would not be quite so serious under normal traffic conditions.

Stop-on-Busy Troubles

Stop-on busy as applied to a group selector is a condition where a subscriber making a call stops on a busy trunk on which a call between two other subscribers is already in progress. This trouble may develop on any earth testing group selector provided with switching relays holding to earth via the private wipers, and is not, as is commonly thought, confined to the 2000 type selector. However, as all 100 outlet selectors in Australia are provided with circuits which include an interacting relay which must operate to rotate the switch it is with the 200 outlet 2000 type selector that the trouble predominates.

In order to simplify the explanation of stop-on-busy, portion of the 2000 type group selector circuit is shown in Fig. 1. It will be seen that the

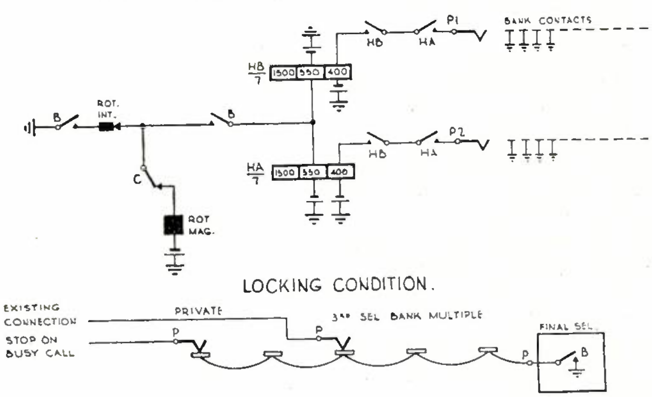

Fig. 1.—200 Outlet Group Selector Circuit.

switching relays must hold to earth on the private bank contacts during rotary search of a busy level. When a private contact which is free from earth potential is found, the corresponding switching relay will restore and switch the call through on this trunk. While the rotary magnet interrupter springs are closed, the switching relays are held operated on their 550 ohm windings, but when the interrupter springs open, which occurs as the wipers reach each contact, earth via the private wipers must hold the switching relays on their 400 ohm test windings should the trunk on which the wipers are standing be busy. The rotary magnet in this case will operate when the interrupter springs again close and step the switch to the next contact. This action continues until a bank contact is reached which is free of earth potential. When the private wipers reach this contact, the associated switching relay restores and cuts the rotary drive.

It will be seen that when testing on a busy bank contact, any condition which will cause a momentary opening of the private wiper circuit, such as wipers slightly overshooting the bank contact due to forward setting of the private wipers, excessive rotary play, or other conditions which will be covered later, will cause the switching relay to restore and switch the caller through to a call already in progress. What is more serious, if the stop-on-busy occurs on a local call it will lock the subscribers to this circuit until the intercepted call is completed. Fortunately, this trouble does not occur with 100 outlet pre-2000 type selectors owing to the test circuit conditions of this type of switch, which are shown in Fig. 2.

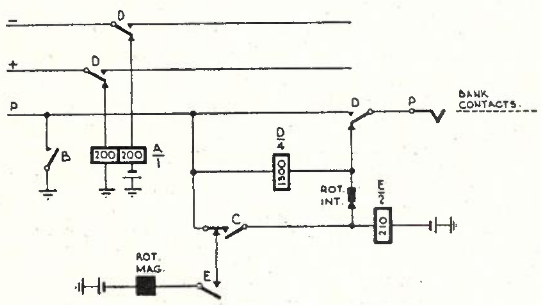

Fig. 2.—Group Selector, Pre-2000 Type.

By reference to the circuit, it will be seen that it is necessary for relay D to operate before switching takes place. This cannot occur until the rotary interrupter springs close after the private wiper has settled on the bank contact. A momentary open in the private wiper circuit during this period would have no effect on relay D, and even if the private were open, relay D would operate when the interrupter springs close but would not hold, as relays A and B would restore and remove the holding earth from the private. Interaction of relays A, B and D would take place while the calling loop was maintained but no interruption to a call in progress would occur. It will be appreciated, therefore, that the possibility of this type of selector stopping on a busy trunk is very remote.

As previously stated, stop-on-busy may be caused by any condition which allows a momentary open to take place in the switching relay circuit. The open period must, of course, be of long enough duration to allow the HA or HB switching relays to restore. It should be clearly understood, however, that a 2000 type selector with all mechanical adjustment well within the tolerances laid down is unlikely to stop on busy unless such a condition as an intermittent open private wiper cord, or faulty wiper to bank alignment is evident. However, the difficulty of maintaining the desired high standard of adjustment necessary, and at the same time retaining a reasonable frequency of inspection will be appreciated, and the position is not improved when it is considered that a large proportion of the maintenance staff is not fully trained.

Some of the many causes of stop-on-busy are:

(i) Faulty wiper to bank alignment.
(ii) Faulty setting of wipers on banks.
(iii) Faulty interrupter spring adjustment.
(iv) Excessive rotary play.
(v) High resistance to bank contact.
(vi) Testing in on busy contacts during metering.
(vii) Faulty adjustment of NR or S springsets.

Faulty Wiper to Bank Alignment: This refers to wipers not set parallel or in correct vertical alignment with the bank contacts, resulting in uneven tension in the upper and lower wiper blades.

Faulty Setting of Wipers: This refers to the forward setting of private wipers on bank contacts causing excessive overshoot of the bank contacts.

Faulty Interrupter Spring Adjustment: This refers to interrupter springs opening early before the private wipers reach the bank contacts.

Excessive Rotary Play: With excessive rotary play in the carriage assembly, the private wipers overshoot the bank contacts, and the open period is sufficient to allow the switching relay to restore.

High Resistance Wiper to Bank Contact: If the condition is severe enough, the holding characteristics of the switching relay are affected.

Testing in on Busy Contacts during Metering: A selector may test in to a busy trunk just as metering is taking place; in this case the full guarding earth on the private bank contact would be replaced by earth via a rectifier in a final selector or repeater.

Faulty Adjustment of NR or S Springsets: Contact open on rotary operation due to insufficient tension or follow.

Investigation of the stop-on-busy trouble on 2000 type group selectors has been proceeding over a number of years in the Department. Early deliveries of 2000 type selectors appeared to be free of this trouble, but as more switches of this type were installed, particularly in the busier exchanges, the trouble was brought under notice and remedial action was taken to combat it. During the investigations it was found that a change in the rotary magnet winding had been made in the history of the switch and this had a very definite bearing on the incidence of the trouble, as will be explained later. Early deliveries of selectors were provided with magnets wound with 900 turns of 37 gauge wire, while the later magnet supplied is wound with 1300 turns of 35 gauge wire. Most of the switches now in use are fitted with the fully wound magnet and the effect of this will now be explained.

The original 2000 type selector was designed to allow the switch to rotate and test at a speed of approximately 40 to 45 steps per second, and in order to avoid passing idle trunks, when testing at this speed, the switching relays HA and HB were required to release very quickly while the interrupter springs were open. To assist the quick release of these relays at high speed, it was necessary to include in the circuit a "kick out" feature. It will be seen by reference to Fig. 1 that the rotary magnet is shunted by the 550 windings of relays HA and HB. This is necessary for two reasons, first to slow down the rotary speed during search and, second, to avoid passing idle trunks by providing the kick out feature. When the interrupter springs open as the private wipers reach each bank contact, a surge caused by the opening of the rotary magnet circuit assists in quickly demagnetising HA and HB relays, and these relays drop out quickly should the bank contacts be free of earth. This circuit functioned satisfactorily on early switches provided with rotary magnets having a relatively low inductance and the holding characteristics of the switching relays were designed accordingly, hence these switches do not stop on busy even with very wide tolerances of adjustment.

It was found necessary later, however, to alter the characteristics of the rotary magnet on all bimotional switches as it was claimed that the original magnet was not powerful enough to drive four bank switches, and in order to maintain standardisation, all bimotional switch magnets, including those on selectors, were changed to the new design. The later magnet is wound with many more turns of heavier gauge wire and consequently the inductance is higher. Unfortunately, this magnet has an adverse affect on stop-on-busy as, due to the higher inductance, the kick out feature on the switching relays is more pronounced, thereby reducing the holding characteristic of these relays. The higher inductance incidentally also reduces the rotary speed by approximately five steps per second.

The introduction of the higher inductive magnet has made the adjustment of the switching relays very critical, and in order to prevent stop-on-busy trouble it has been found necessary to slow down the release of these relays or, alternatively, to reduce the inductive kick by shunting the rotary magnet; this, however, further reduces the rotary speed.

So far as existing switches are concerned, a number of different methods have been tried to reduce the trouble and are as follow:—

(a) Fitting 1000 ohm resistance across the 400 test windings of the switching relays. This prevents the switching relays restoring too quickly and allows a much wider tolerance in the adjustment of the switch.

(b) Fitting rectifiers in series with the 550 ohm windings of the switching relays. This has a beneficial effect on stop-on-busy by reducing the effect of the kick-out feature. It was found necessary, however, with this modification to also shunt the rotary magnet to reduce the rotary speed and prevent passing idle trunks.

(c) Fitting a low inductance magnet. This has a marked effect. It increases the rotary speed from 35 to 45 steps per second and the switch will not stop on busy with maximum rotary play; however, the operating efficiency of this magnet is lower than that of the later magnet.

(d) Connecting a 300 ohm shunt across the rotary magnet. This reduced the magnet surge but also reduced the rotary test speed to 30 steps per second.

(e) Fitting Atmite resistors across the rotary magnet. This reduces the surge and best results were obtained by replacing the existing spark quench condenser and timer with the Atmite resistor. Only a limited number of resistors was available, and it is understood that some difficulty is being experienced in keeping the resistance characteristic of this type of resistor constant during manufacture.

(f) Connecting a high resistance shunt across the 1500 ohm windings of the switching relays. The provision of 20,000 ohm shunts across the 1500 ohm windings of these relays appears to be very satisfactory in preventing stop-on-busy, but prolongs the release time of the relays during normal release which may prevent switches releasing during the momentary open period provided on repeaters on final selectors.

(g) Connecting shunted rectifiers in series with the 550 ohm windings of the switching relays. Two 6A rectifiers shunted by a 2500 ohm resistance are connected in each relay circuit. This reduces the effect of the kick-out feature without the necessity of shunting the rotary magnet, thus the testing speed of the switch is increased. This appears to be the most satisfactory method tried to reduce stop-on-busy trouble, and all new 2000 type selectors will include this modification. Arrangements are in hand also to include this modification in the circuits of all existing selectors.

In order to keep a close check on stop-on-busy a special test is carried out monthly on all 2000 type group selectors during non-busy periods. By means of a special bank busying tool which is associated with a switch mechanism, all privates of a level are busied through a 200 ohm earth, a separate resistance being provided for upper and lower privates. Each selector in the multiple is stepped to this level several times and rotated. The test brings to light any unstandard adjustments or private wiper settings which are likely to cause stop-on-busy faults.

Apart from the modifications listed previously a limited number of selectors have been placed under trial with a modified circuit using an entirely different type of switching relay which is not subject to magnet surge. This switch is free from stop-on-busy trouble, but the rotary speed has been reduced to approximately 30 steps per second; apparently it has been found necessary to shunt the rotary magnet to reduce the speed and prevent idle trunks being passed. A later modification of this circuit has just come to hand however, in which the rotary speed on test has been increased to 33 steps per second, and the magnet shunt removed during the release drive of the switch allowing for a much higher speed of drive during release. Preliminary tests on this circuit were satisfactory.

A battery searching group selector also appears to offer a solution to the stop-on-busy problem, and such a switch was designed some years ago. A limited number of switches to this design has been tried out successfully in a Melbourne exchange. The battery testing principle is illustrated in Fig. 3.

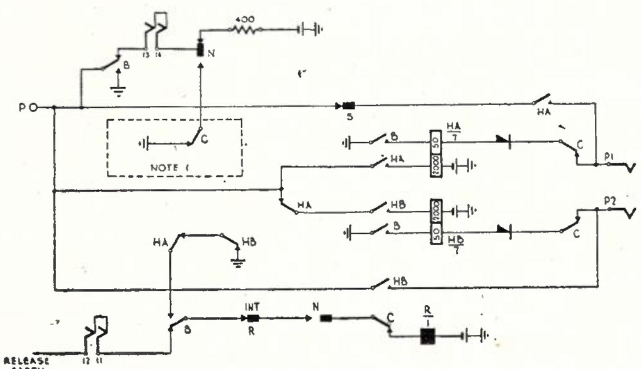

Fig. 3.—Battery Searching Selector.

Note 1.—Release guard required only where earth searching switches trunk into battery searching switches.

With the battery searching selector, there is no possibility of stopping on busy trunks due to momentary opens on the wipers, as the operate time of the switching relay is involved. High speed rotary search is possible and the switch will pass open trunks without releasing. It is not understood why this principle has not been favoured overseas for the 200 outlet group selector, as the objections put forward up to date against battery testing, in the opinion of the writer, have not been very convincing.

Before leaving this subject, the importance of maintaining the adjustments of the 2000 type selector well within the tolerances laid down is again stressed. To be free of stop-on-busy trouble, special attention must be given to the positioning of private wipers on the banks and to bank alignment.

Repeater Unguard Troubles

It has been appreciated for some time that calls are lost, particularly in the larger networks, owing to repeaters and junctions not being fully guarded during the release period of the incoming selectors to which they are connected. Two types of repeaters are in use in Australia; one provides for a release guard period equal to the release time of B relay, approximately 300 milliseconds, and the other, a later type, is provided with additional guard features which include the release time of relay C (150 milliseconds) and relay G (300 milliseconds) giving a total guard period of approximately 750 milliseconds, with a momentary open on the release trunk after the release of relay B (300 milliseconds) to release local switches.

The release guard on any repeater should be maintained until the group selector to which it is tied in the incoming exchange is fully restored, otherwise it could be seized for another call before switches held on the previous call are normal and, in this case, calls would be lost or misdirected. An incoming selector will not commence to release mechanically until earth has been removed from the release trunk by the restoring of relay B on a final selector, or another repeater, if the call is passing through the distant exchange. This period is approximately 300 milliseconds, unless the B relays are abnormally slow, and the mechanical release time of the incoming group selector must be added to this. With the exception of a limited number of very old pre-2000 type selectors which provide for an additional guard on the release trunk after the release of relay B, when the switch is releasing from the 11th contact overflow busy, pre-2000 type selectors have a comparatively short mechanical release time which rarely exceeds 100 milliseconds. The average mechanical release time of the 2000 type selector however is approximately 250 milliseconds and may be as long as 350 milliseconds.

It will be seen by reference to Fig. 4 that when using a short guard repeater, the junction is unguarded for a considerable period after the release of the repeater B relay. The position is improved considerably with the later type repeater owing to the longer guard, and the release unguard is practically eliminated, apart from the momentary open period of approximately 25 milliseconds. It is important, however, to keep the release time of B relays on repeaters and final selectors within the limits of 250 to 350 milliseconds, otherwise unguard will result even with the long guard repeater. See Fig. 5.

Some attempt has been made to reduce the unguard period of the short guard repeater by adjusting the guard relay (B relay) to give a very slow release. While this may be an advantage in the case of repeaters in sub-branch exchanges and for local calls in a main exchange, it must be remembered that in main exchanges the same repeater is used for both local and through calls, and any additional guard on the repeater

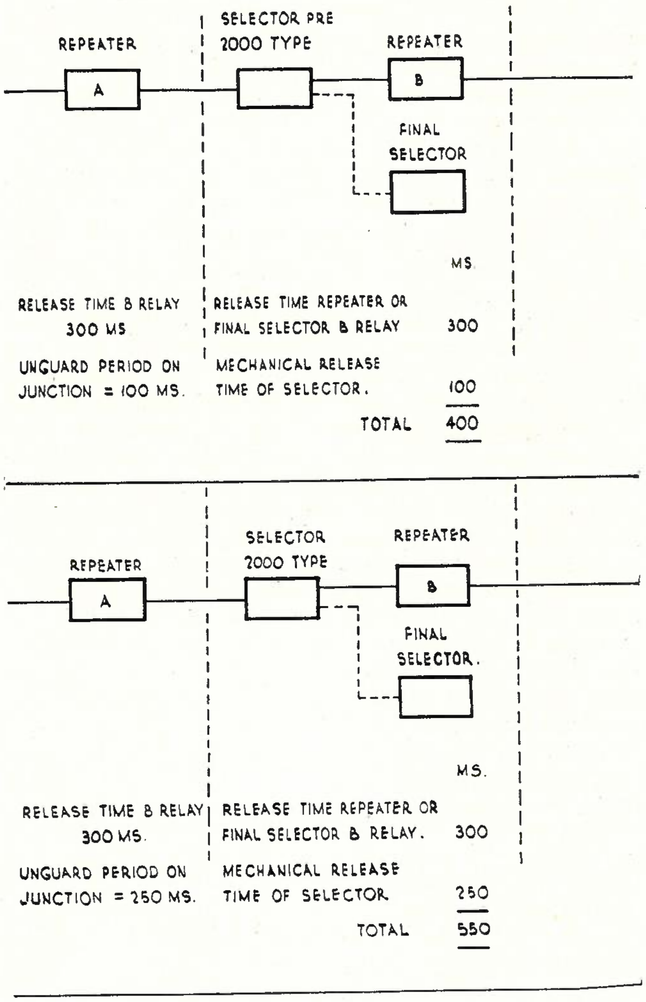

Fig. 4.—Early Type Repeaters.

without an open period to release the local switches would increase the unguard period on junctions from other exchanges should these calls pass through the main exchange concerned.

It would appear necessary, therefore, to modify all existing short guard repeaters to provide for release guard facilities similar to those included in the more modern repeaters. The most straightforward way to do this would be to provide additional relays, and modify the older circuits in accordance with the later circuits. Until recently this was not possible in the case of many of the older circuits as most of the relay bases had insufficient mounting space for the additional relay. However, it has now been decided to discontinue the use of barreters for economic reasons, and the elimination of these from repeaters will provide room for the additional relay in most cases.

Unguard on Discriminating Selector Repeaters

In the case of the 2000 type D.S.R., two problems must be given consideration. These are:—

(i) The guard on a main exchange junction which has been released after the local exchange prefix has been dialled.

(ii) The guarding of repeaters and junctions in sub-branch or satellite exchanges which trunk into D.S.R.'s in branch exchanges.

In the first case, the guard period on the junction is equal to the release time of the junction guard relay, approximately 300 milliseconds, while the release time of the incoming selector in the main exchange may be 600 milliseconds in the case of 2000 type selectors and would be at least

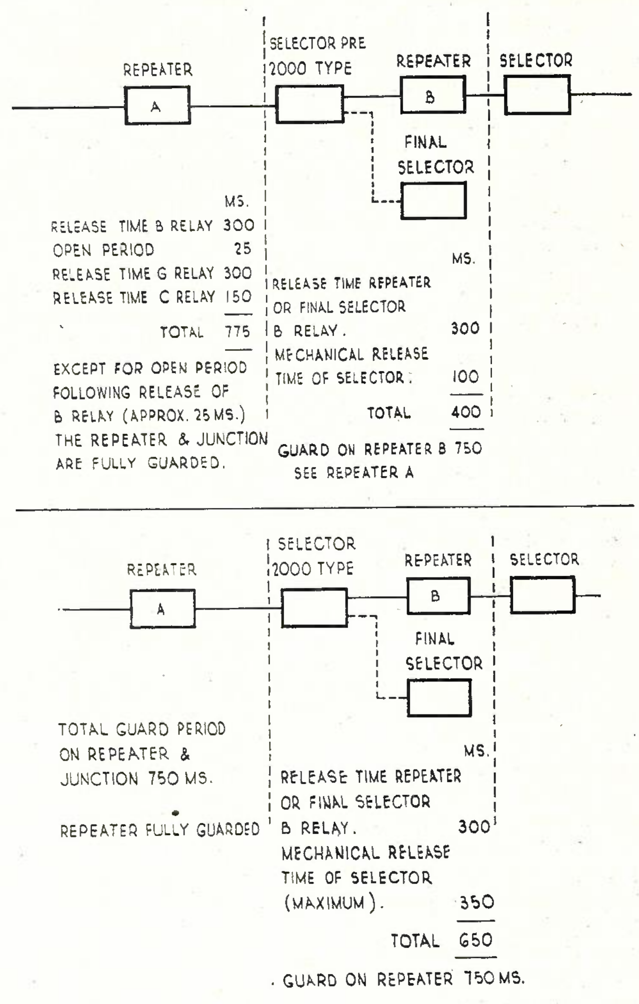

Fig. 5.—Later Type Repeaters.

400 milliseconds in the case of pre-2000 type incoming selectors. It will be seen, therefore, by reference to Fig. 6, that the branch to main junction is unguarded for a considerable period following a local exchange call, therefore, some means of increasing the release time of the junction guard relays appears to be necessary.

In the second case, where repeaters in a sub-branch exchange trunk into D.S.R.'s in a branch exchange, an unguard period exists even when the long guard repeater is used in the sub-branch exchange (see Fig. 7). If a short guard repeater is used in this type of exchange, the unguard period could be 500 milliseconds. It is necessary, therefore, to use the long guard repeater in sub-branch exchanges which trunk into D.S.R's and in addition the release time of B and G relays should be increased. With regard to the pre-2000 type D.S.R., or switching selector repeater as it is commonly termed, the only unguard problem associated with these switches is in the case of local calls, and as explained for the D.S.R. the release time of the junction guard relay should be increased to prevent junction unguard.

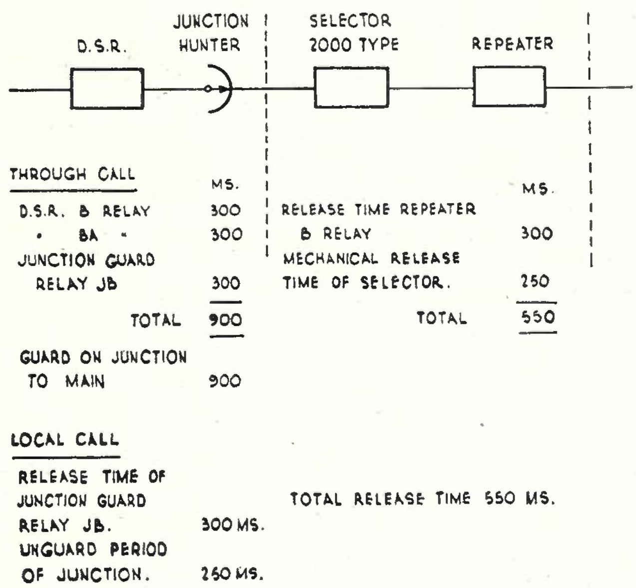

Fig. 6.—Discriminating Selector Repeaters.

