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Telecommunication Journal of Australia

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TELECOMMUNICATION POWER PLANT IN TELEPHONE EXCHANGES

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Introduction

The rapid growth of the P.M.G. Department activities since the end of World War II has emphasised the importance of long term planning and the application of engineering techniques to improve overall economies and increase operational efficiency in the power plant field. The standardisation of equipment and installation, operational and maintenance practices must play an important part in achieving these objectives, and a full knowledge of local and overseas developments is essential in order to fully appreciate the problems.

Since the power plant used by all sections of the Department is basically similar in design and varies only in certain operational aspects and other minor details, a high degree of standardisation and simplification should be possible with minimum variations in design. There can be no question that unnecessary variety of product considerably increases manufacturing costs. Added to this is the related problem of non-interchangeability, delay in obtaining non-standard spare parts, increased stocks, and unnecessary design and administrative work. No doubt, in order to gain the maximum degree of rationalisation in this field, it is of interest to note that some large Overseas Administrations such as the British Post Office, the B.B.C. and German Posts and Telegraphs have employed a separate power section to deal with all the power work.

Although this article covers in detail the power plant requirements of telephone exchanges, it is applicable in many respects to other sections of the Department using similar power plant.

General

The normal power plant arrangements at telephone exchanges and other centres, consist of the incoming supply mains with the supply authority's protective device, the energy meters, the consumer's incoming switching and protection device, the sub-circuit distribution and protection, the conversion plant for the communication equipment including any ringing and tone equipment, the batteries and the stand-by plant. Various methods of providing a power supply are used at locations where the public mains supply is not available, and these are described in detail under the heading "Power Supply."

The main subdivisions involved in the development of standardised power practices in the Department are shown in Fig. 1 under various headings, and it will be seen that a considerable amount of work is necessary to cover this field. An interim step has already been taken in this direction by the issuing, in August, 1952, of a General Engineering Instruction A0510, under the heading "Power Plant for Telecommunication Activities" covering the more important general principles which apply to all engineering sections pending the revision of the earlier detailed instructions to bring them into line with present practices. The preparation of power plant specifications to include the requirements of all sections is proceeding and general specifications for self-contained fully automatic diesel alternators and for low and medium voltage power rectifiers are now completed.

Power Supply

A.C. Mains. The low tension supply distribution in all States ranges from 380/220 volts to 440/250 volts, 3-phase, 50 c/s. The frequency at Perth and parts of Western Australia is at present 40 c/s, but this is being converted now, and will all eventually be changed to 50 c/s. Meantime, certain items of plant have to be specially ordered for 40 c/s working. The present voltage range presents no problem on the standardisation of equipment, and for obvious reasons 3-phase working should be used at all premises except in the cases of very small loading, where single phase is satisfactory. At important large centres of communication, the public mains supply may be taken from a high tension source such as a 6.6 kV ring main and transformed down to low tension on the premises. This gives a two-way supply, increases con-