As previously stated, it is known that a large number of calls is lost or misdirected, due to repeater or junction unguard and the position is becoming more serious as the number of 2000 type junction switches increase, owing to the comparatively long mechanical release time of this type of switch; and considering the large number of short guard repeaters in use, it may be wondered why the position is not worse than is indicated by the observation returns. There are, however, two saving factors in this regard. These are the comparatively slow dialling of the average subscriber and the inter-digit pause between digits.

With the exception of branch exchanges, a repeater is reached via a bimotional switch and a search takes place over a selector level during the interdigit pause. In non-busy periods, early trunk in the level would be available and the repeater would be looped early, thus a considerable portion of the inter-digit time, plus the re-operating time of the dial would remain before dialling commenced on the repeater. The looping of the unguarded repeater without dialling would not affect the call, and in most cases the incoming selector in the distant exchange would be fully released before dialling commenced. This is not the case, however, during busy traffic periods when a large proportion of the inter-digit pause may be taken up by the selector search over the level. In this case, dialling would commence immediately the repeater was looped. In branch exchanges, where repeaters are used as first selector equivalents, these switches may be seized at any instant by the subscriber, both in light and heavy traffic periods and lost calls must result should unguarded repeaters be seized.

Staff Problems

It has been mentioned previously that lack of fully trained maintenance staff is making it more difficult to provide a reasonable grade of service, and it is necessary to consider how the best use can be made of limited trained staff on maintenance work. At the same time, the problem exists of replacing large quantities of pre-2000 type switches or, alternatively, completely reconditioning this equipment. Many of the earlier 2000 type switches have reached the stage also where complete reconditioning is necessary.

With regard to general maintenance, short term training courses covering maintenance procedure have been introduced for inexperienced staff. The release of some of the adult Technicians-in-training from the training school after completing the three-year course should relieve the staff position considerably, provided these men are not absorbed on other duties. Automatic routiners are being provided for all 2000-type exchanges, and this will enable more comprehensive testing to be carried out at increased frequencies, in those exchanges where manual or semi-automatic testers only were provided previously. With regard to the general overhaul of equipment, there appears to be three alternative methods of carrying out this work. These are:—

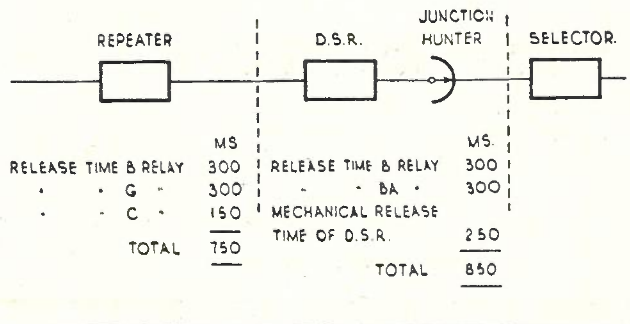

Fig. 7.—Repeaters Trunking into D.S.R's.

(i) Carry out the work in the exchange with existing or augmented staffs.
(ii) Provide special maintenance teams to carry out a complete overhaul of equipment at the various exchanges.
(iii) Provide a centralised switch repair depot where all bimotional switches and relay sets would be reconditioned.

It is obvious that the work could not be done in reasonable time by the first method without additional trained staff, and this does not appear to be possible in the near future.

Serious objections to the second method would be the lack of sufficient suitable space for carrying out this work in most of our exchanges, and the shortage of fully trained staff. The third method, therefore, appears to be the most satisfactory and this scheme has been introduced recently in Melbourne. To introduce the scheme, it was necessary to provide 1000 new switches to replace a similar number which require reconditioning in the exchanges. The switches to be reconditioned are designated with the code letters of the exchange to which they belong, before despatch to the centre, and are returned to the same exchange after reconditioning. One of the advantages of this scheme is the fact that semi-skilled staff can be used in the switch repair centre to dismantle and replace switch parts, and the final adjustment of the switches will be carried out by a staff who should in time become highly specialised in this work.

It is expected, when this centre is firmly established, that the routine examination work necessary in the exchange will be limited to the periodical inspection of the equipment and the adjustment and changing of minor parts, such as wipers, detents, etc. In the exchanges, a record of all bimotional switches will be necessary in the form of a history card for each rack of switches. The frequency of overhaul will be laid down for each type of switch depending on the estimated number of switch operations rather than a fixed period of service.

With the limited fully trained staff which is available at present it is essential that these men be used only on the higher grade work, such as testing, fault attention and switch inspection. This would leave the remaining work, such as routine testing, cleaning of switches and banks, changing of minor switch parts, etc., to be carried out by the less experienced staff.

The very extensive programme of new work and manual conversions following the war has made it necessary to transfer a large number of key men from maintenance to installation work, and to assist in staff training. It is hoped to replace these men in time from the training schools, but in the meantime maintenance must be carried out by the existing staff. This is throwing a very heavy load on the limited experienced staff and also on the maintenance supervisory staff in the exchanges, and great credit is due to these officers, who have continued to maintain a reasonable grade of service through the war years and after.

ACCOMMODATION OF LOADING COILS ABOVE GROUND LEVEL

G. A. Wiffen, B.C.E.

To provide for development taking place in the Footscray and Sunshine exchanges in the Melbourne metropolitan area, an additional 1200 pair 10 lb. junction cable was recently installed between City West and Footscray exchanges. The cable was capacity balanced and loaded with 88 mH coils at 6000 feet spacing. For an appreciable proportion of the total distance of 3.8 miles the new cable was laid in footway ducts along the new Footscray Road. On this section, which also accommodates the Melbourne-Geelong and Melbourne-Ballarat trunk cables, it was found that one of the existing manholes required as a loading coil location could not be deepened or widened owing to obstructions. The swampy nature of the ground, the cost of manhole alterations, and difficulties in jointing and testing, precluded extension of the manhole in a longitudinal direction.

As the footpath was wide and has little pedestrian traffic, it was decided that the best arrangement was to retain the existing manhole and house the loading coils above ground level. Accordingly, two steel cabinets were manufactured in the Melbourne Postal Workshops each to accom-

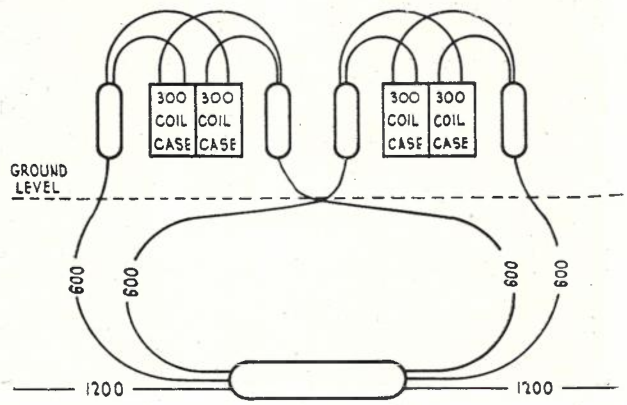

Fig. 1.—Loading Coil Case Jointing Arrangement.

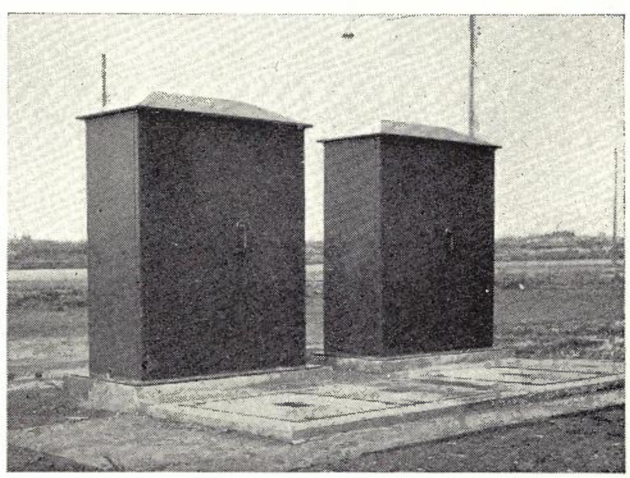

Fig. 2.—Completed Cabinets in position.

modate two 300 coil 88 mH loading coil cases. It was designed to be compact and yet accessible so that the joints could be made in the cabinet and tails extended readily to the manhole.

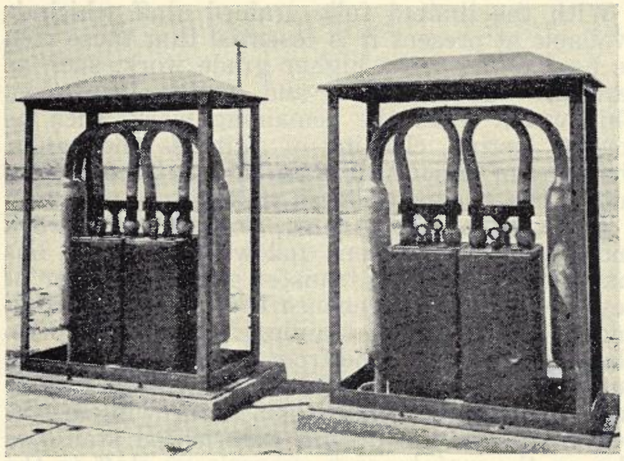

Fig. 3.—View showing all doors and sides removed for accessibility.

Fig. 1 shows the jointing arrangements, and Figs. 2 to 6 inclusive are views of the completed installation, illustrating in detail how this was carried out. Each cabinet has detachable sides and ends, and the double doors can either be opened individually or detached as required. It is weatherproof and rustproof as all exposed steel was sheridised. The approximate dimensions are, height, 4′ 6″; width, 3′ 9″ and depth, 1′ 8″. The two cabinets, having a total capacity of 1200 loaded pairs, were erected together on a concrete base, which had four-inch diameter glazed earthenware pipes leading to the manhole to accommodate the 600 pair cable tails.

The advantages of this method are accessibility, appearance and ease of assembly, the provision of better conditions for jointing and a considerable saving in cost compared with that of a large manhole.

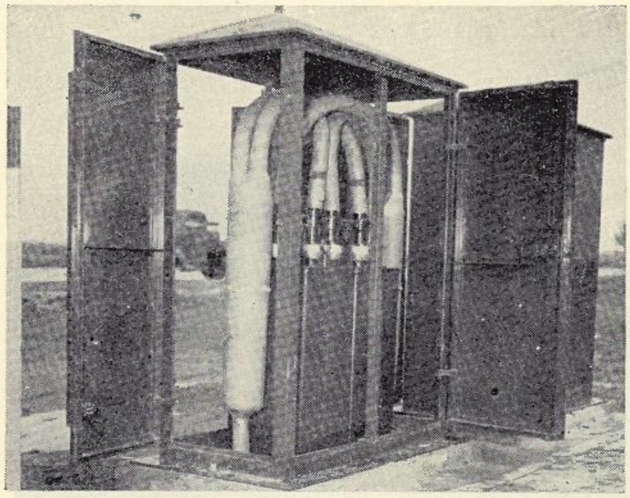

Fig. 4.—End view, with doors and sides open.

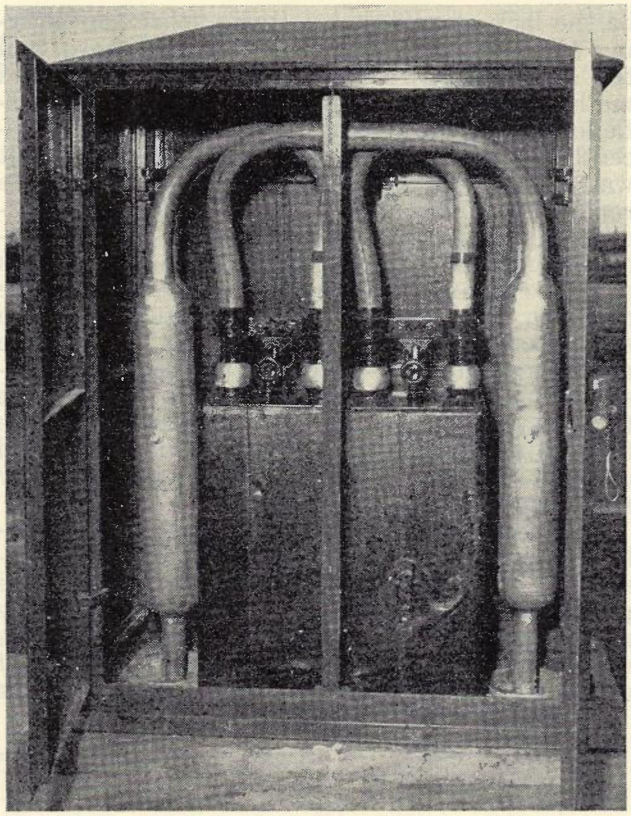

Fig. 5.—Side view with doors open.

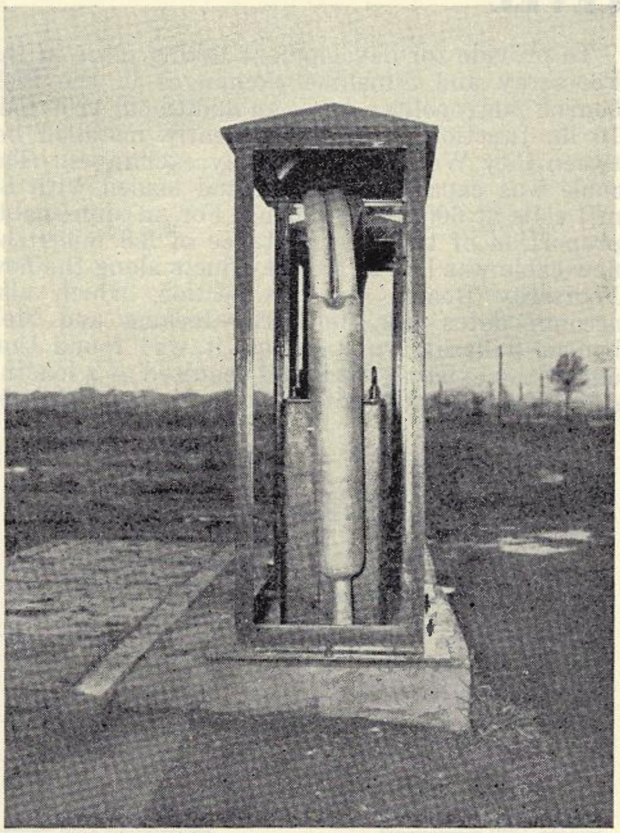

Fig. 6.—View showing all doors and sides removed for accessibility.

LARGE P.B.X. FINAL SELECTOR ARRANGEMENTS WITH SPECIAL REFERENCE TO EDISON EXCHANGE.

J. K. Petrie

Introduction

Exchange line requirements of telephone subscribers in an automatic network vary from single line services to large P.B.X. and P.A.B.X. subscribers requiring a large number of lines. Single exchange line services are catered for by an appropriate type of automatic exchange equipment. Subscribers requiring two or more lines, up to a maximum of ten, are accommodated by standard 2/10 P.B.X. final selector equipment. With this type of equipment a single directory entry is required, the final selector performing a rotary search round the ten bank contacts to locate the first free line. Exchange lines in the above two cases are bothway lines, thus being available for either incoming or outgoing traffic. However, although the maximum number of lines in a small P.B.X. group is ten, subscribers may be allotted additional lines outside the group for use as outgoing lines, retaining the ten line sequence solely for incoming calls. If the subscriber requires more than ten lines to cater for incoming traffic, in general a second rotary search group must be taken, involving a second directory entry and a loss of efficiency due to the use of two groups.

A large P.B.X. subscriber then is one who will require more than ten incoming exchange lines in one searching group, in the forseeable future. The last part of the preceding statement is most important because some consideration must be given to future requirements of each subscriber thereby involving some sort of multiple reserve for development.

Methods of Providing for Large P.B.X. Groups

Large P.B.X. subscribers can be catered for in several ways, some employing bothway lines and others requiring the use of unidirectional incoming lines for calls to the subscriber and unidirectional outgoing lines for originating traffic. Three of these methods will be described briefly.

Use of Ringing Repeaters Relay Sets. With this method a group selector bank level is allotted to each subscriber for incoming calls, a single directory entry being made.

The group selector level is cabled to a T.D.F. in the normal manner, and graded for the number of lines required. Each line is wired to the M.D.F. via a ringing repeater relay set, which is used to supply ringing current to the called line and ringing signal to the calling party. Depending on the exchange system, a transmission bridge and metering circuit may also be included in the relay set. Separate exchange numbers must be allotted to the subscriber for use on outgoing calls, as lines connected to ringing repeaters cannot be used as bothway lines. Although this method has been widely used, it suffers from several serious disadvantages. A relay set is required for every incoming exchange line for each subscriber, and the expense of this item on large groups of lines, especially when a transmission bridge and a metering circuit is required, renders this method uneconomical. No night switching facilities are available within the main group. Night service must be provided on outgoing lines, using odd exchange numbers. In the case of a P.A.B.X. the connection of outgoing lines in this manner requires additional equipment at the subscriber's premises. Standard testing facilities cannot be used for the testing of incoming exchange lines, which must be tested by the insertion of a test shoe on the M.D.F. Some form of special test final would have to be arranged if these lines are to be tested from the normal test distributor circuits.

Siemens No. 16 Large P.B.X. Final Selectors. Facilities for large P.B.X. subscribers have been available in Brisbane for many years using this type of equipment. Subscribers may be allotted an exchange line sequence of up to 100 lines—the full capacity of a Siemens No. 16 10/10 bank.

With this system, use is made of the rotary release of the Siemens No. 16 large P.B.X. final selector, and when the first line of a subscriber's group is dialled, the switch commences to search for a free line as in an ordinary small group P.B.X. final selector. However, after searching over the first ten choices, and reaching the eleventh step a special rotary release magnet is energised and the final selector performs a rotary release, automatically takes one vertical step followed by one rotary step and commences a rotary search over the next level. This continues until a free line is found or until the last line is reached when busy signal is returned to the calling party. By this means it is possible to give a rotary search over the whole hundred lines of the final selector bank. This system has the advantage that subscribers may be allotted up to 100 lines in one full availability searching group with one directory entry and any line within the group can be night switched.

Although this system has given long and satisfactory service it has two disadvantages. A considerable time may elapse between the dialling of the last digit and the commencement of ringing or busy tone, especially where very large groups are involved. This time lapse could be as great as nine seconds in the case of a hundred line group. Each line of each subscriber's group represents an exchange multiple number so that, when providing for the future growth of each subscriber, large multiple reservations must be made. If insufficient reservation is allowed, a second searching group must be started, thus losing the advantage of the full availability group, and requiring a second directory entry. It must be remembered that each multiple number is associated, via an I.D.F., with a pre-selector, and that each multiple reservation means a spare preselector. Although spare preselectors can be used with other lines, a large number will remain idle before the reservation has been completely allotted.

2000 Type Large P.B.X. Equipment. As in the Siemens No. 16 exchanges, large P.B.X. subscribers on the 2000 type system are catered for by the use of special large P.B.X. final selector equipment. This equipment makes use of 100 point 2000 type switches, the circuit of which is similar to the standard 100 point, 2/10 P.B.X. switch with the addition of eleventh step contacts for busy purposes. These switches are mounted seventy to the rack on seven shelves of ten 440 point banks, each shelf having an individual bank multiple. The bank multiples are extended to terminal blocks on the rear of each shelf and cabled from this point to a standard T.D.F. On this T.D.F. each level is graded for the required number of lines, and jumpered to a large P.B.X. I.D.F.

Each subscriber is allotted one level of the group. The first digit dialled when the final selector has been reached selects the subscriber's level and the second digit (always one, except under night service conditions) starts a rotary search over the ten bank contacts of that particular multiple. Due to the grading of outlets, final selectors in other shelves search over a different group of lines, belonging to the same subscriber. If all ten outlets from the particular shelf are engaged, the switch steps to the eleventh bank contact, busy tone is fed to the calling party, and the subscriber's overflow meter is operated to indicate an ineffective call. Night service conditions are applied by means of bare tinned copper commons on the rear of each shelf. As each group of subscribers lines are graded, no multiple reserve is required to provide for future growth. This can be readily appreciated by reference to Figs. 1 and 2.

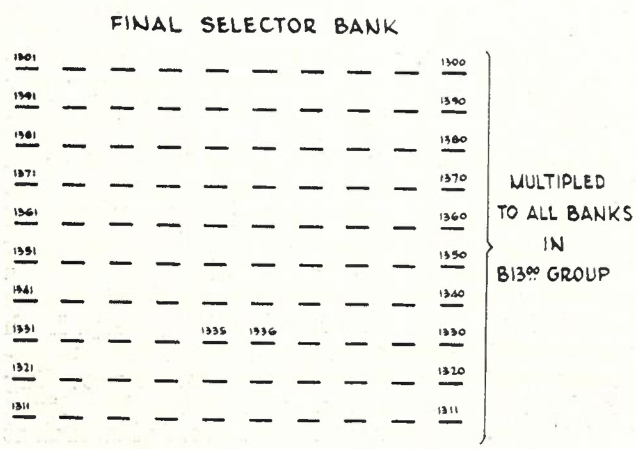

Fig. 1.—Siemens No. 16 Large P.B.X. Final Selector Bank.

Fig. 1 shows the layout of one bank of a Siemens No. 16 large P.B.X. final selector rack. Each contact represents one exchange line and there are one hundred numbers to the bank. (In this case B1300-B1399). If there are 80 banks in the B1300 multiple, this layout is repeated 80 times and the hundred contacts multipled over the whole 80 banks, that is, no matter how many switches and banks there are in the group, there can be no more than 100 lines connected, for example, B1300-99. Therefore, a subscriber requiring 25 lines would be allotted B1311-B1335; a reserve of say 15 lines would be allowed (B1336-B1340), the next subscriber's group starting from B1351. If the reserve of 15 lines proved inadequate for future growth, a second sequence would have to be started, and a second directory entry given.

Fig. 2A shows the layout of a similar bank on a 2000 type large P.B.X. final selector rack. In this

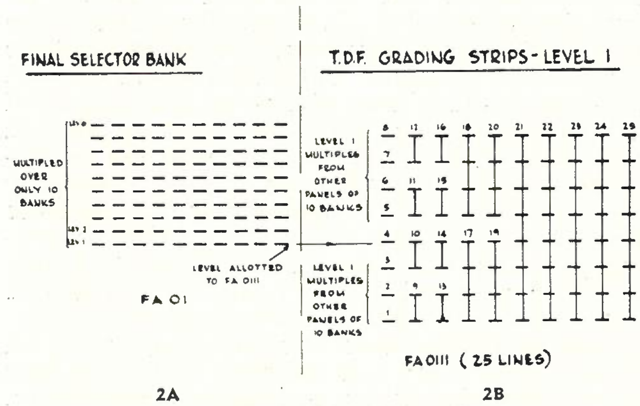

Fig. 2.—2000 Type Equipment.

case, however, each contact is multipled over only ten banks, and then extended to a T.D.F. grading strip. Thus, in the case of a group of 80 banks, 8 such multiples for each level would appear on the T.D.F. as shown in Fig. 2B for level one. By grading these 8 groups of 10 choices, a subscriber (say FA0111) may be given a group of 25 lines, using only one level of the final selector bank. Nine other subscribers could, therefore, be accommodated on the remaining levels. Future growth for the subscriber's group is provided by cutting commons on the grading, and jumpering the new choices, without using any additional bank multiple contacts. By installing additional bank multiples in the same group, a subscriber may be given any desired number of lines.

From this it can be seen that in the Siemens No. 16 system, growth of each subscriber's group is dependent on the spare consecutive contacts available in the existing multiple, whereas in the 2000 type system, growth is dependent only on the number of multiples which can be installed within the physical limitations of the exchange switchroom. As standard switch circuits are used for 2000 type large P.B.X. final selectors, equipment can be connected to the standard final selector routiner, thus ensuring a high standard of switch performance.

By means of overflow meters connected to the eleventh step of each subscriber's level, congestion of any group is brought to notice. Daily readings of overflow meters indicate if any additional lines are required by any particular large P.B.X. subscriber. When using this type of equipment several difficulties must be overcome. All lines cannot be night serviced, and the larger the subscriber's group the smaller the number of incoming lines which can be night serviced. This is readily seen by reference to Fig. 2B. Only lines which can be seized from all sources are suitable for normal night service and this applies only to common choices of the grading, for example, lines 21-25 in Fig. 2B, which could be reached by dialling FA0116, FA0117, etc. It has been found convenient to limit the number of night services on incoming lines to five.

A new method of numbering each line of a subscriber's group must be used (the numbering scheme used in Edison exchange will be explained later) and arrangements made to provide access from the test distributor to each line of each subscriber's group. There is a loss of efficiency due to grading of lines as against a full availability group. For example, a subscriber with 25 incoming lines in a full availability group in a Siemen's No. 16 large P.B.X. system would handle approximately 13 T.U. in the busy hour at the standard grade of service. A similar subscriber with 25 lines in a 10 outlet grading group out of 2000 type large P.B.X. equipment would handle approximately 11 T.U. at the same grade of service. However, if insufficient multiple reserve has been allowed in the Siemens group, and the lines are allotted in two sequences, say one of 12 and a second of 13, the traffic handling capacity at the standard grade of service would be reduced to approximately 10 T.U.

The Edison Exchange Installation

Due to heavy traffic overloads in the Central Exchange ("B") in Brisbane, it became necessary to transfer a large number of heavy calling rate lines out of the "B" exchange. In order to provide the maximum relief it was decided to establish large P.B.X. final selector equipment in Edison Exchange ("FA"-"FB") and to transfer large P.B.X. subscribers from Central, giving them their permanent FA and FB numbers.

Sufficient large P.B.X. final selector equipment to cater for 40 subscribers' groups has been installed, employing levels FA01, FA02, FB01, and FB02. The exchange layout provides for an additional 60 subscribers' groups within five years. Two large P.B.X. final selector racks have been installed for each group of ten subscribers, providing an ultimate of 14 shelves of which 12 are now in use. The number of switches installed in each group varies from 68 to 94, depending on traffic requirements. The final selector bank multiples are cabled to a number of T.D.F's, one per ten subscribers, on which grading of subscribers' lines is performed. Fig. 3 shows the layout of two such T.D.F's. The outlet side of each T.D.F. is cabled to large P.B.X. subscribers' I.D.F's, one per twenty groups, the M.D.F. and registers also being cabled to this point. A shelf of test final selectors is mounted on each I.D.F., the bank multiples being wired directly to the I.D.F. terminal strips.

By jumpering and commoning on the I.D.F. each line of a subscriber's group can be connected to a "P" wire resistor, uniselector or first selector, as required for the particular type of line. Unidirectional incoming lines are strapped to a "P" wire resistor for testing-in purposes, no uniselector or register connection being required. In Fig. 4 the equipment associated with twenty large P.B.X. subscribers can be plainly seen. Large P.B.X. final selector racks for the extension of Edison will be provided with grading facilities on the rear of each shelf, thus eliminating the need for T.D.F's and resulting in a considerable saving of floor space and switchboard cable.

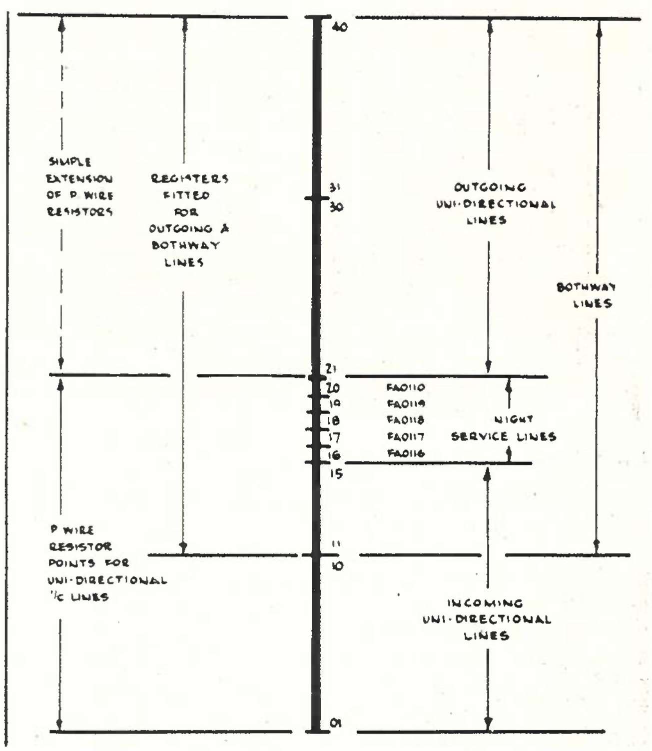

Fig. 3.—Numbering Arrangements—Typical 40 Line Group (FA0111)

Numbering Scheme. As each line of a subscriber's group does not necessarily represent a particular contact on the final selector bank multiple, a special numbering scheme is necessary. In the Edison installation it was decided that each individual line number should have some reference to the subscriber's main number for quick identification. To achieve this, the main calling number was followed by an oblique bar and two additional figures. Each individual line of a subscriber's group was numbered in sequence, that is, the first line of the FA0111 group would be FA0111/01, and the nineteenth line would be FA0111/19. This means that at any point in the exchange, on T.D.F's, I.D.F's, M.D.F. uniselectors, etc., the actual subscriber can be identified without difficulty.

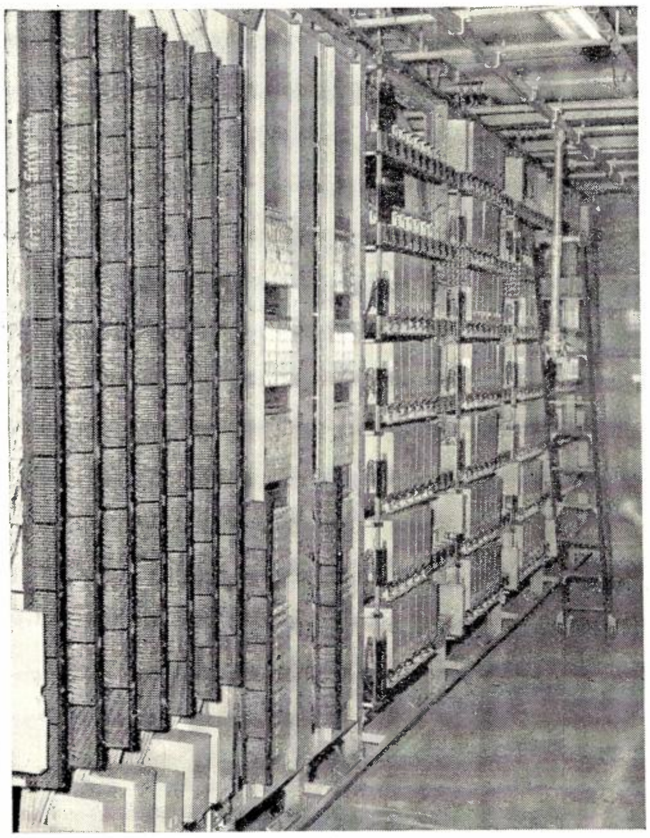

Fig. 4.—Large Group P.B.X. Final Selectors, with associated T.D.F's and I.D.F.

Any numbering scheme for large P.B.X. lines causes one slight difficulty to arise in that each final selector level must be tentatively allocated a certain number of lines; this amounting in some degree to a line reservation (not a multiple reservation) for each group. This problem is due to the need for cabling each final selector bank level to the T.D.F. during installation, but is overcome in the latest type equipment which has grading facilities on the final selector racks. In the Edison exchange an average size group of forty lines per subscriber has been allotted, groups varying in size from thirty to one hundred lines, but the groups are to some extent interchangeable and can be extended, also each group is arranged for either both way or unidirectional working.

The arrangement of lines within a typical 40-line group (e.g. FA0111) can be appreciated by reference to Fig. 5. Groups of various sizes are arranged similarly. The individual line numbers are FA0111/01 to FA0111/40. Of these, lines 01 to 20 are used for incoming lines and equipped with P wire resistance commoning points. Lines 21 to 40 are used for outgoing lines and are equipped with registers. To cater for night service and bothway lines, registers are fitted to lines 11-20, night service lines being jumpered to lines 16-20, the directory entries being FA0116, FA0117, etc. When an entire group of bothway lines is required, the first line is connected on line 11, as there are no registers on lines 01-10.

In order to use large P.B.X. equipment to the best advantage, all P.B.X. groups of 15 or more lines should be divided into unidirectional incoming and outgoing lines, with bothway night serviced lines. Groups of 14 or less lines should retain full bothway working. This practice has been followed and the numbering of a typical bothway group of 14 lines is, lines 11-15 bothway, lines 16-20 bothway night service, lines 21-24 bothway. The night service lines in this case are still allocated to lines 16-20 to save re-arrangement should the group grow large enough for unidirectional working. In allotting the appearances of bothway exchange lines on P.B.X. manual positions it is also customary for the order of selection of lines by the telephonist and the automatic equipment to be in opposite directions; this facilitates operating and tends to equalise the traffic loading over the lines.

Before allotting numbers to subscribers, manual traffic counts and automatic traffic measurements were taken to determine the present requirements of each subscriber, the groups arranged to allow for 100 per cent. growth to meet future requirements. If future growth is required beyond that allotted, the outgoing sequence can be taken out of the large P.B.X. group and connected to ordinary exchange numbers, the incoming group being allowed to expand, thus allowing for a possible 400 per cent. increase in exchange lines. Any increase beyond this would require some re-arrangement of the existing grouping. In Edison exchange the average number of lines required for each subscriber was 21, this being the principal factor in allowing for an average group of 40, with possible rearrangement to 80.

Testing Arrangements. Due to the adoption of the numbering scheme previously explained, test distributor access is considerably simplified. Special test final selectors are mounted on a shelf on each I.D.F. and the test final bank multiple wired directly to the subscriber's line circuit. To test a particular line, say FA0111/21, the testing officer, using the FA test distributor, dials the subscriber's number, that is, 0111, followed by the line number, in this case 21. Testing is then performed in the normal manner. Consecutive line numbers, that is lines 22, 23, 24, etc., can be selected by dialling an additional unit when each line in sequence is required.

Routing of Outgoing Traffic. Due to the very high calling rates experienced on unidirectional outgoing lines from P.A.B.X.'s and the difference in the calling rates of various types of lines, all traffic originating from large P.B.X. subscribers in Edison exchange has been divided into three groups. A possible fourth group may be required at some later date. These groups are:—

(1) Lines with a measured busy hour calling rate of greater than 0.5 T.U. are connected directly to individual first selectors. At this calling rate it is not economical to provide uniselectors. These lines, of which there are approximately 80 in the present Edison exchange, are mostly first choice outgoing lines from busy P.A.B.X's, and many of them have a measured busy hour calling rate of approximately 1 T.U. Connection is made by means of two triple jumpers, one on the large P.B.X., I.D.F., and the other on the uniselector T.D.F., a two relay circuit being included in the trunk to facilitate testing. Meter terminals on the I.D.F. are commoned to the "P" wire and earth respectively to bring the subscriber's register into circuit. First selectors, directly connected to subscriber's lines in this manner, are provided with a specially coloured designation for identification purposes.

(2) Lines with a busy hour calling rate of from 0.2 T.U. to 0.5 T.U. are connected to a uniselector group with a large outlet grading to cater for dense traffic loads. Connection is made by means of a five-wire jumper on the large P.B.X., I.D.F. to connect any desired uniselector in the group. Uniselectors are allotted in columns instead of the usual rows to obviate the risk of congestion being experienced in any particular outlet grading group.

(3) Lines of less than 0.2 T.U. busy hour calling rate are connected to uniselectors in the normal exchange uniselector field. These lines are mostly last choice outgoing lines, bothway or night service lines. Approximately 10 per cent. of the medium calling rate lines from group (2) are included in this section in order to increase traffic in this group. Connection is made by means of two five wire jumpers, one on the large P.B.X., I.D.F., and one on the normal subscriber's I.D.F.

(4) Lines with a very low calling rate may at some future date be catered for by a fourth outgoing group. Night serviced incoming exchange lines which originate no outgoing traffic in the day time and very little at night, would fall into this category. These lines could be catered for by the installation of one four hundred line composite line finder rack, with about six directly connected primary line finders in each of the two groups. Connection would be made by means of one five-wire jumper on the large P.B.X., I.D.F. This would prove a very economical method of dealing with this type of line which at present is connected to an individual uniselector as is group (3).

Before the cutover of large P.B.X. subscribers to the Edison exchange, the calling rate of each outgoing and bothway line from every subscriber was measured, and the results used to divide the lines into the foregoing categories, thus ensuring that each subscriber's line and all exchange equipment is being used as efficiently and economically as possible.

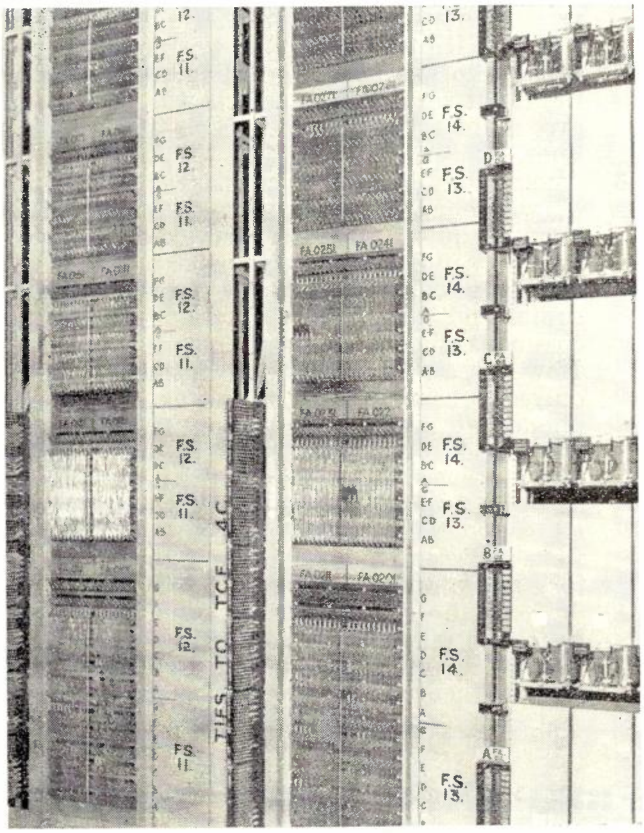

Fig. 5.—T.D.F's, showing grading of outlets from large group final selectors.

Special Arrangements. Included among the subscriber's cutover to 2000 type large P.B.X. equipment in Edison exchange are many types of commercial, industrial and government subscribers. In providing for the various requirements of these different types of service in the large P.B.X. field, much experience has been gained which will be of great help to both Engineering and Telephone Branch officers in dealing with future cutovers of this nature.

Some of these special requirements will be briefly described.

(1) Some subscribers required more night service lines than were available on the five common choices of their final selector grading. These were made available by allotting ordinary exchange numbers to some of their outgoing group, and providing night service on these lines with suitable directory entry. Due to the flexibility of the jumpering arrangements in Edison exchange, no loss of efficiency occurs

on these lines in the daytime, as they can still be connected to direct first selectors, large P.B.X. uniselectors, or ordinary uniselectors as required by their particular busy hour calling rate.

(2) One subscriber requiring extra night service lines, had six extensions connected to an extension switchboard which was staffed at night. These extensions were night serviced as a rotary group within the main incoming group. With this method it was no longer necessary to use all full grading commons for the night service lines, and it was possible to give night service conditions on ten incoming lines.

(3) Another subscriber, a considerable quantity of whose advertising business occurs after hours, required the night service of the main directory number for this purpose. This is not usually possible with 2000 type large P.B.X. equipment, due to the fact that full grading commons should be used for night service. However, as all advertising business was required to be dealt with on two extension telephones at night, satisfactory arrangements were made by fitting these two instruments to a non-switching unit, and the night service of up to 10 lines to the unit. By this means, all early choices of the final selector grading were intercepted, and no night service directory entry was required.

(4) An hotel in which guests initiate a large number of trunk line calls, required trunk line booking on a number other than the main directory entry, for accounting and identification purposes. This was arranged by booking trunk line calls on the sixth choice of the grading, that is, on FB0136, instead of FB0131, thus giving a rotary search group of five lines within the normal searching group.

Brief Outline of Cutover. Cutover of the 35 subscribers to large P.B.X. equipment in Edison exchange took place on the Saturday afternoon and Sunday preceding the issue of the new directory. Each subscriber's number change took place to a timetable, acceptable to the subscribers, and lines were cutover one at a time, or in groups, depending on whether or not continuous service was required. The old numbers were immediately placed on interception, each interception position dealing with one large, or two small subscribers.

Exchange installing staff, working in conjunction with P.A.B.X. and subscribers installing staffs located at the subscriber's premises, performed the cutover, and every line concerned was tested and proved when rearrangements were completed. On P.B.X. switchboards where previous bothway lines were converted to unidirectional calling, variously coloured designations were provided for the identification of incoming, outgoing and bothway lines. All telephonists had been previously instructed in the new arrangements.

Thanks to the active co-operation of Engineering Branch staffs, Telephone Branch officers, and representatives of the subscribers themselves, not one line was out of service at the start of business on the Monday morning following the cutover, and subscribers were enjoying a more efficient and better grade of service.

FREQUENCY SHIFT KEYING RADIO TELEGRAPH EQUIPMENT.

D A. Brooke, B.Sc.

Introduction: Over the past ten to twelve years, one of the outstanding developments in point-to-point radio communication techniques has been concerned chiefly with the improvement of radio telegraph reliability to facilitate the introduction of time-division multiplex systems using direct printing equipment, and to ensure continuous communication under difficult radio conditions. These have led to the introduction of frequency shift keying techniques. It is intended in this article to give a brief historical survey of the development of this method of working, describe the equipment used on a typical point-to-point H.F. Departmental radio telegraph circuit working between Perth, Western Australia, and Melbourne, Victoria, and present and discuss some results of performance tests carried out on this link.

History of Development: In the earliest days of radio telegraphy, skilled operators using a hand key for transmission and aural reception could seldom copy at working speeds in excess of 20 words per minute, even under the best circuit conditions. However, a remarkably high degree of accuracy could be maintained on very weak or noisy signals due to the discriminating ability of the human ear to "sort out" the wanted from the unwanted signals. The success of the early circuits soon brought requirements for greater efficiency in the use of the radio circuit to increase the message handling capacity for the use of higher signalling speeds and the use of the direct printing methods then becoming available. The application of these techniques, borrowed from wire telegraphy, soon revealed that the increase in circuit speed consequent upon the removal of the human operator also removed one of the operator's most valuable contributions, the ability to discriminate between signal and noise. It was soon found that a radio telegraph circuit using the newer mechanical "operator" required a much better signal to noise ratio. This requirement led to the development of improved apparatus, the use of higher transmitter powers, and high gain aerial systems, resulting in more reliable and higher speed traffic circuits.

Up until this time the keying methods in use, utilised almost exclusively, and regardless of the particular signalling code employed, the transmission of the carrier wave for the "mark" and the interruption of the carrier for the "space." For some time it had been known that intelligence could also be transmitted by varying the frequency of the radio carrier wave, but it was not realised that some advantages could be obtained by using this keying method. In the very early days of radio telegraph transmission using arc transmitters, the signalling method used was by frequency shift, although the technique was then not recognised as such. Since it was not possible to interrupt the arc at normal telegraphic speeds, it was the practice to vary the transmission frequency by several kilocycles per second for the "space" condition by short-circuiting part of the tuning coil with a relay or similar device operated from the telegraph key. The receiver was tuned to the "mark" frequency and normal "on-off" reception was used. It was not apparently realised that the "space" frequency also transmitted intelligence and hence this only represented a loss of power and possible interference to other transmissions. With increased occupancy of the radio spectrum and hence increased interference from other transmissions some operators became sufficiently skilled to copy the "space" signal when the "mark" frequency was subject to bad interference, often by the "space" signal of some other transmitter. Little development and use of the system was made in the intervening period prior to the outbreak of World War II, but since 1940, many successful units have been placed into operation (Refs. 1, 2, 3, 4).

Principle and Methods of Frequency Shift Keying: The principle of frequency shift keying involves the transmission of two slightly different frequencies for the "mark" and "space" signalling conditions. The amount of frequency shift used varies from system to system, and may even be varied in one system to suit certain operating conditions, but is usually of the order of a few hundred cycles per second. In the system installed on the Melbourne-Perth link, the total frequency shift is the C.C.I. recommendation of 850 c/s, that is, plus and minus 425 c/s from the assigned frequency, and by convention, the "mark" signal is taken to be higher frequency of the two. The chief difference between the present day systems and the earlier transmissions is that in the former the frequencies corresponding to "mark" and "space" are both used to convey intelligence.