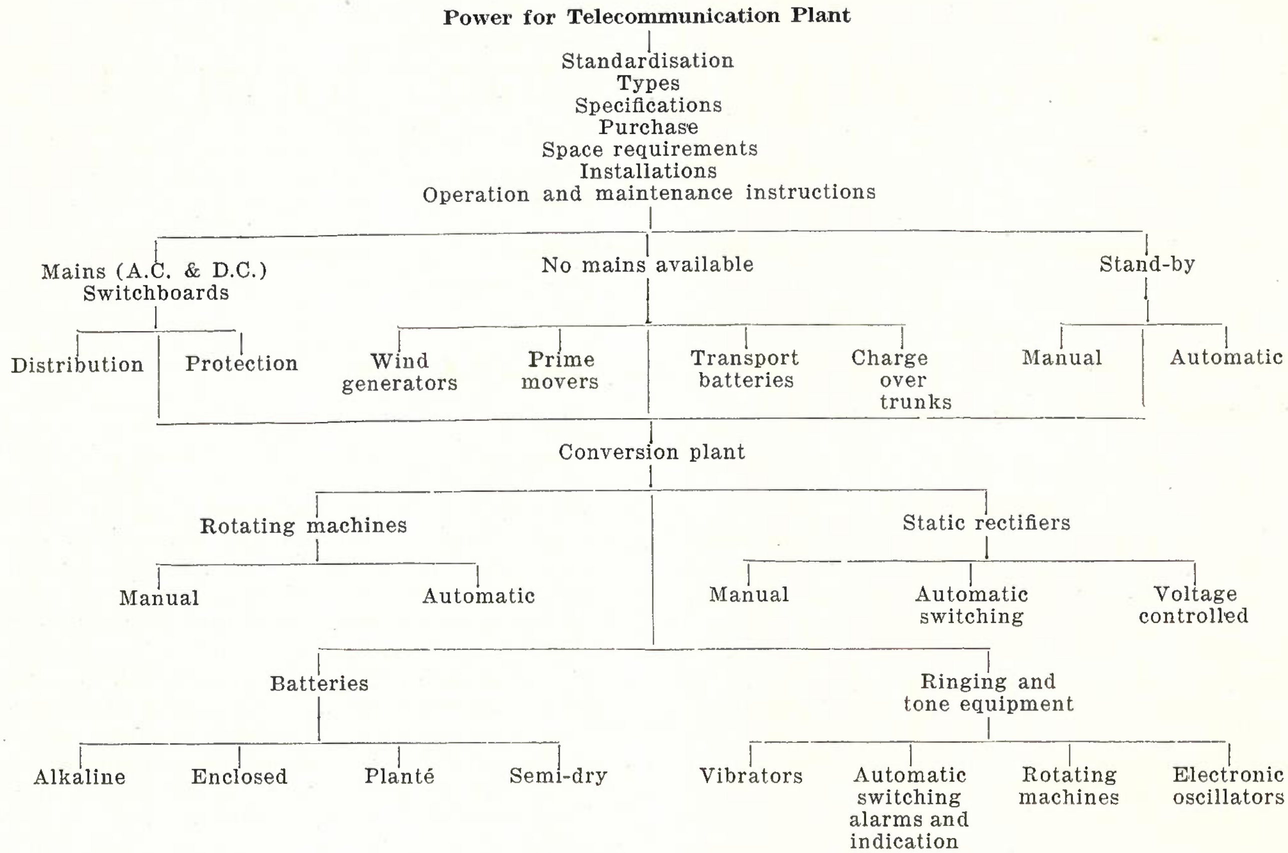

Fig. 1.—Power Equipment for Telecommunications.

tinuity and reliability and provides a most flexible arrangement in the case of enforced power cuts.

D.C. Mains. No comments are necessary as the small number of existing D.C. networks is gradually being converted to A.C.

Fault Capacity. The continuous increase in capacity of modern power stations and of the distribution system results in the flow of large currents into a fault or short circuit. This fact must be taken into account in the design of consumers' incoming mains equipment to ensure that satisfactory protection is provided at all our premises.

Interruptions due to the Failure of the Public Supply. Whilst the avoidance of interruption is a general objective throughout the Department's plant, there are some cases where it is not economical to provide equipment that will eliminate entirely the possibility of short interruptions due to power failure. However, in the case of telephone exchanges, the power plant is provided on the basis of ensuring that mains failures do not interrupt service. In achieving this objective, the breaking-down of established trunk switching connections on metropolitan and intra-state routes will be avoided. This principle also applies to locations carrying important inter- and intra-state telephone and telegraph service.

Locations without Public Power Supply. At many small communication centres in outlying country areas such as R.A.X's, repeater stations, etc., no public power supply is available. The various methods of providing a power supply in such cases are set out below. Under all the conditions of supply, with the exception of that under (c), a certain degree of smoothing is required depending on the type of communication equipment being used.

(a) The provision of batteries on a charge-discharge basis with a suitable prime mover-generator charging plant with manual or automatic operation depending on staffing conditions. A typical example is the small 500 watt automatic start and stop engine-driven generating set which is being provided at a number of R.A.X's. This set uses petrol start with an automatic change-over to kerosene when running, to reduce the fire risk. A contact volt meter control is used to start the the engine when the battery voltage falls to 46 volts, and stops the engine when the battery voltage reaches approximately 56 volts. The unit can be used either in a suitably ventilated asbestos enclosure in the R.A.X., or on a concrete slab outside the exchange with a metal protecting cover locked in position to prevent any unauthorised person from interfering with the engine. Fig. 2 is a photograph of such an installation. Diesel driven sets are preferred for this type of work, but are unobtainable at present in this particular size.

(b) The provision of batteries with wind-driven generators for battery charging. This method of power supply has been in use for some years at a number of R.A.X's and repeater stations, and is quite satisfactory at locations where wind conditions are favourable. At the moment there are about 200 of these units in use at R.A.X's throughout the Commonwealth. These generators operate in a similar manner to motor car generators, with cut-out and voltage control arrangements. A variable pitch propeller, which is automatically feathered, according to the wind velocity,