At the present state of the art, there are two main methods by which frequency shift transmission can be achieved. The first method is by "pulling" the frequency of a crystal or master oscillator by keying additional capacitance into the oscillator circuit, either directly or by means of a reactance tube. The second method employs a reactance tube controlled oscillator, the output of which is mixed in a balanced modulator circuit with the output of a crystal oscillator. The upper sideband output is then applied to the power amplifier stages of the transmitter. Apart from the frequency control and keying sections, the transmitter is quite conventional, and equipment normally used for on-off keying or radio-telephony may be adapted for frequency shift working by using a frequency shift exciter employing either of the above methods in place of the normal oscillator unit. The "pulled" crystal method is not greatly favoured except for mobile installations, where its simplicity and small weight are advantageous. The distinct change of frequency upon keying causes keying transients and produces distortion of the transmitted frequencies. Crystal characteristics affect the amount of frequency shift, and the method cannot be used where a continuous variation of frequency is required, such as for facsimile. The mixing oscillator method is superior, although more complex, since keying transients are eliminated and distortion minimised by the use of reactance tube control. In addition, the frequency shift is independent of the characteristics of the crystal as the frequency shift occurs in the low frequency oscillator and not in the crystal oscillator stage. Also, as the frequency shift may be continuously varied from zero to its normal value, facsimile and picture transmission are possible.

Many methods of frequency shift reception have been developed, most of which differ only in detail, the choice of any one system depending on the application. The receiver units are fairly conventional and do not greatly differ from those employed in on-off telegraph reception. It is usual to operate in dual diversity, the receivers being of the superhetrodyne type with common frequency determining oscillators of high stability, usually crystal controlled and temperature compensated, a common automatic gain control system and means of combining the final outputs in the detecting stages. The main differences in the various methods appear in the means employed for dealing with the frequency shift signals after passage through the receiver units. Two methods of frequency shift reception have found considerable application; these are known as the discriminator and audio filter methods. In discriminator detection, the signal from the receiver at the receiver intermediate frequency is converted to a low I.F. in the region of 50 kc/s, limited and fed to a discriminator as used for F.M. radio-telephony. The discriminator output is then a variable positive or negative D.C. voltage, depending on whether the incoming signal corresponds to a mark or space. This output of square-wave form operates a telegraph relay sending to line. In the audio filter method, the receiver output is two audio frequency tones spaced by the amount of the frequency shift, one tone corresponding to transmission of mark signal and the other corresponding to the space. The tones are amplified, limited and passed through two narrow bandpass filters to separate the two tones which are then separately amplified and rectified to operate a telegraph relay. Consideration of this method will show that the two audio filters actually constitute a non-linear frequency discriminator. A comparison between the two methods of frequency shift detection would be rather too lengthy to discuss in this short article, but in general it can be stated that the discriminator type gives somewhat more distortion than the filter type, but it can tolerate much greater frequency drifts, both of carrier and of shift or deviation. A more detailed comparison between the different methods of obtaining frequency shift reception and transmission may be found in Refs. 5 and 6.

It will be appreciated then, that both the transmitter and receiver of a frequency shift system require a high degree of stability in the frequency determining elements. The requirement of stability of a few cycles per megacycle, both for the amount of frequency shift and the nominal value of the carrier frequency, can be noticed in equipment design, as the achievement of such stability can be obtained only by the application of modern techniques.

Frequency Shift Transmitter: The transmitter on the Melbourne-Perth link is of the mixing oscillator type. This method employs the telegraphic signals to operate a reactance tube controlled oscillator on a low frequency, the output of which is mixed with a H.F. crystal oscillator, the upper sideband frequency of the combination selected, frequency multiplied and amplified to the required final frequency and power output.

For convenience, the transmitting side of the equipment is divided into two parts:—

(i) The Drive Unit or frequency determining element and low power amplifier stages.

(ii) The Transmitter proper, consisting of frequency multiplying and power amplifying stages.

Physically, the Drive Unit is built up of a number of standard 19-inch panel mounting units fitted into a cabinet type rack 5 feet high, making a compact self-contained unit. The cabinet also contains all necessary power supplies, and is operated from single phase 230 volt 40-60 c/s power mains through a voltage regulating transformer mounted in the bottom of the cabinet. The transformer ensures a constant voltage supply to the unit irrespective of all supply or load variations and contributes materially to the stability of the transmitter equipment. Fig. 1 shows a photograph of the F.S.K. Drive Unit. A block diagram of the Drive Unit is shown in Fig. 2, and the unit will accept telegraph signals, either DC pulses on a single or double current basis up to speeds of approximately 80 bauds, or keyed tone signals as in facsimile up to 500 dot cycles per second. The tone signals are fed directly from line into tone amplifiers, the output of which is kept constant by an A.G.C. circuit. In the case of either single or double current DC telegraph pulses, these are switched first to a modulator using copper oxide rectifier elements and which is also supplied with

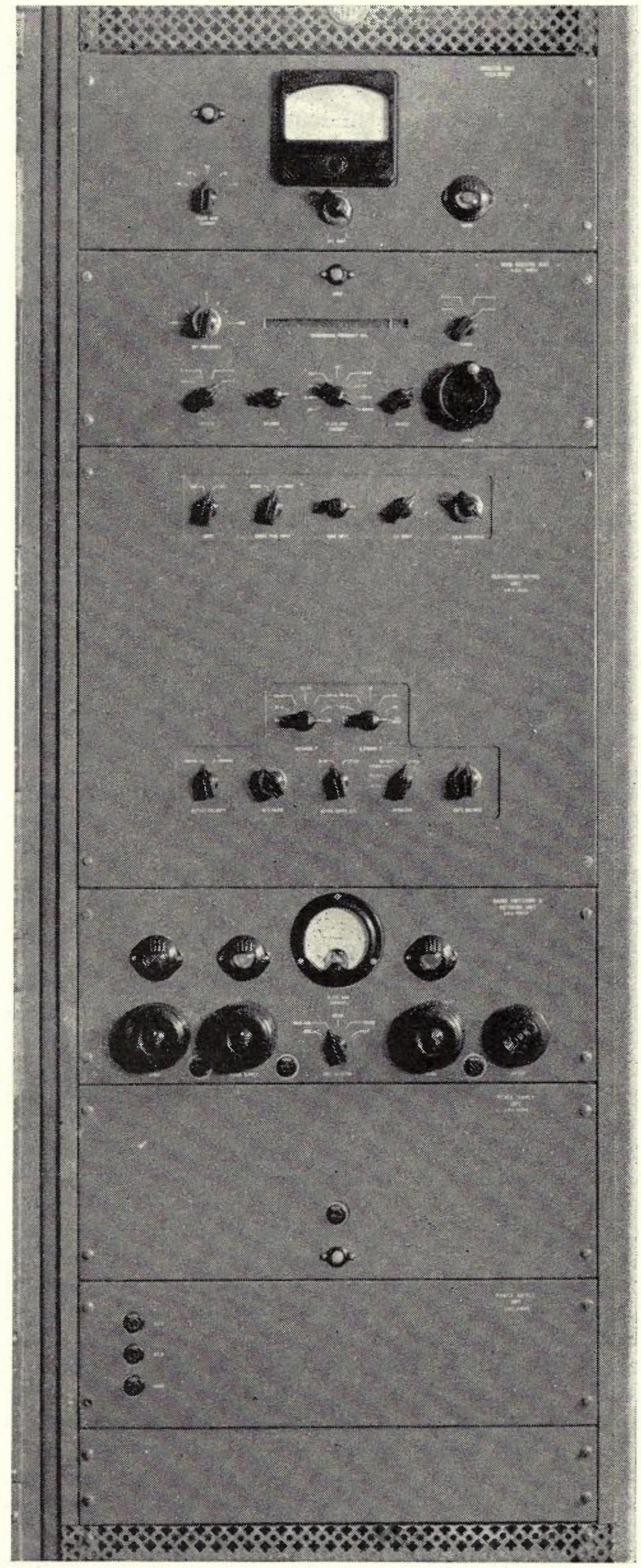

Fig. 1.—Front view of F.S.K. Transmitter Drive Unit in cabinet type rack, showing standard 19 in. panel mountings.

4.7 kc/s tone from an oscillator, and then into the tone amplifier. The output of the tone amplifier is rectified to produce DC pulses corresponding to the incoming telegraph signals and after filtering operates a DC amplifier and Eccles-Jordan trigger circuit. The keyed output from the trigger stage operates a further DC amplifier and is applied through a shaping filter to the Exciter Unit. The shaping filter changes the square-wave output of the trigger stage to a somewhat trapezoidal form, to reduce the bandwidth required and eliminate keying transients.

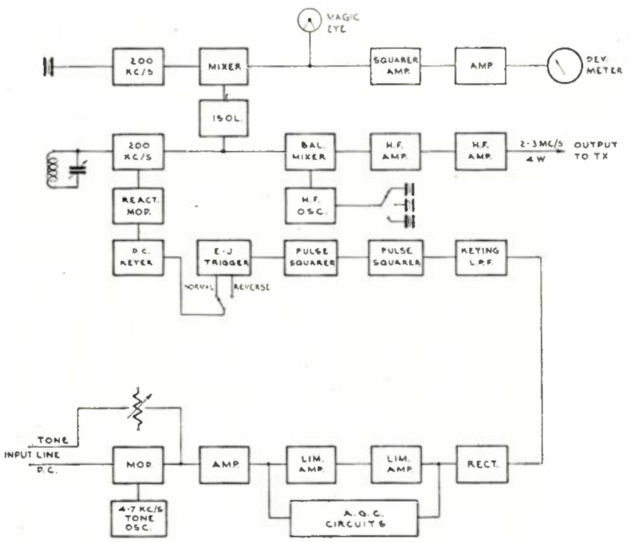

Fig. 2.—Block diagram of F.S.K. Drive Unit. Power supplies for the individual units are not shown.

The Exciter Unit comprises a reactance tube associated with a 200 kc/s variable frequency oscillator so that the keyed DC output of the keying unit applied to the reactance tube produces frequency shift operation of the variable oscillator. The frequency shifted variable oscillator output together with the output of a H.F. crystal oscillator is applied to a balanced mixer, the upper sideband frequencies selected, and amplified in a tuneable RF amplifier section to a power level of the order of 1 watt. The lower sideband is suppressed by the RF stages, and selection of the crystals determines the transmitted frequency.

A Monitor Unit is also provided to enable the nominal carrier frequency to be set accurately to its correct value. In this unit, the output of the 200 kc/s variable oscillator is mixed with the output of a precision temperature controlled crystal oscillator of 200 kc/s, and the beat frequency applied to a magic eye tube as a zero set device for correct carrier frequency adjustment, and to a frequency measuring circuit for checking and adjusting the amount of frequency shift. For those radiated frequencies which necessitate frequency multiplication of the Drive Unit output, then both the nominal frequency and the frequency shift will be multiplied in the same ratio. Normally this would require a readjustment of the frequency shift each time the multiplication ratio was changed, such as when the transmission frequency was changed. This need for shift readjustment has been obviated by coupling with the crystal selection switch a voltage dividing network, whereby the DC voltage to the reactance tube in the Exciter Unit is reduced from its normal value in the same ratio as the amount of frequency multiplication. Hence, after adjustment of the frequency shift to ± 425 c/s, the required submultiple is selected automatically with the crystal and an extension on the switch also changes the scale of the Monitor Unit frequency meter to give a corresponding presentation of the indicated shift. The Exciter Unit may also be used for "on-off" operation in which condition the D.C. amplifier provides a keyed high negative voltage to control the first HF amplifier stage.

The transmitter, a simplified block diagram of which appears in Fig. 3, conforms to standard practice and consists of a number of frequency multiplying or buffer stages, the function of which depends on the frequency range being used, and power amplifying stages. The input to the transmitter is of the order of 1 watt in the frequency range 2 to 3.5 mc/s, and the output is in the frequency range 2 to 30 mc/s at a level of 1 kW.

The construction of the transmitter represents a rather novel departure from normal practice. It comprises two main units—the R.F. circuits and the power supplies (shown in Fig. 4). The two

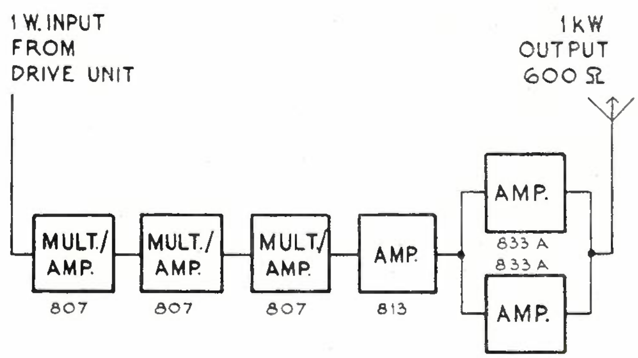

Fig. 3.—Block diagram of F.S.K. Transmitter. No power supplies shown.

units each occupy cabinets measuring 20 inches wide by 32 inches deep, by 6 feet high, and placed side by side. The cabinets are on rollers running in rails bolted in place on the floor, and pull out to allow doors on both sides of the units to be opened for servicing all circuits. All power and control leads and the coaxial input cable enter the rear of the cabinets through flexible metal conduit, and the aerial output circuit is completed through spring-loaded plugs when the R.F. cabinet is in the "home" position. These features, plus the provision of manual operation of the door safety interlock switches, allow operation of the transmitter, with the exception of the final stage, when either cabinet is drawn forward on its rollers. Fig. 5 shows the power supplies cabinet construction through the open side door, and the R.F. cabinet in the forward position is shown in Fig. 6. The method of construction used in the 1kW output stage may be seen in Fig 7.

Frequency Shift Receiver: The Frequency Shift receiver used is of double space diversity type and has been fully and admirably covered in a published paper (Ref. 6). A block diagram appears in Fig. 8, and it will be seen that the receiver is of

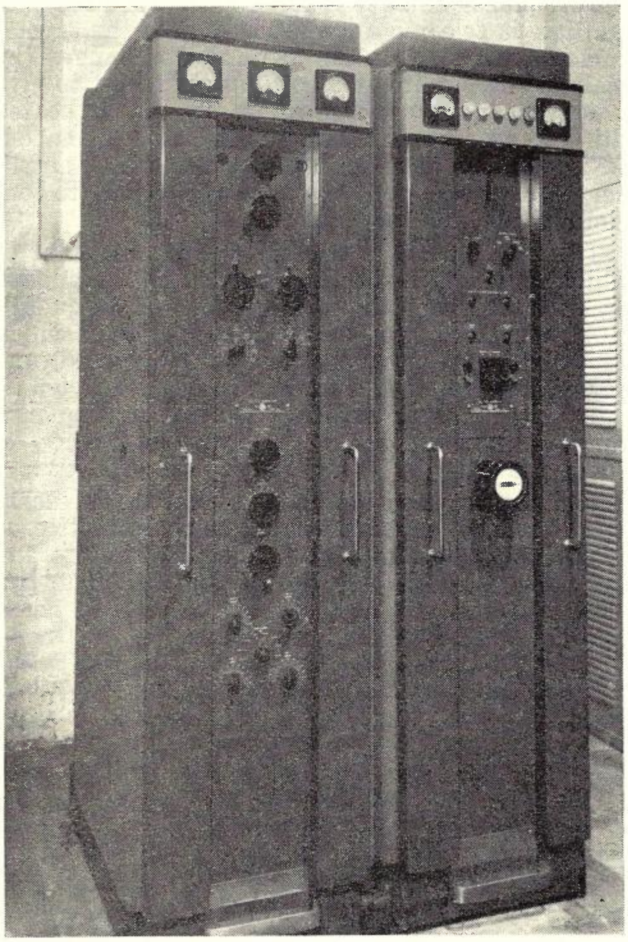

Fig. 4.—F.S.K. Transmitter, showing unit cabinet style construction with R.F. unit on the left and power supplies unit on right.

the filter type and uses narrow band-pass filters to separate the two audio tones resulting from the detection of the radio frequency signal. Lindsay, in his article, fully discusses this method and the advantages over the discriminator method.

Briefly, the receiver consists of a double diversity system of fairly standard pattern, with common H.F. and B.F. oscillators, the B.F.O. frequency 452.45 kc/s being so chosen that two separate A.F. tones are produced for the "mark" and "space" frequencies, in this case 2125 and 2975 c/s respectively. The two tones pass through a 1800-3500 c/s band-pass filter for noise reduction, an A.F. limiter to eliminate level variation, and are then separated by narrow bandpass 2125 ± 300 and 2975 ± 300 c/s filters respectively. The separate tones are further amplified and rectified to operate D.C. amplifier stages controlling a telegraph relay. The output is thus positive and negative D.C. pulses corresponding to "mark" and "space" signals respectively. The D.C. pulses from both receivers combine in a common telegraph relay to give the resultant diversity working. A differential noise suppressor circuit is also included to suppress the output of the channel in which noise appears and at the same time produce a compensating increase in current from the other channel. For convenience in setting up and adjusting the receiver, oscillators supplying "mark" and "space" frequency tone are provided, together with a frequency deviation indicator. This unit accepts the 2125 and 2975 c/s audio output of the receivers and after mixing with a fixed oscillator of 2550 c/s, the resultant 425 c/s

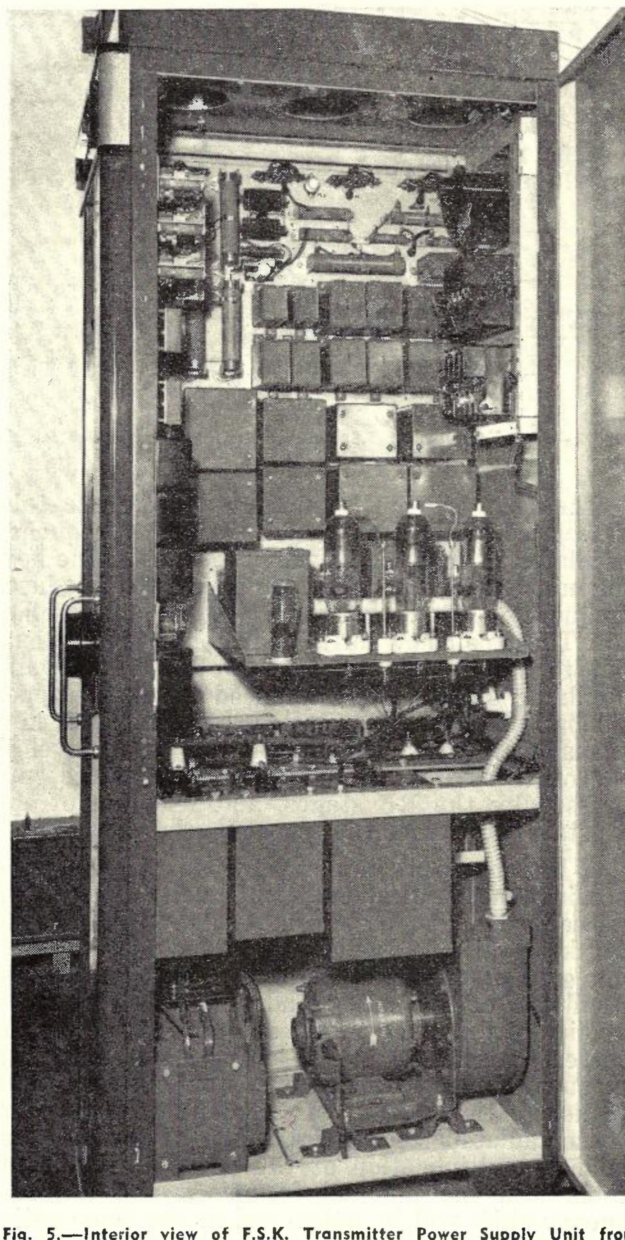

Fig. 5.—Interior view of F.S.K. Transmitter Power Supply Unit from side.

beat frequency is fed to a discriminator circuit, the D.C. output of which operates a frequency deviation indicator calibrated 100-0-100 c/s. With the transmitter and receiver circuits set up correctly, the meter will read zero for either mark or space condition, and during operation allows observation of change of deviation or drift in centre frequency adjustment of the transmitter.

Automatic frequency control is provided on the receiver for use under those conditions when, for reason of centre frequency drift or frequency shift variation, the Crystal and Manual positions of the B.F. oscillator cannot be used. The A.F.C. circuit is operated from the "mark" audio output of both receivers, the audio tone being amplified and passed through a 2125 c/s discriminator circuit to derive a D.C. voltage to operate a reactance tube controlling the B.F. oscillator. Special precautions are taken to guard against false or incorrect operation of the A.F.C. circuits by the "space" signals.

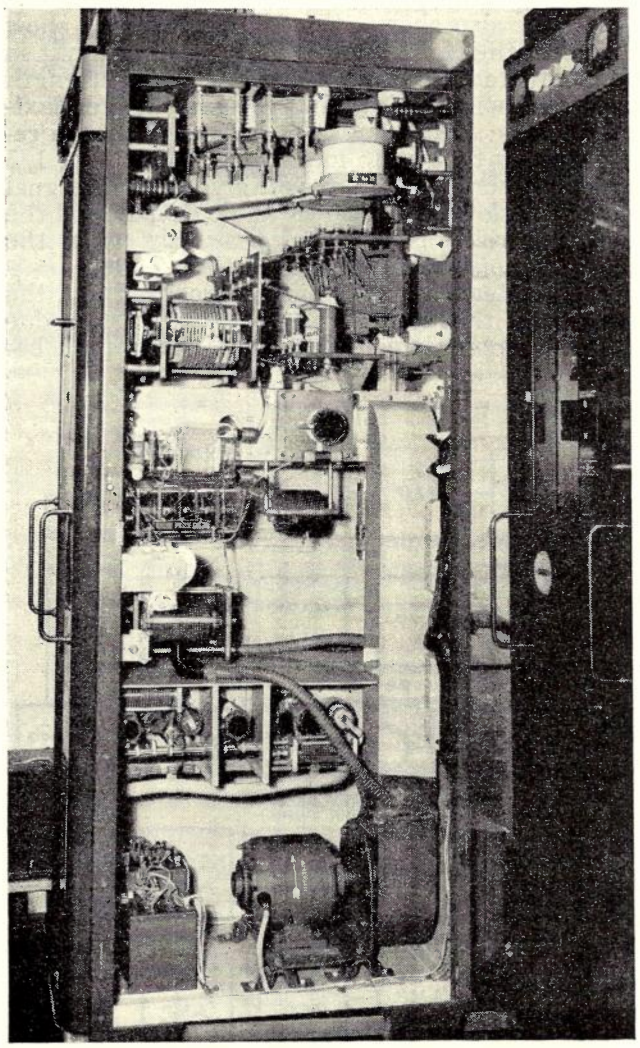

Fig. 6.—Interior side view of F.S.K. Transmitter R.F. Unit, showing circuit layout.

The receiver is similar in style and construction to the transmitter Drive Unit, and consists of a number of 19 inch panel mounting units housed in a cabinet 7 feet 6 inches high and 14 inches deep, with a full length hinged door at the rear. Fig. 9 shows the layout of the receiver cabinet, and each individual rack unit has its own power supply on the same chassis. The complete receiver is powered through a voltage regulating transformer from 230 volt 40-60 c/s single phase mains.

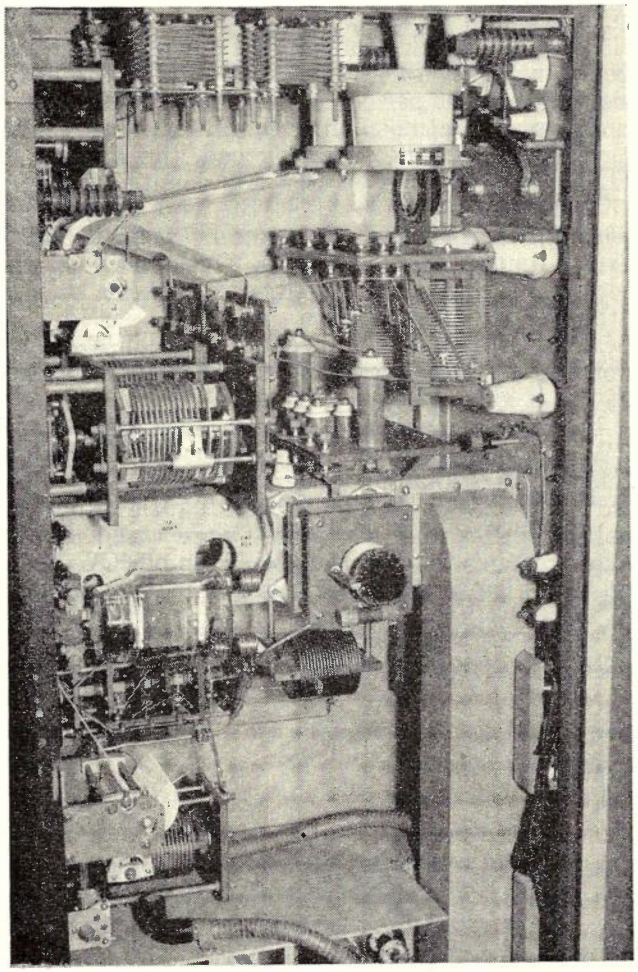

Fig. 7.—Details of 1 K.W. output stage of F.S.K. Transmitter Unit.

Description of Test Setup: After installation of the link, measurements and comparison tests were made to evaluate the advantages of this type of radiotelegraph transmission. One section of the tests was a direct comparison between FSK and on-off CW signals for the same circuit conditions. Rhombic aerials located on reciprocal Great Circle bearings are used at both the transmitting and receiving locations of this link. At the receiving site, two spaced rhombics are employed in order to make full use of the diversity facilities of the equipment. Alternatively, a number of different types of aerials located on various bearings, are available to the receivers for special tests. The field strengths of the incoming signals, both for the two receivers independently and also in diversity were recorded by means of pen recorders. The send teleprinter was connected by landline direct to the input of the Transmitter Drive Frequency Shift Keying Unit, whilst the receiver relay loop was extended back to the receive teleprinter located at a position adjacent to the send machine.

The general procedure followed in making comparative tests was to transmit a repeating tape for a period of 15 minutes with the circuit set up for one set of conditions. The next 15 minutes, the circuit would be set up for another set of conditions and the link would then be kept alternating between the two sets of conditions for the duration of the test period. In this way, fading cycles and varying atmospheric conditions were averaged out. At the receiving end, the number of errors made by the printer was counted for each 15 minute interval, and at the end of the test period, a comparison was made between the total errors under each condition. Over most of the test periods, the observed errors were due to atmospheric noise, any record taken during periods of radio interference or local electrical noise at the receiver being rejected for purposes of the trial.

For the comparison between FSK and on-off CW methods of signalling, the five-unit stop-start teleprinter signalling code was used with FSK working, and for on-off CW working, the same signalling code and machines were used in an arrangement to give simulated on-off CW transmission. The transmitter drive unit was operated in the ON-OFF condition with the polarity switch in the REVERSE position. By this means, the rest position for teleprinters of sending mark to line was represented by "carrier off" at the transmitter which is the normal rest condition of a CW system. A space from the send teleprinter then places the transmitter in the "carrier on" position. At the receiver, the tuning was so arranged that the transmitter carrier was placed in the MARK filter passband, and with the polarity switch in REVERSE, a space was sent to line. Thus, correct operation between send and receive teleprinters was obtained with simulated on-off CW transmission.

Test Results: With a maximum use of two frequencies daily, the link has proved to provide a 24 hour reliable circuit apart from occasional short duration black-outs due to ionospheric disturbances. Most of the black-outs experienced over the past 14 months have been from 5 to 30 minutes in duration and are generally characterised by an extremely large reduction in received field strength. One such fade-out is shown on the lower field strength recorder chart appearing in Fig. 10. This fade-out occurred at noon and was accompanied by rather disturbed ionospheric conditions which are also shown. The top two graphs show an interesting feature of this particular circuit in the characteristic rapid decline in signal strength associated with the evening decrease in the maximum usable frequency. Measurements on the receiver show that at 15 mc/s, an R.F. input of 1/5 microvolt across 75 ohms will give a 10 db signal to noise ratio at the receiver audio output, and the telegraph relay is operated positively when the signal to noise ratio is greater than 7 db.

The systematic distortion introduced by the equipment, that is, the telegraphic distortion due to the radio equipment and propagation path be-

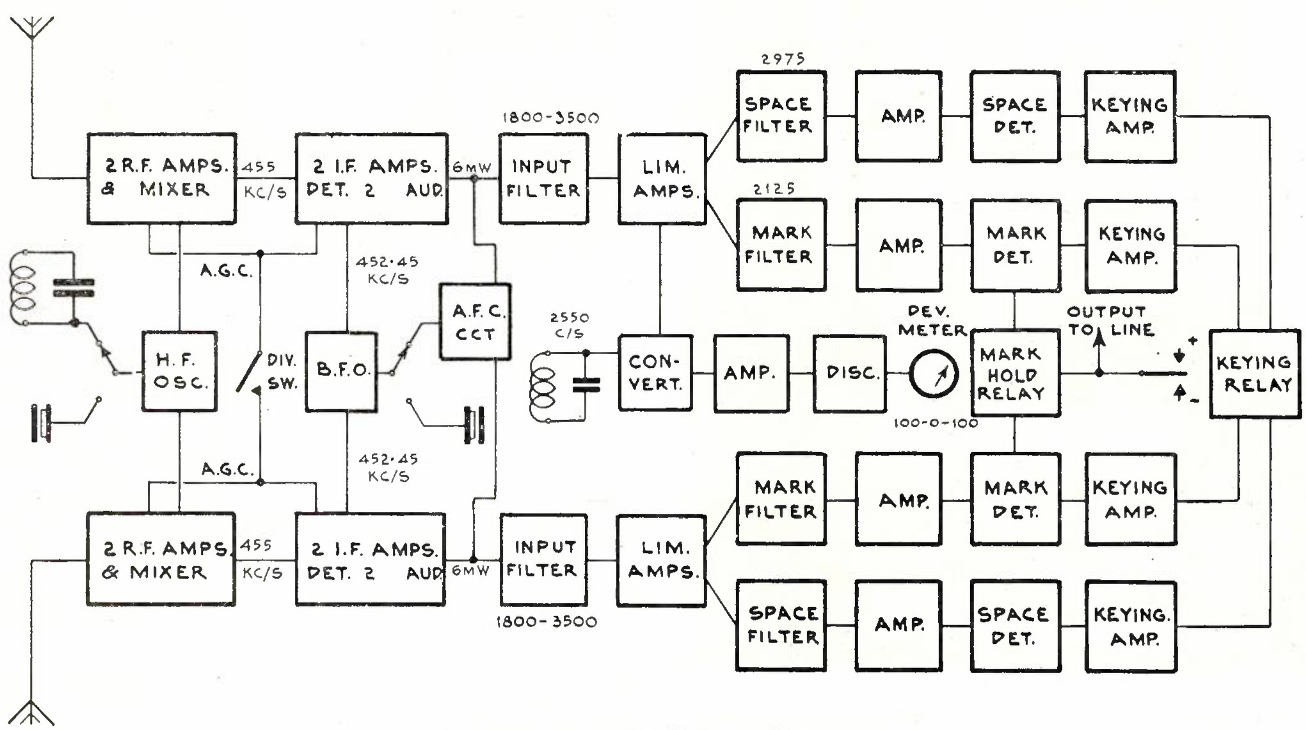

Fig. 8.—Block diagram of dual diversity F.S.K. receiver.

tween circuit terminals, under normal conditions is of the order of 5 per cent. However, under conditions of low signal strength or poor propagation, increasing radio distortion characterised by random time shifts of the edges of the signal elements caused by noise and other irregularities, reduces the margin of the signal elements.

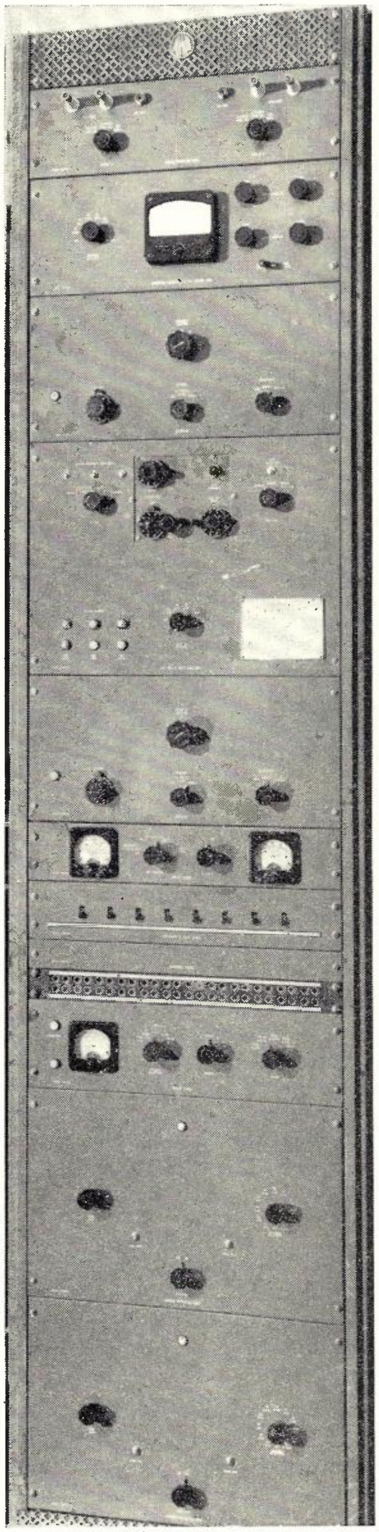

Fig. 9.—Front view of F.S.K. Receiver. The cabinet type rack houses dual diversity receivers and all associated circuits.

As an indication of what performance the system is capable of giving, an extensive run was undertaken during which an error count was made of over 400,000 characters for various received signal field strengths. Fig. 11 gives a graphical analysis of these results, and it will be seen that for an accuracy of one error in ten thousand characters, a field strength of approximately 20 microvolts per meter is required when dual diversity Frequency Shift Keying with 850 c/s shift is used. In the case of dual diversity C.W. telegraphy, a field strength of the order of 100 microvolts per meter was found to be necessary to give the same order of accuracy, as seen in Fig. 12. It is reported in Reference 4, that under similar conditions, field strengths of 10 microvolts per meter for the dual diversity Frequency Shift and about 40 microvolts per meter for triple diversity C.W. working, were necessary for errors of the same magnitude. It is interesting to note that although the field strengths for given errors are different, the law of variation of error with field strength, of the graphs shown in Figs. 11 and 12 is almost exactly the same as that obtained in the above report. The comparison in error count was made under exactly similar conditions since the same transmitter and receiver were used for both the F.S.K. and on-off trials, and arrangements were made for equal power to be radiated in both cases, with alternate 15 minute periods of each type of transmission. For these conditions a comparison between the two error counts shows that the dual diversity F.S.K. working has a gain of about 14 db over dual diversity C.W. working.

During an extension to the previous test, in an effort to determine the gain of dual diversity reception over a single receiver in F.S.K. working, it was noticed that very wide discrepancies were obtained. Under normal working and propagation conditions when circuit noise is the limiting factor, the dual diversity system had a gain on error count of the order of 8 db, but under poor propagation conditions, and especially when working the circuit close to the maximum usable frequency, the gain was very much higher. In extreme cases, it has been found that whereas with dual diversity working the circuit is usable with an error count of 2 or 3 per 1000 characters, on switching to single receiver, the circuit becomes useless with more than 50 per cent errors. It is during such periods of selective fading or multipath propagation that the true benefits of diversity F.S.K. working are realised. This effect noticed when multipath distortion is a limitation has been reported by others to give a considerable diversity gain, which cannot be expressed on a power basis since this type of distortion causes errors independent of power.

Advantages of the Frequency Shift System: The foregoing information and data has been compiled as a result of a series of tests on a typical

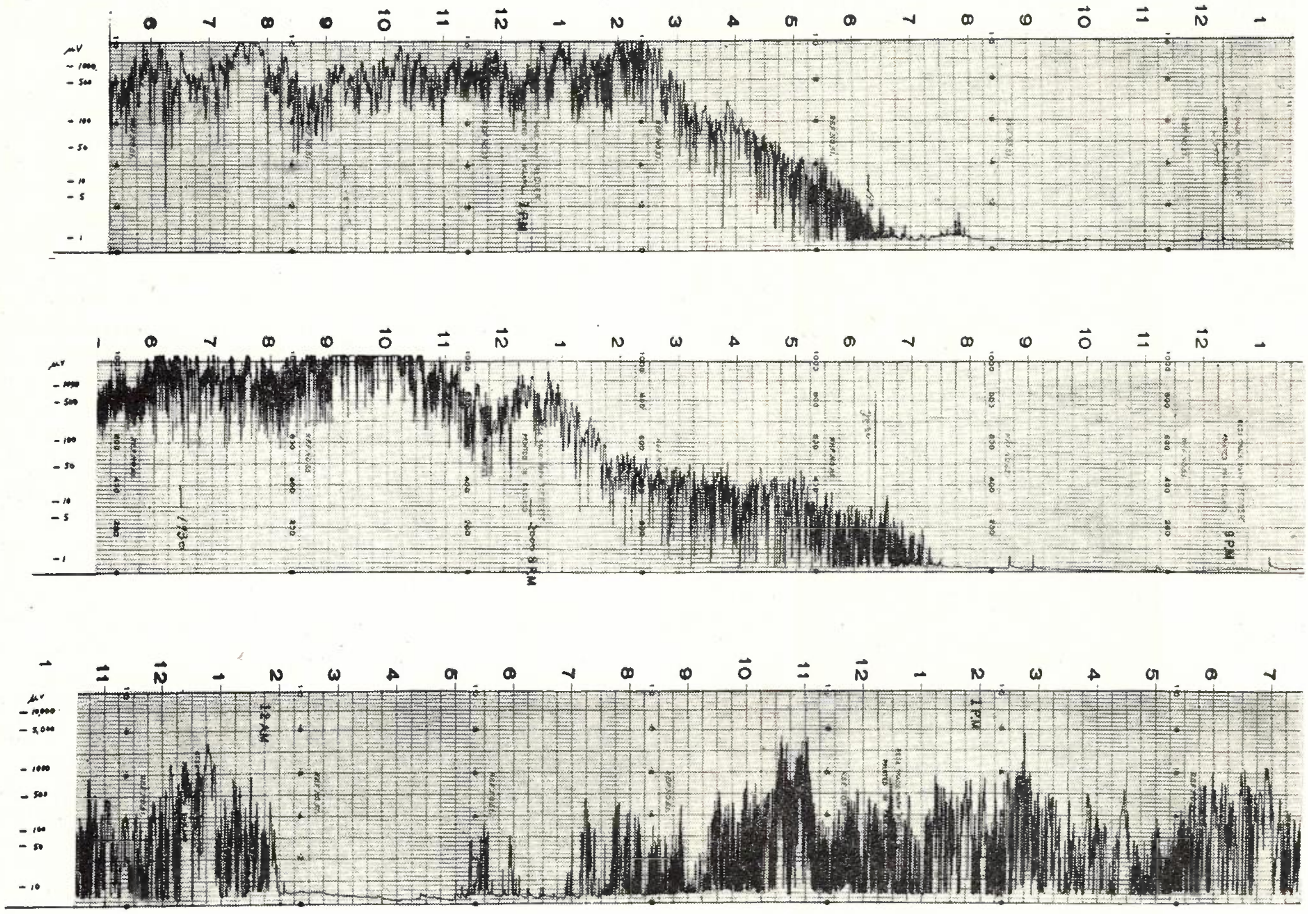

Fig. 10.—Typical field strength recorder charts made during F.S.K. performance tests.

H.F. point-to-point radiotelegraph link using Frequency Shift Keying as the method of working. It would appear that this system has little advantage over on-off keying for operation on circuits that supply stable conditions and adequate received signal levels. The improvement under conditions where noise is the limiting factor has been variously expressed at from 8 db to 20 db (Refs. 2, 4, 5), although one source (Ref. 7) gives rather lower figures of 3 to 6 db. In this case, however, greater improvements were indicated for smaller amounts of signal distortion. It is under conditions of low received signal level and rapidly fading signals that the frequency shift system shows the greatest advantage. There is some divergence of opinion concerning the merits of F.S.K. working during periods of selective fading, but laboratory tests (Ref. 8) indicate that signal element distortion can be much less than with on-off keying. Field trials (Ref. 4) also support this result.

A further important advantage of frequency shift working is that this method is more economical in channel width and creates less adjacent channel interference than conventional on-off systems operating at equivalent speeds. This is due to the method of keying and operating the transmitter enabling the proper shape of the keyed signals to be preserved in passage through the transmitter stages, since there is always a signal present and the small variations in frequency upon keying cause little disturbance to the circuits.

The most likely development to the F.S. system of working is the application of time-division multiplex systems to obtain multi-channel facilities, and it would appear that this method has certain advantages over competitive systems such as the use of a frequency-division multiplex method of obtaining multichannel telegraph facilities on a single sideband system.

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3. "Frequency Shift Keying Techniques," C. Buff; Radio, Vol. 30, No. 8, page 14.

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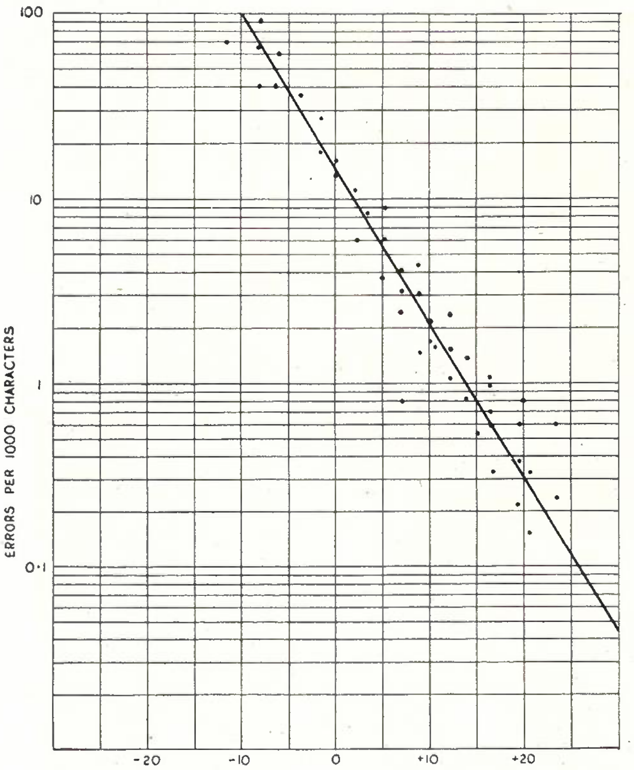

Fig. 11.—Errors versus field strength for frequency shift keying using dual diversity receivers with Rhombic aerials, 1.5 kc/s receiver bandwidth, 850 c/s shift and five unit stop-start teleprinter signals. Frequency 15,665 kc/s, total count approximately 430,000 characters. Each dot represents a sample of approximately 10,000 characters.

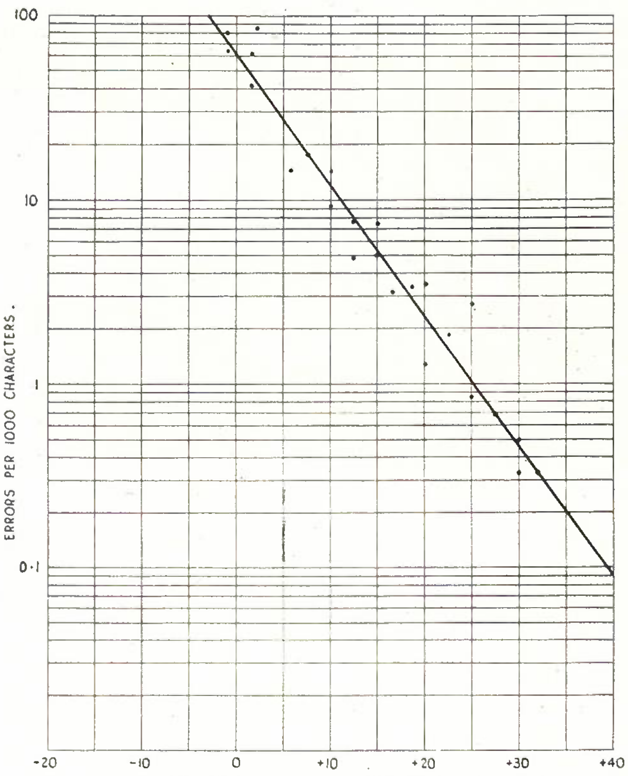

Fig. 12.—Errors versus field strength for on-off keying using dual diversity receivers with Rhombic aerials, 1.5 kc/s receiver bandwidth and five unit stop-start teleprinter signals. Frequency 15,665 kc5s, total count approximately 260,000 characters. Each dot represents a sample of approximately 10,000 characters.

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9. "Relative Amplitude of Side Frequencies in On-off and Frequency Shift Telegraph Keying," G. S. Wickizer; R.C.A. Review, Vol. 8, page 158.

MOBILE CROSS ARM BORING MACHINE

R. G. Spratt, B.A., B.Sc., A.M.I.E. (Aust.)

Considerable numbers of cross arms have been supplied from saw mills throughout Victoria to country line stations to meet the requirements of the surrounding districts. In only a few cases have the arms been available bored, and a mobile machine, illustrated in Fig. 1, was accordingly developed for boring these arms.