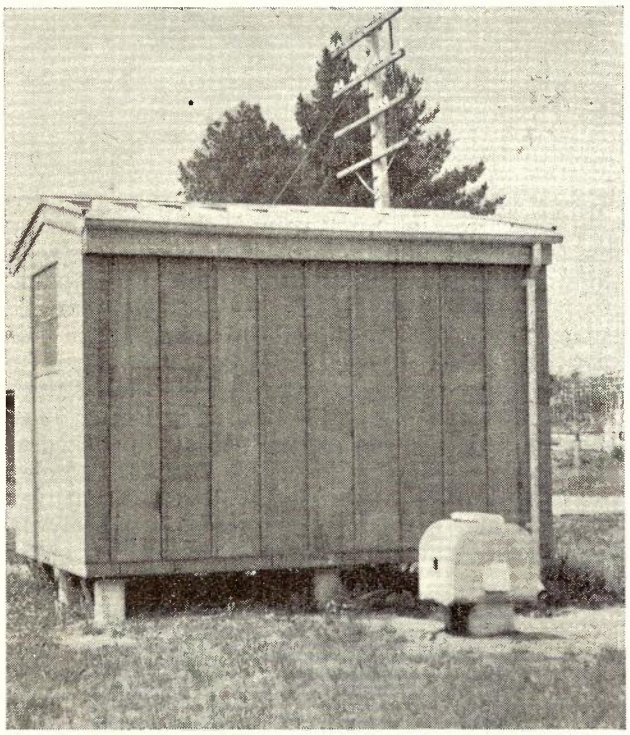

Fig. 2.—R.A.X. Engine Generator Installation.

to give efficient operation and at the same time provide protection against over-speed in high winds is used. There are some interesting developments taking place overseas at the present time on wind generator design. One of the significant points for small sets is the advance now being made on the generator design. Up to the present all the generators used by the Department are of conventional D.C. type, and require a certain amount of regular maintenance. It is now possible to design small alternators of equivalent output with a permanent magnet field operating at a nominal frequency of between 400 and 600 c/s, and using dry plate rectifiers for conversion to D.C. supply. This type of alternator is much lighter than the equivalent D.C. generator. It has a higher efficiency, requires very little maintenance and has a very good regulation characteristic. Due to full field being available at all speeds it should be possible to utilise very low speed winds for generating power. It is interesting to note that the type of wind generators now in use are cut-in at a wind speed of approximately four miles per hour, and it is expected that with the new design alternator this can be reduced. The design and production of the latter type unit is being investigated.

(c) The provision of batteries only with regular replacement with fully charged cells at intervals depending on the battery capacity and current drain. This arrangement involves transport and the use of two sets of batteries and is adopted as a temporary measure.

(d) The provision of batteries with charge over trunk facilities during slack traffic periods from a location where the public mains supply is available. A rectifier is used to provide the D.C. supply, and its output voltage is adjustable over a wide range to allow for the voltage drop over the line or lines in parallel on which the charging current is transmitted. The voltage range is limited to 150 volts maximum for line personnel safety reasons. This method may in some cases cause electrolysis troubles on the underground cable systems.

(e) A continuously running prime mover generator set with a similar set as a stand-by. The use of low speed diesel alternator equipment is preferred, and such an arrangement would probably only be used at unattended centres. The plant would be of the fully automatic type. Details of diesel alternator plant are described under the heading "Stand-by Plant."

A.C. Switchboards

For many years in the past low tension A.C. switchboards consisted of heavy slate panels on which were mounted the associated open type circuit breakers and switches, porcelain handle rewireable fuses and surface mounted indicating instruments. At a later stage the slate panels were replaced with sindanyo, or its equivalent, which has much better mechanical and electrical insulating properties. The development of all steel cubicle type switchgear, together with advance in fuse and circuit breaker techniques, has introduced a new phase in switchgear design. It is now possible to design A.C. switchboards or cubicles which occupy much less space than the older type boards and at the same time provide a better degree of protection with positive discrimination under severe fault conditions.

The purpose of the incoming and main distribution board must be clearly understood in order to determine the design and type suitable for telephone exchange work. The protection on the incoming supply and main distribution board is to give proper discrimination and back up protection to all the consumers' power plant in the event of severe fault conditions. The small circuit breakers, motor starters with oil dash pots or thermal overloads, and fuses fitted on the main items of power plant all give adequate overload protection under normal service conditions. The protective equipment on the power board should only function in the event of a sub-circuit cable fault or a short circuit in the power plant where the low rupturing capacity circuit breakers or starters are not capable of clearing heavy fault currents without damaging their mechanism.

Similarly, the supply authority's incoming fuse or circuit breaker protects the connections between the incoming mains and the consumer's equipment, and the consumer's incoming fuse or circuit breaker protects the connections to the main distribution. The discrimination on these circuits should be such that a severe fault at any point only operates the associated protective device and under no circumstances should a fault on the outgoing side of the consumer's main incoming fuse or circuit breaker operate the supply authority's incoming protection. The likelihood of severe faults occurring under the normal service working at telephone exchanges is very remote. However, this condition must be catered for and, therefore, any standard design of A.C. board adopted should be capable of dealing with all the supply conditions met with throughout the Commonwealth.