The multiple spindle type of machine which is used at large depots where there is a continuous flow of arms, is too cumbersome and the peak power requirements of this type is considerable as the holes are bored simultaneously. Accordingly, the mobile machine was based on a single unit drill.

To make the unit independent of commercial power supply, a 3-phase 7 K.V.A. alternator, driven by a Ford 10 H.P. engine, was used and the equipment was mounted on a Chevrolet 4 x 2, 15 cwt. truck. The drill is powered by a 2 H.P. motor operating at 1500 R.P.M., and is the type supplied by Wolfenden Bros., Pty. Ltd., of Footscray, Victoria, for pole boring heads in pole slotting and boring depot rigs.

The arms are held in an angle frame fitted across the rear of the truck, see Fig. 2, and with small rollers to assist the sliding of the arm between drilling positions. The ends of the angle frame are hinged. The arm is clamped in position for each hole, see Fig. 3, by a vacuum operated piston controlled by a valve situated just below

Fig. 1.—General view of mobile cross-arm boring machine.

the frame. A vacuum tank connected to the Ford engine intake manifold can be seen near the engine (see Fig. 1). Holes to suit all possible spindle spacings are provided in the angle frame and the arm is located in the appropriate position by "stop" pins as shown in Fig. 4.

The unit is positioned close to the stack of unbored arms, and a team of three is required, one for feeding, one for stacking the bored arms, and the machine operator. The arm is placed on the frame and the holes bored in order from end to

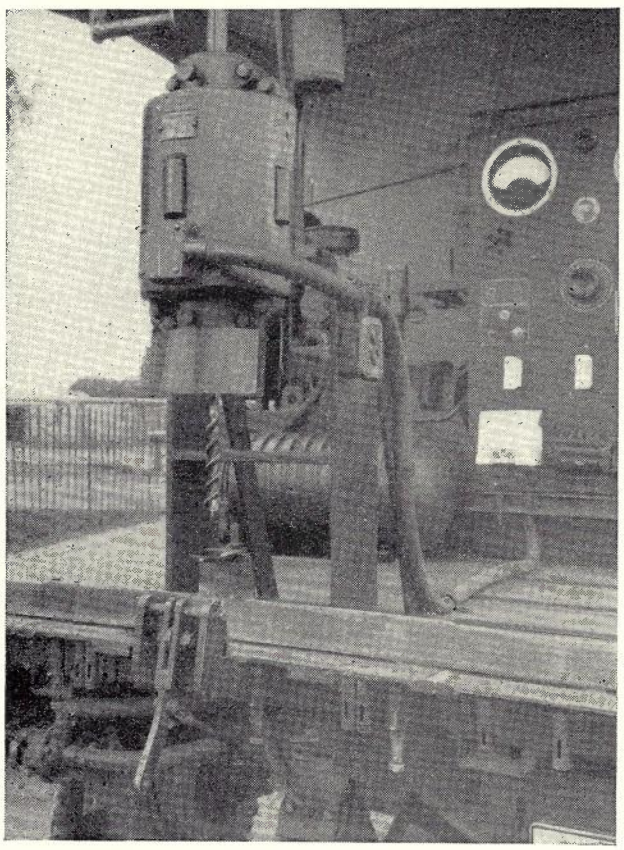


Fig. 2.—View showing angle frame for holding arms.

Fig. 3.—Vacuum operated piston (at left hand of operator) for clamping arms.

centre. The arm is then moved so that the other end is under the drill and the holes bored back to the centre. This method of operation is necessary to avoid extending the frame six feet past the side of the vehicle.

Approximately forty-five, eight-way arms can be bored in an hour, that is half a man-minute per hole. For costing purposes the alternator and boring unit are charged as a small compressor unit. Being mobile, the alternator has also been called upon as a stand-by power unit for small exchanges and other small power requirements.

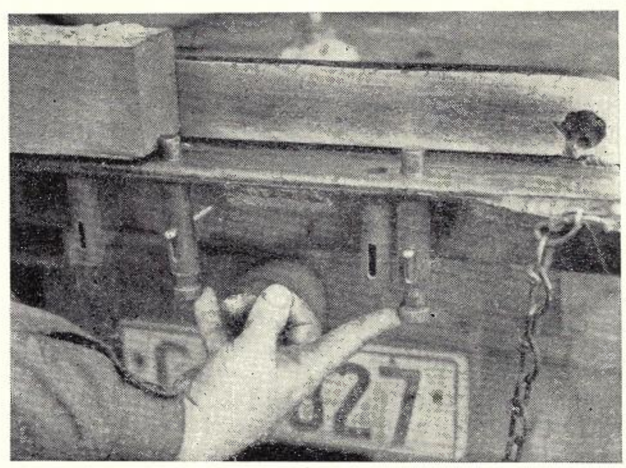


Fig. 4.—Pins for positioning arms for various spindle spacings.

RETIREMENT OF MR. JOHN HILL, SUPERINTENDING ENGINEER, VICTORIA.

Having reached the retiring age, Mr. John Hill ceased duty in the Department on 11th June last. Mr. Hill held the position of Superintending Engineer for Victoria since 1948 and, for several years prior to that date, he was associated with the late Mr. N. W. V. Hayes as Assistant Superintending Engineer.

Mr. Hill commenced duty in this Department in 1907 as the first Cadet Engineer in Victoria, and shortly afterwards took up duty in the Central Administration under the Chief Engineer at that time, the late Mr. John Hesketh. Some time later he was transferred to South Australia, where he remained for a number of years. During that period he was actively associated in laying the foundations of the present engineering structure in that State. During the early portion of his term in Adelaide he studied at the local University and obtained the B.Sc. degree. Whilst in Adelaide he trained a number of promising Cadet Engineers and Technicians, enabling them to qualify as Engineers who are now employed in various States.

In 1935 Mr. Hill was promoted to the important position of Supervising Engineer for Lines in the Central Administration. In that capacity he became well known throughout the Commonwealth, and not only was he associated with many large engineering projects, such as the Sydney-Maitland trunk cable, but served on many special committees concerned with costing methods, Arbitration matters, etc., and was chairman of the Estimates Committee for several years.

During the strenuous war years, while Assistant Superintending Engineer in Victoria, Mr. Hill played a very active part in the provision of essential communication needs for the armed forces and civil defence.

During his long and meritorious career as an Engineer Mr. Hill displayed great qualities of leadership and administration, as well as marked technical ability. His quietly spoken manner, mature judgment and great personal charm endeared him to the many hundreds who were fortunate to be associated with him. An outstanding characteristic was his sincere regard for the welfare of the lower ranks, to whom he was everready to lend a helping hand.

At a very representative gathering on the evening of his retirement, many fine tributes were paid to him by his various associates, including representatives of a number of service Unions, who made special reference to the extreme courtesy and helpful assistance Mr. Hill had rendered them. Suitable presentations were made to Mr. and Mrs. Hill by Mr. P. Vanthoff, Deputy Director-General, who referred to the splendid service rendered to the Department by Mr. Hill. Able support was given Mr. Vanthoff by the Acting Assistant Director-General (Engineering Services), Mr. R. E. Page, and by the Director of the Victorian Administration, Mr. N. W. Strange.

OMISSIONS:

Examinations Nos. 2854/5—Technician, Telephones.—The answers published in Vol. 8 No. 6, February, 1952, were written by J. Hibberd.

Examination No. 2101—Senior Technician, Telephones—Telephony II.—The answers published in Vol. 8, No. 6, February, 1952, were written by L. White.

ANSWERS TO EXAMINATION PAPERS

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

EXAMINATION No. 3101—SENIOR TECHNICIAN TELEPHONY II. SECTION II

L. White.

Q. 4.—What are the functions of an amplifier detector in a voice frequency telegraph system? Describe how you would adjust the gain of an amplifier detector in any system with which you are familiar.

A.—An amplifier detector is connected to the output side of the receiver filter in each channel of a voice frequency telegraph system, and serves to reproduce the direct current signals which operate the receiving telegraph relay. The rectified current output of the detector valve passes through the line windings of the receiving relay. Through the auxiliary or bias winding of this relay, there is a steady current (adjusted by means of a variable potentiometer) which tends to hold the relay tongue to space. When alternating current signals are being received, the rectified current operates the receiving relay tongue to "marking." When there is no input to the detector, the relay tongue moves to "spacing" under the control of the bias winding.

Included in the amplifier detector circuit is an automatic volume control feature which holds the detector current substantially constant with line attenuation variations over a given range of decibel and thus ensures that signals of constant amplitude are applied to the receive relay.

The following is a method adapted for adjusting the gain of an amplifier detector with respect to its limiting point and carrier input. (It is assumed that the send sides and receive amplifier gains for both terminals have been adjusted to the specified values for the particular system.)

A continuous marking signal from the distant terminal, via the receive line, is obtained on each channel in turn, and a pad, the value of which depends on the specified A.V.C. range for the system under test, is patched in circuit between the "Rec. Filter Out" and "Amp Detector In" jacks. The detector current of the channel amplifier detector under test is observed and the input potentiometer varied until the limiting point is just reached. Having obtained the limiting point, the pad is removed from circuit and this increases input level to the amplifier detector and ensures that it is operating above the limiting range and is, therefore, in the correct condition for the operation of the A.V.C. circuit.

Endeavour should be made to arrange the overall gain of the receiving side so that the gain control of each detector is near the centre of its range. This can be achieved by observing the highest and lowest gain control settings and altering the gain setting of the receive amplifier accordingly.

Q. 5.—(a) Describe a method of locating an open circuit on a trunk line.

(b) A physical trunk line terminating on a trunk test board is reported faulty, one wire being earthed. Line details are:—

(a) lead in cable (near end), 2½ miles, loop resistance 120 ohms;

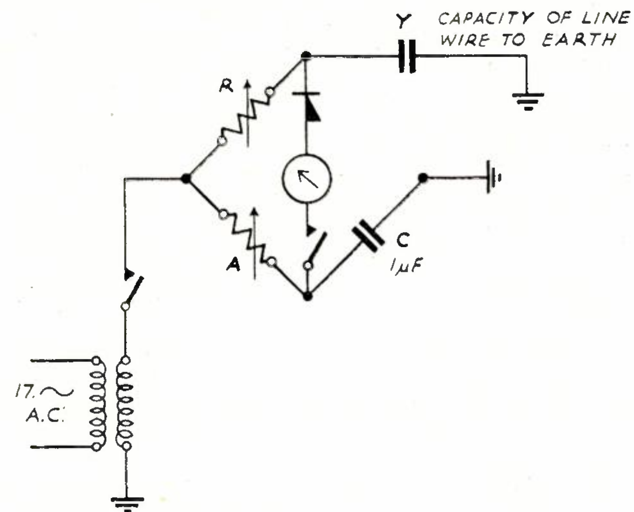
(b) lead in cable (far end), 1 mile, loop resistance 40 ohms;

(c) Open wire construction 200 HDC, 8.8 ohms per loop mile.

The measured value of CR to the distant station is 1,200 ohms and the Varley test reading with unity ratio arms is 300 ohms. Calculate the location of the fault.

A.—The location of an open circuit on a trunk line can be obtained by means of a Wheatstone Bridge using the capacity balance method.

The arrangements of the test circuit as used on Siemens Trunk Test Boards is shown in Fig. 1, where a standard 1 microfarad condenser becomes one arm of the bridge and the capacity to earth of the line wire the unknown arm.



Q.5.—Fig. 1.

Y = Capacity to earth of line wire in microfarads.
A = Resistance of ratio arm in ohms.
R = Resistance in rheostat arm in ohms.

For condition of balance,

$A \times 1/j\omega Y = R \times 1/j\omega C$; that is $A/j\omega Y = R/j\omega C$

J and ω are common to both sides of the equation as the frequency is the same. Therefore, the equation becomes: $A/Y = R/C$

Therefore, $Y = AC/R$

If $A = 1000$ ohms and $C = 1\mu$.F.
then $Y = 1000/R$.

In the open location test two capacities are measured, Y and Y_1, where reactances correspond to readings R and R_1 on the bridge.

R = Reading on the R rheostat when the faulty wire is connected to bridge.

R_1 = Reading on the R rheastat when the good wire is connected to bridge.

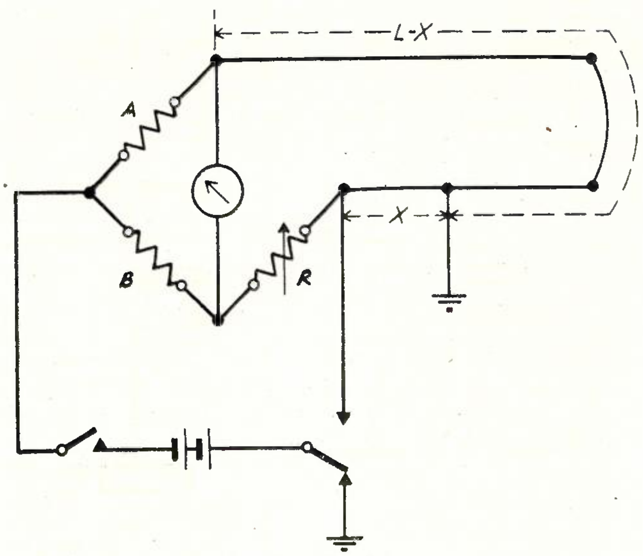
The capacity reactance of the faulty wire will be a proportion of the capacity reactance of the good wire, therefore:

$$Y/Y_1 = (1000/R)/(1000/R_1) = R_1/R$$

If D is the distance between the testing stations, then distance from testing station to the fault $= R_1 \times D/R$.

(b) The conditions of the problem as shown in Fig. 2 are:—

A = B
R = 300 ohms
L = 1200 ohms
X = Single wire resistance to earth fault.



Q.5.—Fig. 2.

When balance is obtained for circuit as shown in Fig. 2.

A (R + X) = B(L–X)

∴ X(A + B) = BL – AR

∴ X = (BL – AR)/(A + B)

Since A = B, ∴ X = (L – R)/2 ohms.

Substituting the given values of L and R.

X = (1200 – 300)/2

= 450 ohms.

Loop resistance of near end lead in cable 2½ miles long = 120 ohms.

∴ Single wire resistance of open wire construction to fault = 450 – (120/2) = 390 ohms.

∴ Length of open wire construction to fault = 390/4.4 = 88.63 miles.

Answer: Distance to the fault from testing station end is 88.63 + 2.5 = 91.13 miles.

EXAMINATIONS 2858 and 2859—TECHNICIAN TELEGRAPH MAINTENANCE

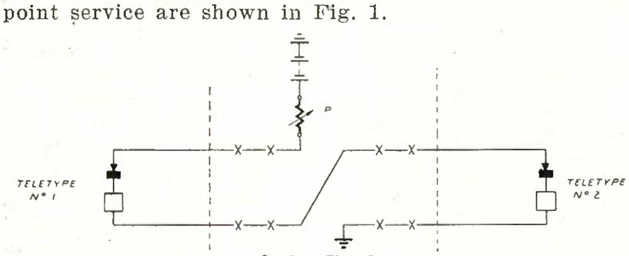
P. S. Bethell, B.Sc.

Q. 1.—Draw and describe the signalling circuit arrangements used for a point to point connection, with a metropolitan network, between—

(a) Two Model 15 Teletype terminal machines,

(b) two model 7 Teleprinter terminal machines.

A.—(a) The signalling circuit arrangements for connecting two Model 15 teletype machines as a local point/point service are shown in Fig. 1.



Q. 1.—Fig. 1.

In the normal (marking) condition, current flows from battery through limiting potentiometer P., send contacts and receive magnet of Teletype No. 1 via local loop No. 1, send contacts and receive magnet of teletype No. 2, via local loop No. 2 to earth.

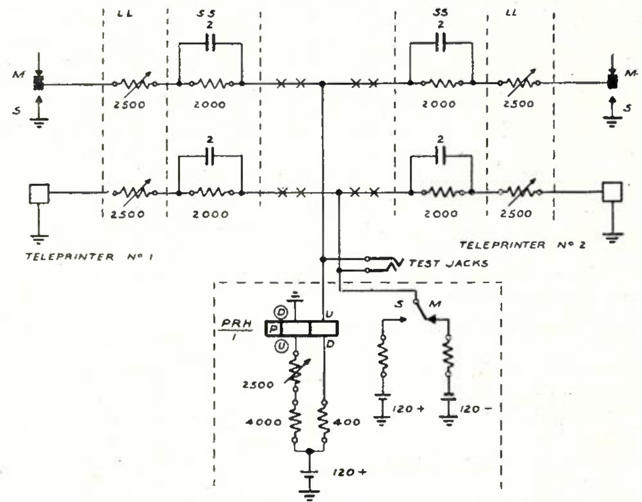
"P" is adjusted so that the current is 60 ma in the marking condition and both receive magnets are held to mark.

Spacing signals are sent from a teletype by opening the send contacts. Thus a spacing signal from either teletype will interrupt the current through both receive magnets and allow the magnets to release to the space condition.

Each subscriber's loop is connected through a jack quad to facilitate monitoring and testing of the service.

On long loops the circuit may be returned to negative battery via another potentiometer instead of to earth.

(b) Figure 2 shows the circuit for connection of two Model 7 teleprinters in a local point/point circuit.



Q1. FIG. 2.

With both machines at rest, relay PRH is held to mark by a current of 15 ma from 120V.+, 4000 ohm resistance, 2500 ohm potentiometer, U circle–D circle winding PRH to earth. 120V.– marking battery from the mark contact of PRH holds both receive magnets to mark via signal shaping network, line limiting potentiometer and receive line. The line limiters are set to give a current of 25 ma through each magnet.

Operation of either teleprinter send contacts to space causes current to flow through the U – D winding of PRH in the spacing direction, signal shaping network, line limiting potentiometer send line to earth at the space contact of the sending teleprinter. The line limiter is set to give a 30 ma current in the send line in this condition. This current through the relay is sufficient to operate PRH to space, connecting its spacing contact to the receive lines and providing spacing current to both receive electro-magnets. Pulses of signalling current from either transmitter therefore causes double current signals to flow in both receiving magnets thus providing a home record as well as signals to the distant machine.

The signal shaping network in each send line is designed to modify the signal shape to overcome marking bias which occurs due to inductance of the relay winding and transit time of the transmitter contacts. The $2\mu F$ capacity connected between the mark contact of the transmitter and earth, reduces the spacing bias which occurs on long lines due to capacity of the line.

Signal shaping networks in the receive lines are provided to square the pulses being sent to the receive magnets, thus making their adjustment less critical.

Q. 2.—Describe with the aid of a suitable sketch, the construction and operation of a Creed Type 27 Polarised Relay. How would you adjust this relay before putting it into service?

A.—A description and sketches of the construction of operation of the Creed Polarised Relay is given in the Telecommunication Journal, Vol. 4, No. 3, on page 192.

The adjustment of a polarised relay is carried out in two ways, (a) mechanical, and (b) electrical adjustment.

Mechanical Adjustment.

Set the bias adjusting screw to Zero. Unscrew both contact screws until they are clear of the armature contacts. Advance the left hand contact screw, after pressing the armature contact against it, until the armature moves to the opposite side. Turn back the contact screw 1 mil. (Each small division on the contact screw represents a movement of 1 mil.)

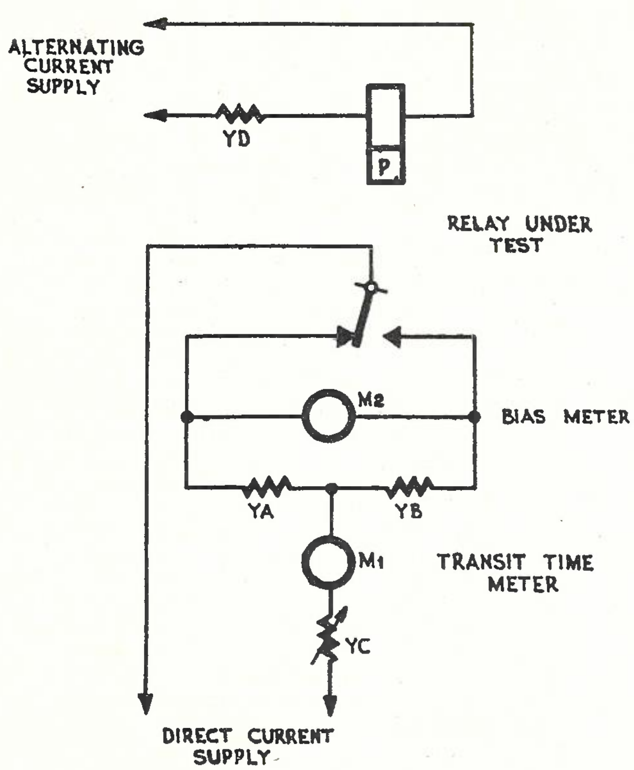
Advance the right hand contact screw until the armature contacts are just held between the two contact screws.

Normally the relays are operated with a contact gap of approximately 3 mils, so that each contact screw should be retracted 1½ mils.

Electrical Adjustment.

When an electrical relay tester is available, the relay should be checked for neutrality and transit time.

A simplified relay tester is shown in Fig. 1.



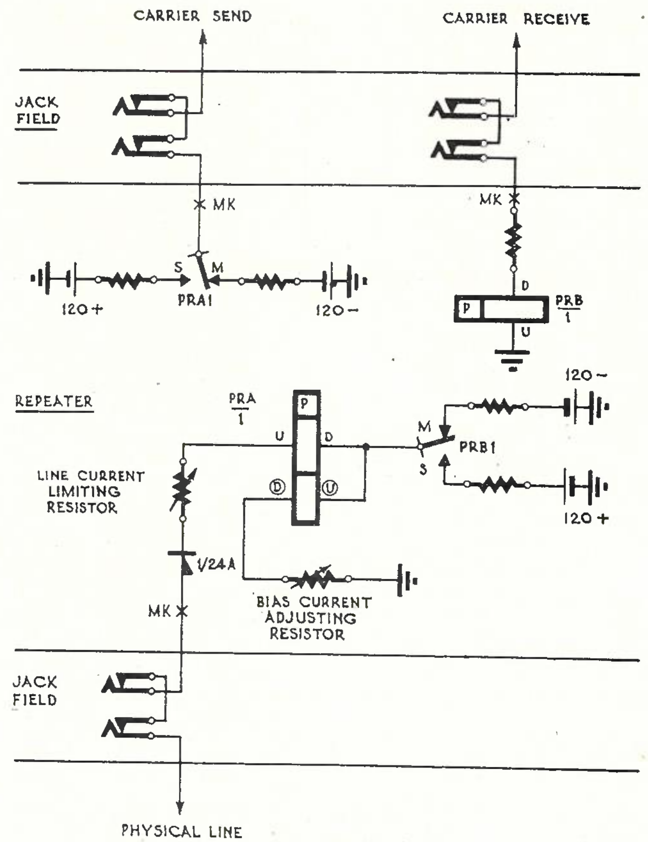
Q.2.—Fig. 1.

Alternating current or rounded signals from a reversals source are applied to a winding of the relay to be tested, so that any bias in the relay will be shown by a deflection of the centre-zero bias meter. Bias is corrected by turning both contact screws in the same direction by equal amounts until the bias meter reads zero.

The transit time meter is arranged to read full scale with the relay tongue held to one contact. The percentage contact time with reversals is then shown as the percentage of full scale deflection indicated on the meter. The contact gap should be adjusted to give 80-82% contact time, i.e., 18-20% transit time. This is done by turning the contact screws in opposite directions.

In practice these two adjustments are carried out sumultaneously.

Q. 3.—The circuit of one type of carrier to physical simplex repeater is shown in Q.3, Fig. 1.



Q. 3.—Fig. 1

The operation of the circuit is as follows:—

In the rest condition negative marking battery is being received from the carrier via a limiting resistance, D–U winding of PRB to earth. This current (set at 25 ma.) holds PRB to mark. Line current can now flow from earth at the far end of the physical line via the rectifier in the pass direction, line limiting resistor, U – D winding of PRA mark contact of PRB to negative marking battery. Bias current flows through the adjusting resistor D circle – U circle winding of PRA also to negative battery. The bias current, which is in the spacing direction, is set to less than the line current which is marking, thus allowing PRB to remain on mark and connecting marking battery to the carrier send.

Sending from the carrier to line. When a space is received from the carrier receive, PRB changes over to space connecting positive spacing battery to the windings of PRA, but no current flows in the line as the rectifier is in the blocking direction. The bias current through the D circle – U circle winding changes to marking thus holding PRA to marking. Since no current is flowing in the line during spacing signals, single current signals are being sent to line.

Sending from the physical line. When a key is opened on the simplex line, current falls through the U circle – D circle winding of PRA and the bias current operates the relay to space thus sending spacing battery on to the carrier send.

The bias current of PRA is set so that its magnetic effect will be midway between that of the line currents with the most distant key open and closed. Thus with no leakage the line currents would be 0 and 30 ma. and the bias current 15 ma. With leakage, the current may be 20 ma. with the line open and 40 ma. with the line closed and the bias would be set at 30 ma.

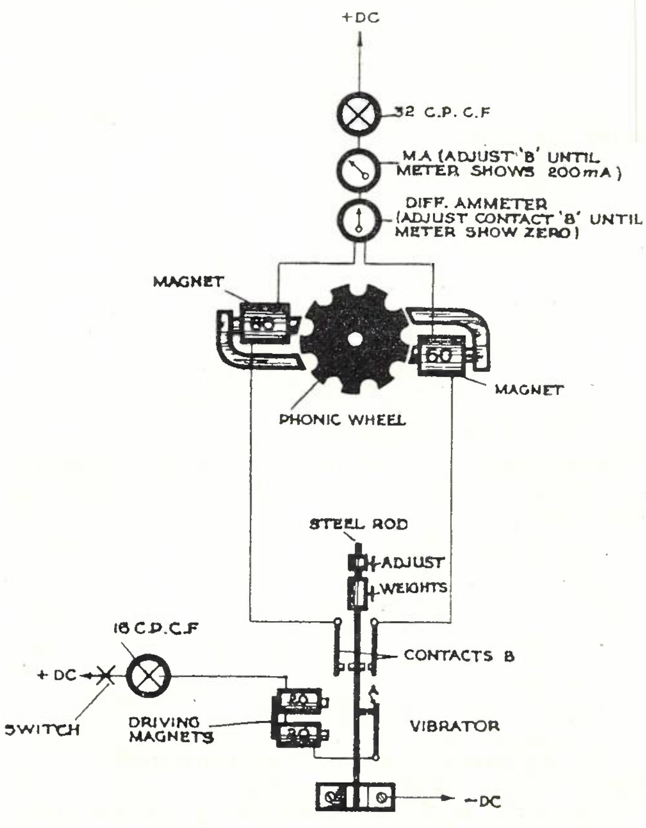
Q. 4.—Describe with the aid of suitable sketches, the sequence of operations associated with the selection and printing of a character on receipt of a train of signals by a Model 8 "receiving only" teleprinter.

A.—This question was answered in the Telecommunication Journal, Vol. 6, page 250, Question 3.

Q. 5.—Describe the distributor driving motor and synchronising arrangements of a Murray Multiplex installation.

A.—The distributor brushes on a Murray Multiplex installation are driven by a phonic motor controlled by a vibrator. The vibrator is a steel reed type, operating on the same principle as the trembler bell, i.e., a contact on the vibrating reed is opened and closed as the reed vibrates, this contact being used to open and close a D.C. magnet circuit. Pulses of current through this magnet cause the steel reed to be attracted, thus maintaining vibrations.

Connections of the phonic motor and vibrator are shown schematically in Fig. 1.



Q.5.—Fig. 1.

Contacts on either side of the vibrator reed alternately complete the circuits to two magnets in the phonic motor, pulses being received alternately in the magnets thus providing magnetic pulses sufficient to maintain the phonic wheel in motion.

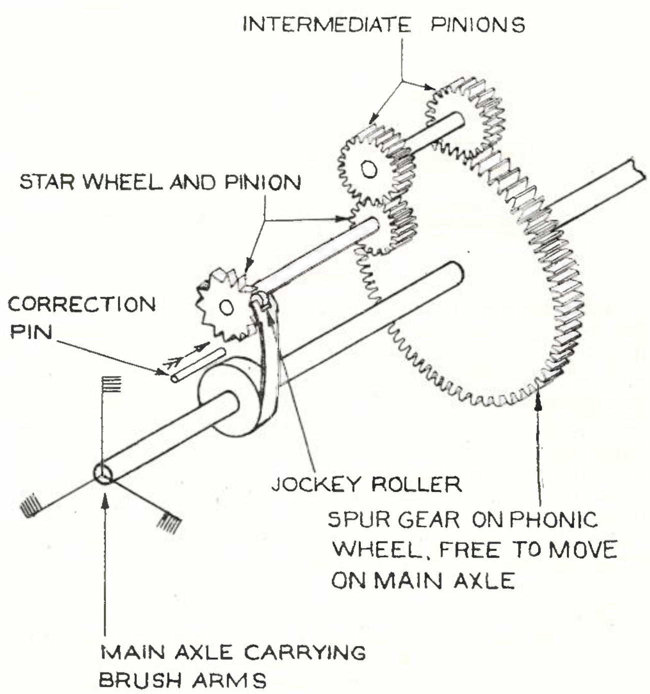
The phonic wheel is a toothed wheel, having 9 teeth. A pulse in one magnet causes the nearest tooth on the phonic wheel to be attracted, thus pulling the wheel round until the tooth is in line with the magnet. A pulse in the other magnet then causes the next tooth to be attracted and providing a further pull on the wheel. Thus one complete cycle of the vibrator, which delivers one pulse to each magnet, rotates the wheel one tooth and 9 cycles will rotate the wheel through one revolution. As there is no starting torque with this type of motor, the wheel must be spun up to speed by hand until it "locks in".

To damp out oscillations in the running of the motor, the phonic wheel has an enclosed cavity loosely fitted with iron wire and mercury.

The synchronising of the distributor speeds at two terminals of a Murray Multiplex installation is accomplished by operating the vibrator, and consequently the motor, about 0.2% faster at one end but allowing the brushes to be stepped back in relation to the motor so that the mean brush speed is synchronised with that at the distant terminal.

The actual correction is carried out by sending a correction signal from the "correcting station" once in each cycle and having a correction segment in the receiving ring of the "corrected" station connected to a magnet. The operation of the correction magnet causes the correction mechanism to be actuated, thus stepping the distributor brushes back $1\frac{1}{2}°$ relative to the phonic motor for each operation. The correction segment is so positioned that, when the receive brushes are approximately $\frac{3}{4}°$ in advance of the received signals, the correction magnet will be operated by the correction signal.

To enable the "stepping back" to occur, the phonic wheel is made free to rotate on the main axle to which the brushes are fixed. Fixed to the phonic wheel is a star wheel and pinion as shown in Fig. 2.



Q. 5.—Fig. 2.

Drive is applied to the main axle via a jockey roller fixed to main axle, the jockey roller preventing the star wheel from rotating except when correction is occurring. Operation of the correction magnet places a pin in the path of the star wheel, causing it to rotate one tooth. The star wheel is connected via its pinion and intermediate pinion to a spur gear fixed to the phonic wheel.

When the correcting pin is interposed in the path of the star wheel, the jockey roller "jumps a tooth", the resultant rotation of the star wheel being applied to the spur gear, enabling the phonic wheel to rotate through a small angle without driving the brushes.

With the speeds of the two stations adjusted correctly, correction should occur approximately once every two revolutions.

Q. 6.—Describe, with the aid of a sketch, the construction of a micrometer screw gauge. Explain why it is possible to measure accurately with this instrument.

A.—A description and sketch of the micrometer screw gauge is given in Telecommunication Journal, Vol. 3, page 181.

The reason why great accuracy is attainable with a micrometer screw gauge is that a very small movement of the spindle is caused by a relatively large movement of the measuring scale on the sleeve. Thus, for a sleeve diameter of $\frac{1}{2}$ inch, a movement of $^1/_{40}$ inch of the spindle (1 revolution) is given by a movement of more than 3 inches of the sleeve. The 25 scale divisions, each representing $^1/_{1000}$ inch, are therefore sufficiently widely spaced to enable measurements easily to be made to an accuracy better than $^1/_{1000}$ inch.

Q. 7.—Describe and sketch the distinctive features of:

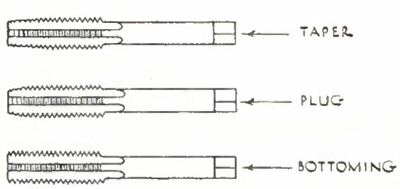
(a) Plug.

(b) Taper.

(c) Bottoming taps: Why is each of these taps used?

A.—Some confusion exists in the terms used to describe the taps which constitute a set. Many authorities regard a plug tap as being identical with a bottoming tap, but it is assumed in this answer that the term "plug" is intended to mean what is more generally known as second or intermediate.

The three types of taps named are shown in Fig. 1.



Q. 7.—Fig. 1.

A tap may be regarded as a bolt with a perfect thread cut on it, provided with cutting edges and hardened, so that it can cut an internal thread when screwed into a hole of the correct size. A tap is made of high-carbon or high-speed steel with a thread cut on it and four flutes cut along it to provide cutting edges. The shank is left plain and the end squared to accommodate a tap wrench. After hardening and tempering, the front edges of the flutes are ground to provide sharp cutting edges on the thread.

The distinctive features of the three types of taps are:

(a) A plug tap is chamfered at the leading edge for two or three threads.

(b) A taper, as the name suggests, is tapered at the leading end for about 8 to 10 threads, and

(c) A bottoming tap has threads cut right to the end.

The taper tap is the first used, the tapered end enabling the tap to enter the hole and cut the thread gradually. For shallow holes it is common to turn the taper tap clear through the work, but for deep holes it is often necessary to relieve the long cut by using it alternately with a plug tap.

The plug tap is used in conjunction with the taper tap as above, and is also used when tapping blind holes to follow the taper, thus extending the thread to near the bottom of the hole.

When threads are required right to the bottom of a blind hole, a bottoming tap is used after the plug to cut the last two or three threads.

The drill size used for a tapped hole is equal to the diameter to the bottom of the tap thread. Tables showing the correct size holes for the various sizes of taps are usually readily available.

Q. 8.—In the circuit shown calculate the total current flowing through the battery. Also calculate the current flowing in the 4,000 ohm resistance. Battery resistance is negligible.

A.—Consider first the resultant resistance from R_1 and R_2 in parallel. Call this R_A.

$$R_A = \frac{R_1 R_2}{R_1 + R_2} = \frac{4000 \times 1000}{4000 + 1000}$$

$$= \frac{4000 \times 1000}{5000} = 800 \text{ ohms.}$$

Let R_B be the equivalent resistance of R_3 and R_4 in parallel. Then

$$R_B = \frac{R_3 R_4}{R_3 + R_4} = \frac{1600 \times 400}{1600 + 400}$$

$$= \frac{1600 \times 400}{2000} = 320 \text{ ohms.}$$

Total resistance in circuit consists of $R_A + R_B$

$\therefore$ Total resistance $= 800 + 320$

1120 ohms.

Current through the battery can now be calculated using ohms law.

$$I = \frac{E}{R}$$

where $E = 10$ volts

$R = 1120$ ohms.

$$\therefore I = \frac{10}{1120} \text{ amps}$$

$$= \frac{10 \times 1000}{1120} \text{ milliamps}$$

$$= 8.93 \text{ milliamps.}$$

To determine the current through R_1 first determine the voltage across it, which is the voltage across R_A. Call this E_A.

$$E_A = I R_A$$

$$= \frac{8.93 \times 800}{1000}$$

$$= 7.144 \text{ volts}$$

If current through R_1 is I_1

$$I_1 = \frac{EA}{R_1} = \frac{7.144}{4000} \text{ amp.} = 1.786 \text{ milliamps}$$

EXAMINATION No. 2906—ENGINEER NATURAL SCIENCE

K. W. Macdonald, B.Sc., Dip.Pub.Admin.

PART 1.

Q.1—(a) If $\frac{dy}{dx} = -y$, show by integration that the most general solution which satisfies this equation is—

$y = ae^{-x}$ where "a" is a constant.

(b) An electric current which decreases according to an exponential law, falls to half its initial value in one-hundredth of a second. How long will it take to fall one-millionth of its initial value?

A.—(a)

$$\frac{dy}{dx} = -y$$

$$\therefore \quad \frac{1}{y}\frac{dy}{dx} = -1$$

$$\therefore \int \frac{1}{y}\frac{dy}{dx}\,dx = \int -1\,dx$$

$$\therefore \quad \log y = -x + C \text{ where C is constant.}$$

i.e., $y = e^{-x+c}$

$= e^{-x} e^{c}$ where e^{c} is a constant which may be written as $= a$.

$y = a\,e^{-x}$ is the general solution of the equation.

(b) $I = I_o\,e^{-kt}$

$$\therefore e^{kt} = \frac{I_o}{I}$$

$$\therefore e^{k/100} = 2$$

$$\therefore \frac{k}{100} = \log_e 2 \qquad k = 100 \times .301 \times \log_e 10$$

$$\text{Now } e^{kt_2} = \frac{I_o}{I_2} = 10^6$$

$$k\,t_2 = 6 \log_e 10$$

$$\therefore t_2 = \frac{6 \times \log_e 10}{100 \times .301 \times \log_e 10} = \tfrac{1}{5} \text{ second.}$$

Q. 2.—Prove that the function—

$$y = ae^{-kt} \sin \omega t$$

has extreme values y_o, y_1, y_2, etc.,

when $t = t_o$, $\frac{\pi}{\omega} + t_o$, $\frac{2\pi}{\omega} + t_o$, etc., where $t = \frac{1}{\omega}\,\text{artan}\,\frac{\omega}{k}$ and that the values y_o, y_1, y_2, etc., form a Geometrical Progression.

State the rule you would use to determine which of these values are maxima and which are minima.

A.

The function $y = ae^{-kt} \sin \omega t$ is a function of t of the form UV where both U and V are themselves functions of t. Extreme values of a function are indicated at points where the derivative of the function is equal to zero.

Differentiating y according to the rule $\frac{d}{dx}$ (U.V.)

$$= U\frac{dv}{dx} + V\frac{du}{dx}$$

$$\frac{dy}{dt} = a\,e^{-kt}\,\omega \cos \omega t + \sin \omega t \times -k\,a\,e^{-kt}$$

$$= a\,e^{-kt}(\omega \cos \omega t - k \sin \omega t)$$

$$\therefore \text{When } \frac{dy}{dt} = o,\ \omega \cos \omega t = k \sin \omega t$$

$$\text{or } \tan \omega t = \frac{\omega}{k}$$

i.e., first extreme value occurs at t_o where $t_o = \text{artan}\,\frac{\omega}{k}$

However $\tan \omega t$ has recurring values at intervals of π so $\frac{dy}{dt}$ again $= o$ where $t = t_1 = t_o + \frac{\pi}{\omega}$

Since $\tan(\omega t_o) = \tan(\omega t_o + \pi)$.

Similarly, an extreme value occurs at $t = t_2$ where $t = t_o + \frac{2\pi}{\omega}$

Applying particular values for t

$$y_o = a\,e^{-kt_o} \sin \omega t_o$$

$$y_1 = a\,e^{-kt_1} \sin \omega t_1 = ae^{-k\left(t + \frac{\pi}{\omega}\right)}.\ \sin \omega t_o + \pi$$

$$= a\,e^{-kt_o} \sin \omega t_o \times e^{-k\frac{\pi}{\omega}} = y_o \times e^{-k\frac{\pi}{\omega}}$$

$$\text{similarly } y_2 = a\,e^{-kt_o}.\ \sin \omega t_o \times e^{-k\frac{2\pi}{\omega}}$$

$$= y_1 \times e^{-k\frac{\pi}{\omega}}$$

$$= y_o \times (e^{-k\frac{\pi}{\omega}})^2$$

i.e., y_o, y_1 and y_2 form a geometric progression with common ratio $e^{\frac{-k\pi}{\omega}}$

To distinguish whether an extreme value is a maximum or a minimum, apply the rule—

At a maximum $\frac{d^2y}{dt^2}$ is negative.

At a minimum $\frac{d^2y}{dt^2}$ is positive.

$$\text{NOTE that } \frac{d^2y}{dt^2} = \frac{d}{dt}\left(\frac{dy}{dt}\right)$$

$$= \frac{d}{dt}\left(a\,e^{-kt}(\omega \cos \omega t - k \sin \omega t)\right)$$

$$= a\,e^{-kt}(-\omega^2 \sin \omega t - \omega k \cos \omega t)$$

$$- a\,e^{-kt}(\omega k \cos \omega t - k^2 \sin \omega t)$$

$$= a\,e^{-kt}((k^2 - \omega^2) \sin \omega t - 2\,\omega k \cos \omega t)$$

For $\frac{d^2y}{dt^2}$ positive, $(k^2 - \omega^2) \sin \omega t > 2\,\omega k \cos \omega t$

$$\text{or } \tan \omega t > \frac{2\,\omega k}{k^2 - \omega^2}$$

For $\frac{d^2y}{dt^2}$ negative, $\tan \omega t < \frac{2\,\omega k}{k^2 - \omega^2}$

Q. 3.—

(a) State the expansions for Sin (A + B) and Cos (A + B) and from these deduce the expansion for Tan (A + B).

(b) Eliminate θ and Φ from the equation:—

$a \sin^2 \theta + b \cos^2 \theta = m$.

$b \sin^2 \Phi + a \cos^2 \Phi = n$.

$a \tan \theta = b \tan \Phi$.

(c) If A + B + C = 180° prove that—

Sin 2A + Sin 2B + Sin 2C = 4 Sin A Sin B Sin C.

A.

(a) $\sin(A + B) = \sin A \cos B + \cos A \sin B$.

$\cos(A + B) = \cos A \cos B - \sin A \sin B$.

$$\text{Hence } \tan(A + B) = \frac{\sin(A + B)}{\cos(A + B)} = \frac{\sin A \cos B + \cos A \sin B}{\cos A \cos B - \sin A \sin B}$$

Dividing both top and bottom by cos A cos B

$$= \frac{\dfrac{\sin A}{\cos A} + \dfrac{\sin B}{\cos B}}{1 - \dfrac{\sin A}{\cos A} : \dfrac{\sin B}{\cos B}}$$

$$= \frac{\tan A + \tan B}{1 - \tan A . \tan B.}$$

(b) From equation (3) $\dfrac{\tan \theta}{\tan \Phi} = \dfrac{b}{a}$

From (1) $a \sin^2 \theta + b\,(1 - \sin^2\theta) = m$

$$\sin^2 \theta\,(a - b) = m - b$$

$$\sin^2 \theta = \frac{m - b}{a - b}$$

and $\cos^2 \theta = 1 - \sin^2 \theta = 1 - \dfrac{m - b}{a - b}$

$$= \frac{a - b - m + b}{a - b} = \frac{a - m}{a - b}$$

$$\therefore \tan^2 \theta = \frac{\sin^2 \theta}{\cos^2 \theta} = \frac{m - b}{a - b} . \frac{a - b}{a - m}$$

$$= \frac{m - b}{a - m}$$

From (2) $a \cos^2 \Phi + b\,(1 - \cos^2) = n$

$$\therefore \cos^2 \Phi\,(a - b) = n - b$$

$$\cos^2 \Phi = \frac{n - b}{a - b}$$

$$\sin^2 \Phi = 1 - \cos^2 \Phi = 1 - \frac{n - b}{a - b} = \frac{a - n}{a - b}$$

$$\therefore \tan^2 \Phi = \frac{\sin^2 \Phi}{\cos^2 \Phi} = \frac{n - b}{a - b} . \frac{a - b}{a - n} = \frac{n - b}{a - n}$$

Then $\dfrac{\tan^2 \theta}{\tan^2 \Phi} = \dfrac{b^2}{a^2} = \dfrac{m - b}{a - m} . \dfrac{a - n}{n - b}.$

$$\therefore b^2\,(a - m)\,(n - b) = a^2\,(m - b)\,(a - n)$$

An expression from which θ and Φ have been eliminated.

(c) If $A + B + C = 180$ then $A = 180 - (B + C)$

$\sin 2A + \sin 2B + \sin 2C$

$= \sin 2A + 2 \sin (B + C) . \cos (B - C)$

$= 2 \sin A \cos A + 2 \sin (180 - A) . \cos (B - C$

$= 2 \sin A \cos ((180 - (B + C)) + 2 \sin A . \cos (B - C)$

$= 2 \sin A ((\cos (B - C) - \cos (B + C))$

$= 2 \sin A . 2 \sin B . \sin C$

$= 4 \sin A . \sin B . \sin C.$

Q.E.D.

Q. 4.—(a) State the exponential forms of Sinh x, Cosh x, and Tanh x and sketch their graphs indicating any asymptotic values.

(b) Using the exponential forms prove that—

(1) $\dfrac{2 \tanh x}{1 - \tanh^2 x} = \sinh 2x.$

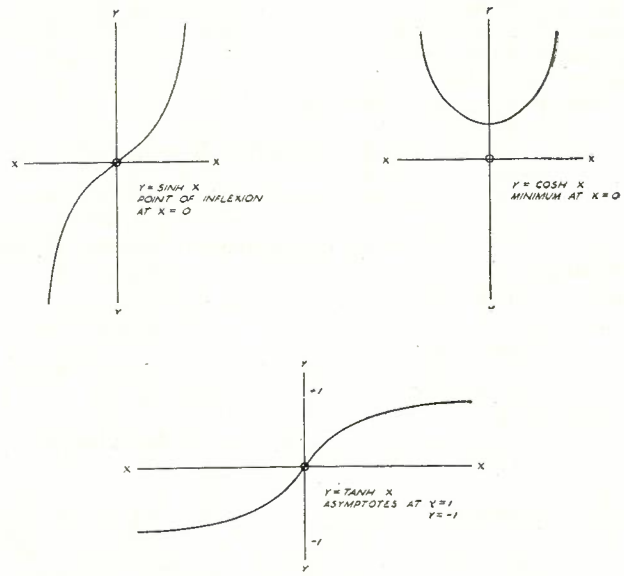
(ii) $\tanh \frac{1}{2} x = \dfrac{\sinh x}{\cosh x + 1}$

A.—

(a) $\sinh x = \dfrac{e^x - e^{-x}}{2}$

$\cosh x = \dfrac{e^x + e^{-x}}{2}$

$\tanh x = \dfrac{e^x - e^{-x}}{e^x + e^{-x}} = \dfrac{e^{2x} - 1}{e^{2x} + 1}$



Q. 4.—Fig. 1.

(b) (i) $$\frac{2 \tanh x}{1 - \tanh^2 x} = \frac{2\,\dfrac{e^{2x} - 1}{e^{2x} + 1}}{1 - \dfrac{(e^{2x} - 1)^2}{(e^{2x} + 1)^2}}$$

$$= \frac{2\,(e^{2x} - 1)\,(e^{2x} + 1)}{(e^{2x} + 1)^2 - (e^{2x} - 1)^2}$$

$$= \frac{2\,(e^{4x} - 1)}{e^{4x} + 1 + 2e^{2x} - e^{4x} - 1 + 2e^{2x}}$$

$$= \frac{2\,(e^{4x} - 1)}{4\,e^{2x}}$$

$$= \frac{e^{2x} - e^{-2x}}{2}$$

$$= \sinh 2x.$$

Q.E.D.

(ii) $$\frac{\sinh x}{\cosh x + 1} = \frac{e^x - e^{-x}}{2\left(\dfrac{e^x + e^{-x}}{2} + 1\right)}$$

$$= \frac{(e^{x/2} + e^{-x/2})\quad(e^{x/2} - e^{-x/2})}{(e^x + e^{-x} + 2)}$$

$$= \frac{(e^{x/2} + e^{-x/2})\,(e^{x/2} - e^{-x/2})}{(e^{x/2} + e^{-x/2})^2}$$

$$= \frac{e^{x/2} - e^{-x/2}}{e^{x/2} + e^{-x/2}}$$

$$= \tanh \frac{x}{2}$$

Q.E.D.

PART 2

Q. 5.—The dust core of a toroidal inductor has a mean diameter of 7 cm. and a cross-sectional area of 2.2 cm². The permeability is 70 and may be assumed constant. Calculate the current required in a winding which has a total of 1,000 turns, to produce a flux density of 100 gauss in the core and determine the inductance of the complete winding.

A.—

$$\Phi = \frac{4\pi n\ I\ .\ \mu\ A}{10\ l}$$

where n = turns, I = current, Φ = flux, μ = permeability, l = aver. length of turn, A = cross sectional area

$$\therefore\ I = \frac{10\ l\ .\ \Phi\ .}{4\ \pi\ n\ .\ \mu\ A}$$

$$= \frac{10 \times 7\ \pi \times 100}{4\ \pi \times 1000 \times 2.2 \times 70}$$

$$= \frac{1}{88}\ \text{amps.}$$

$$= 11.36\ \text{milliamps.}$$

$$\text{Inductance } L = \frac{4\ \pi\ \mu\ n^2\ .\ A}{10^3 \times l}\ \text{millihenries}$$

$$= \frac{4\ \pi \times 70 \times 10^6 \times 2.2}{10^6 \times 7\ \pi}$$

$$= 88\ \text{millihenries}$$

Q. 6.—How does the degree of coupling affect the frequency response of coupled tuned circuits used in intermediate frequency amplifiers?

A 465 kc/s I.F. amplifier using pentode tubes is coupled by pairs of tuned circuits with critical inductive coupling. Coils of Q factor 100, and capacitors of 200 picofarad capacitance are employed.

Calculate:—

(i) The stage gain (assuming the mutual conductance of the valve is 2mA/V).

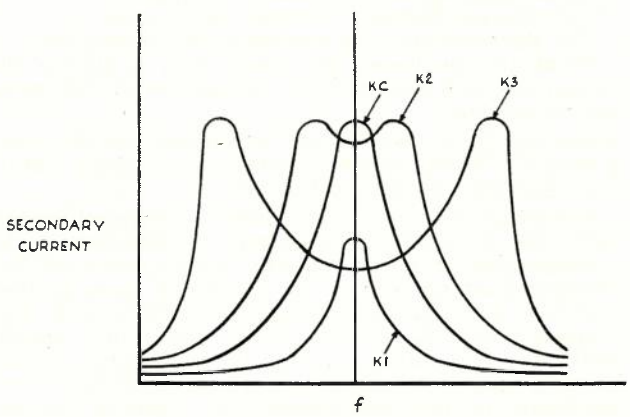
(ii) the inductance erequired.

(iii) the coefficient of coupling.

(iv) the bandwidth of a single stage (3db below maximum response).

A.—When two resonant circuits tuned to the same frequency are coupled together, the resulting frequency response depends upon the degree of coupling. The effects are shown in the figure.

When the coefficient of coupling is small (k_1), the secondary current-frequency curve is much more peaked than the resonant curve of the secondary circuit considered as an isolated circuit.



Q. 6.—Fig. 1.

At critical coupling (Kc) the maximum value of secondary current at resonant frequency is attained, and the curve is broader than the tuned circuit resonance curve, If the coupling is increased beyond the critical value, the curve begins to show 2 humps, whose distance apart increases as the coupling increases. As seen on the curves, the output at the resonant frequency continues to fall, though the maximum value of current at the 2 humps remains substantially constant.

(ii)

$$fr = \frac{1}{2\ \pi\ \sqrt{LC}}$$

$$465 \times 10^3 = \frac{1}{2\ \pi\ \sqrt{L}}\ .\ \frac{10^6}{\sqrt{200}}$$

$$\therefore\ \sqrt{L} = \frac{10^3}{2\ \pi \times 465 \times \sqrt{200}} = \frac{10}{93\ \pi \times \sqrt{2}}$$

$$\therefore\ L = \frac{100}{93^2 \times 2 \times \pi^2} = 0.6\ \text{mH}$$

(iii) For critical coupling—

$$k = \frac{1}{\sqrt{Qp\ .\ Qs}} = \frac{1}{\sqrt{100 \times 100}} = \frac{1}{100} = 0.01$$

(i) Stage gain $= G_m\ Z_L$

$$= \frac{G_m\ \ wo\ \sqrt{Lp\ Ls}\ \ \sqrt{Qp\ Qs}}{2}$$

$$= \frac{2}{10^3}\ .\ \frac{465 \times 1000 \times 2\ \pi \times .6\ \times 10^{-3} \times 100}{2}$$

$= 173$ expressed as a voltage ratio.

$\therefore$ db gain $= 20 \log_{10} 173 = 20 \times 2.238 = 44.7$ db.

(iv) It can be shown for 2 critically coupled circuits.

$\triangle f$ for 3db given by

$$\triangle f = \sqrt{2}\ .\ \frac{fr}{Q}$$

$$= \sqrt{2}\ .\ \frac{465}{100} = 6.6\ \text{kc.}$$

i.e., bandwidth (3db) = 6.6 kc.

Q. 7.—(a) State the laws of electromagnetic induction.

(b) Lenz's law implies the impossibility of a perpetual motion electrical machine. Why is this so?

(c) A circular coil of 200 turns and mean diameter 20 cm. and having a resistance of 4 ohms is mounted with its plane perpendicular to a magnetic field with a flux density of 100 gauss. Calculate the coulombs of electricity which flow through the coil when it is rotated through 180° about a diametral axis.

A.—(a) Faraday's Law of Electromagnetic Induction states that whenever a conductor is moved so as to cut lines of magnetic force, a difference of potential, called an induced e.m.f., is set up between its ends, and if the circuit be complete, a current will flow. More generally, whenever there is relative motion between a conductor and a magnetic field, an induced e.m.f. is produced. The magnitude of the E.M.F. is given by Neumann's Equation and the direction by Lenz's Law, or the Right Hand Rule of Fleming.

Neumann's Equation: The induced e.m.f. is proportional to the time rate of cutting of the lines of magnetic force.

$e = \dfrac{N}{t}$ where N = number of lines of force cut in the time t or the change in the number of lines of force linked with the circuit.

e = induced e.m.f. in electromagnetic units.

$$E = \frac{N}{t \times 10^8} \text{ volts.}$$

Lenz's Law states that in cases of electromagnetic induction the direction of the induced e.m.f. is always such as to oppose the change that caused it.

Fleming's Right Hand Rule.—If the right hand be extended with the thumb and first 2 fingers virtually at right angles, then the first finger indicates the direction of the field, the thumb indicates the direction of the motion of the conductor, and the second finger indicates the direction of the induced e.m.f. Given any two directions, this rule may be used to find the third.

(b) Since Lenz's Law states that an induced e.m.f. always opposes the change causing it, it may be deduced that an original force, causing motion of an electrical machine, will necessarily need to be supplemented by a force to overcome the inherent opposition caused by electromagnetic induction.

Since the concept of a perpetual motion machine implies the continuance of motion without the necessity for continuous application of force, it is apparent that the two phenomena cannot be reconciled.

(c) Linkages = Field x Area x Number of turns.

$$= 100 \times 20^2 \times \frac{11}{14} \times 200 \times 2$$

$$= \frac{88}{7} \times 10^6$$

Suppose that 1 revolution takes t seconds.

$$\text{Then } e = \frac{N}{t} = \frac{88}{7t} \times 10^6 \text{ e.m.u.}$$

$$\text{Current} = \frac{e}{R} = \frac{e}{4 \times 10^9} \text{ e.m.u.}$$

$$\text{Coulombs} = \text{Current} \times \text{time}$$

$$= \frac{1}{4 \times 10^9} \times \frac{88}{7t} \times 10^6 \times t$$

$$= \frac{22}{7000} = 0.00315 \text{ coulombs}$$

Q. 8.—Write an account of photo-electricity and give with circuit diagrams one practical application of the photo-electric cell.

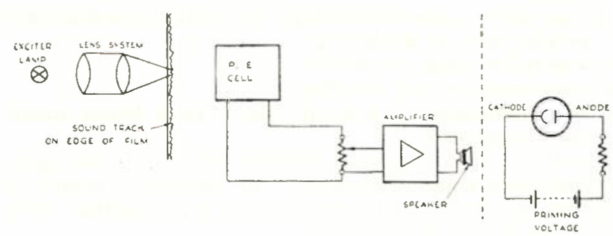
A.—Electrons may be set free from their parent atomic structures by means of radiant energy directed upon an element. This phenomenon was first observed by Hertz, who noted that the electrical discharge between two terminals was facilitated when the negative electrode was illuminated, and that the effect was most pronounced with rays in the ultra-violet region.

Elster and Geitel found that some elements—particularly the alkali metals, e.g., Sodium and Potassium—gave more copious emission of electrons; that the effect was enhanced by enclosing the electrodes in a vacuum. They also observed that the photo-electric emission, as it was called, was directly proportional to the light intensity. It was later shown by Einstein that the phenomenon could be explained on the basis of Planck's Quantum Theory, i.e., the light quanta (photons) disappear as such and their energy content is absorbed by the electrons in the metal, which escape as photo-electrons.

The energy equation is of the form $h\nu - \omega = \frac{1}{2} mv^2$. The right hand side is the kinetic energy of the electrons, h = Planck's Constant, ν the frequency of incident radiation, ω = energy required to overcome the surface restraint and v the maximum velocity. It can be seen that a certain frequency would be required to just liberate a surface electron—known as the threshold frequency. By applying this fact, Milliken was enabled to accurately determine the value of Planck's Constant.

In practice, the phenomenon of photo-electricity is made use of in the photo-electric cell. This comprises a glass envelope containing two electrodes. The cathode is usually in the form of a semi-cylindrical piece of metal with a coating of emitting material—usually a silver plate with a carefully oxidized surface. The anode is either a single wire or a loop of wire. A priming voltage is connected across the cell and the circuit is completed by a load resistance. It is then found that if light of varying intensity is directed on to the cell, the resulting electron emission from the cell will cause a varying voltage to be imposed upon the load resistance. This varying voltage can be amplified and used to carry out a great variety of functions. The glass envelope is either carefully evacuated or, in some cases, filled with a small quantity of inert gas.

A common application of the photo-electric cell is in the sound reproduction of talkie films, using a sound track. In this application, a brilliant beam of light from an exciter lamp is focussed upon the photo-electric cell. The sound track, with its variable intensities of blackness, passes in front of the cell and therefore the varying voltage in the load resistance corresponds with the variations in the sound track. This varying voltage is amplified and ultimately fed to a loud speaker to provide the sound effects for the film. A block schematic of the sound film arrangements and a circuit of the cell proper are shown below.



Q. 8.—Fig. 1.

Q. 9.—Describe with the aid of diagrams:—

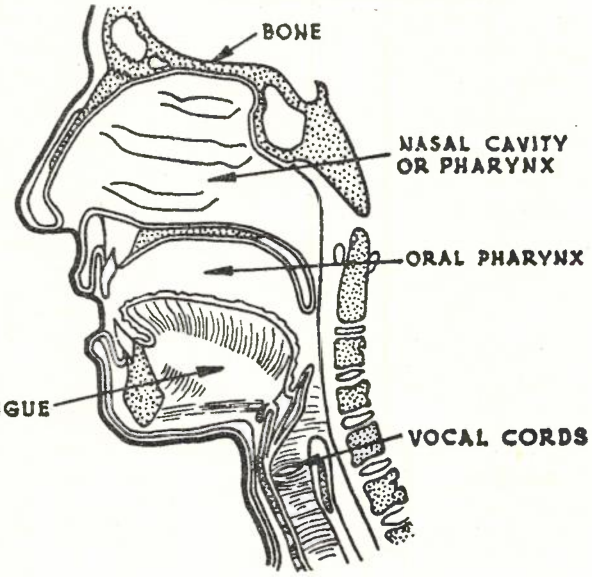
(a) The production of human voice sounds,

(b) the mechanism of hearing in the human ear.

What are the upper and lower pitch limits for the human ear and what are the two effects of increasing age on hearing?

A.—(a) In production of the various voiced speech sounds, the initial source of sound is the human larynx, more particularly the vocal chords.

The sound generated by the larynx, before being radiated into the external atmosphere, is modified by the resonating action of the pharynx, mouth and nose. The different combinations of the shapes of these cavities give rise to the various voiced sounds of speech. The diagram shows the location of the larynx in a normal individual. It is situated at the top end of the trachea or wind-pipe, just behind the base of the tongue. During breathing, the vocal chords, like a pair of lips, are drawn to the sides of the larynx, leaving a free air path to and from the lungs by way of the trachea. In the act of making a noise or speaking, the vocal chords are drawn close together, leaving a slit between them. This slit is known as the glottis. Then the pressure of air is made to flow through the glottis, setting the vocal chords into vibration and thereby imposing periodic fluctuations on the flow of air through the glottis. These fluctuations are the sound waves that are modified by the vocal cavities, tongue and teeth, into the sounds of articulate speech.



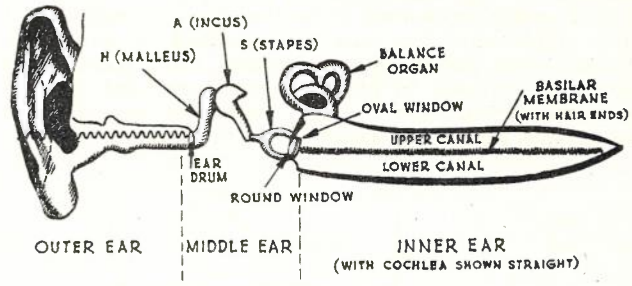
Q.9.—Fig. 1.

(b) The mechanism of hearing brings into use three sections which together form the human ear. Sounds are collected by the external flaps which are so familiar, and passed along the outer ear passage, which is about $1\frac{1}{4}$ inches long, terminating in the ear drum (see Fig.).

The middle ear transmits the sound impinging on the drum through the bones marked H, A and S, to the oval window which separates it from the inner ear. This bone system gives pressures at the oval window some 50 or 60 times as great as the pressure variations on the ear drum. The inner ear is principally a tube wound in a spiral and filled with a lymph fluid in which the nerves end to conduct the sensations to the brain. In the figure, this cochlea is shown stretched out straight for ease of drawing. The system of tubes shown above the left-hand end of the cochlea takes no part in hearing, but helps us to maintain equilibrium and judge our movements. These tubes are known as the semi-circular canals.

In the inner ear, the ends of the auditory nerves divide out to some 3,000 nerve fibres which, in turn, are sub-divided to some 25,000 tuned strings, each having about a dozen hair ends branching out from the basilar membrane, and lying in the lymph liquid of the cochlea. These hair groups appear to be tuned each to a particular small range of frequencies and are stimulated only when those frequencies are received, remaining unresponsive to any others. When the extremely sensitive hair ends and their corresponding tuned strings respond to vibrations, the sensory nerve fibres send pulses to the brain to give the sensation of hearing. This beautifully designed mechanism is not only sensitive to differences of frequency, but also to differences of loudness which cover a power range of a million to one.

The generally accepted upper and lower pitch limits for the human ear are 20,000 cycles per second and 20 c.p.s., but both limits vary with different persons. With increasing age, the frequency range of a person's hearing is reduced; and also the sensitivity is reduced, so that a greater amount of power at a particular frequency is needed to record the sensation of sound for an older person than for a young person.



Q.9.—Fig. 2.

Q. 10.—State Hooke's Law for structural materials, indicating the limiting condition for which it remains true.

Define—

Bulk or Volume Modulus.
Rigidity or Shear Modulus.
Young's Modulus.
Poisson's Ratio.

Describe how Young's Modulus for a wire may be determined.

A.—Hooke's Law states that for a substance **within its elastic limit,** the linear extension due to a stretching force is proportional to the magnitude of the force. The elastic limit is defined as that point at which the material will fail to return to its original shape when the stretching force is removed, i.e., that point at which permanent distortion takes place. Thus, for Hooke's Law to be true, the stress applied must always be less than that which would cause a permanent distortion.

Bulk or Volume Modulus. If a substance is compressed by the application of a uniform pressure, applied evenly at all points on the surface, the ratio of the volume change (expressed as a fraction of the original volume) to the force causing the change in volume is a constant, known as the Bulk or Volume Modulus for the particular substance.

$$k = \frac{FV}{v}$$

Rigidity or Shear Modulus. If a cube of a given material were subjected to equal or opposite forces applied tangentially along two opposite faces of the cube, it would tend to rotate about its centre-point. If this tendency to rotation were prevented by an equal pair of forces applied at right angles to the first couple, the cube would tend to distort. In such a case, the angular distortion caused would be proportional to the applied stress, and the ratio stress/strain is known as the Rigidity or Shear Modulus.

$$n = \frac{p}{\theta}$$

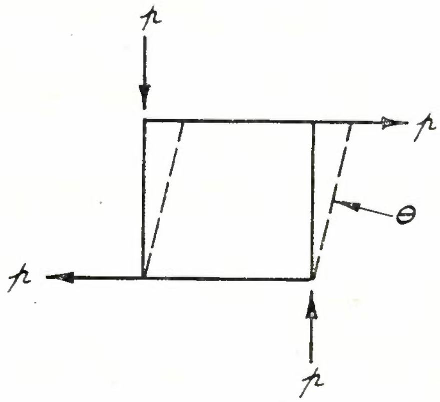
Young's Modulus. The ratio of stress to strain for a change in length of a wire, caused by the application of a force to produce an extension of the wire is known as Young's Modulus.

$$Y = \frac{Fe}{A.L.}$$ where e = extension caused by F. A = cross sectional area of wire. L = normal length of wire.

Poisson's Ratio. When a rod of metal is elongated by the application of a stretching force, the elongation is accompanied by a reduction in the lateral dimensions.

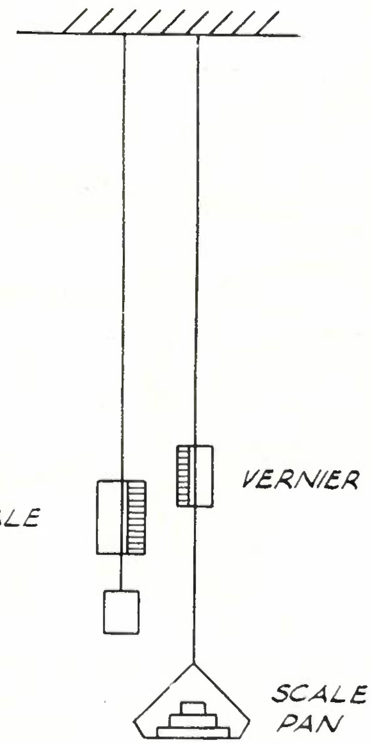
The ratio of the lateral strain to the longitudinal strain is a constant for the particular material, and is known as Poisson's Ratio.

To measure Young's Modulus for a wire, 2 similar wires of adequate length (at least 1 meter) are suspended from the same support. Each wire carries a sufficient weight suspended at its lower end to maintain it in a rigid state. One wire has attached to it a finely divided scale, and the other a vernier, the 2 scales being carefully adjusted to present a truly vertical face on their measuring edge. The rest position of the vernier is noted, and then an increasing weight is added in equal



Q.10.—Fig. 1.

increments in the scale pen of the wire carrying the vernier. At each stage the addition in weight and the resulting extension of the wire are measured. When a sufficient range of readings has been obtained, the weights are removed in similar increments, and the contractions in the wire corresponding to the reduced weights are noted. Averaging the upward and downward readings, the values of extension in centimeters and corresponding forces in gms. are calculated. The ratio $\frac{\text{extension}}{\text{force}}$ will be found to be constant within the limits of experimental error, and the values of this constant is Young's Modulus for the material of the wire.



Q.10.—Fig. 2.

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