Considering all the above factors, the most effective and cheapest method of severe fault protection is the use of high rupturing capacity type fusegear. Standard fuses of this type are available to deal with any value of fault kVA likely to occur in low tension networks. These fuses give excellent discrimination with high speed operation

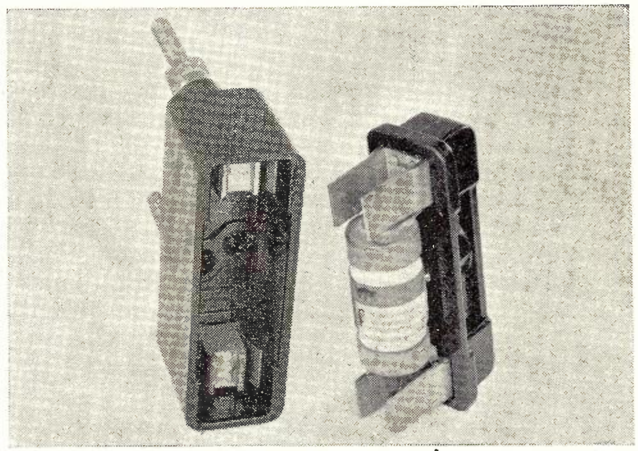

Fig. 4.—H.R.C. fuse and holder.

on short circuit, are non-deteriorating, give positive indication, eliminate fire risk, are space saving, give flexibility and are considerably less costly than circuit breakers of equal rupturing capacity. Fig. 3 shows a simple single line diagram of a typical arrangement of a mains supply board using high rupturing capacity fusegear. A standard fuse of this type, complete with fittings, and suitable for panel mounting, is illustrated in Fig. 4. It will be noted that the contacts are totally enclosed and the rupture indicator is visible through a hole in the centre of the fuse handle. Another feature to note is that the main contacts are adequately protected when the fuse-holder is removed.

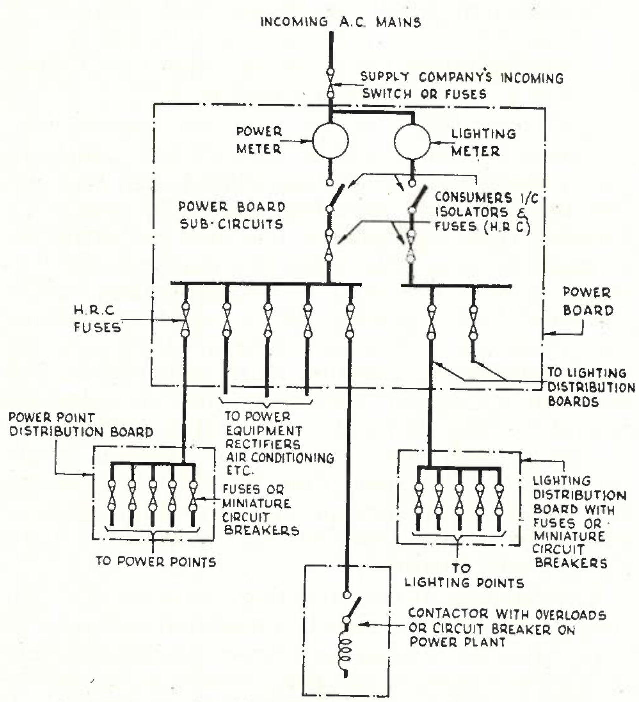

Fig. 3.—Single line diagram of typical power supply board.

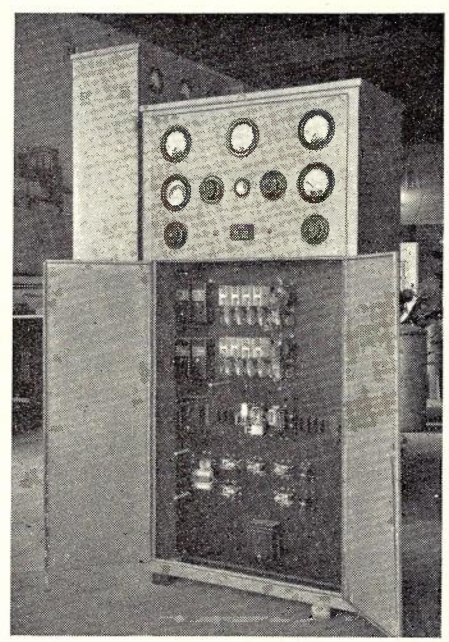

Fig. 5.—Typical A.C. supply cubicle.

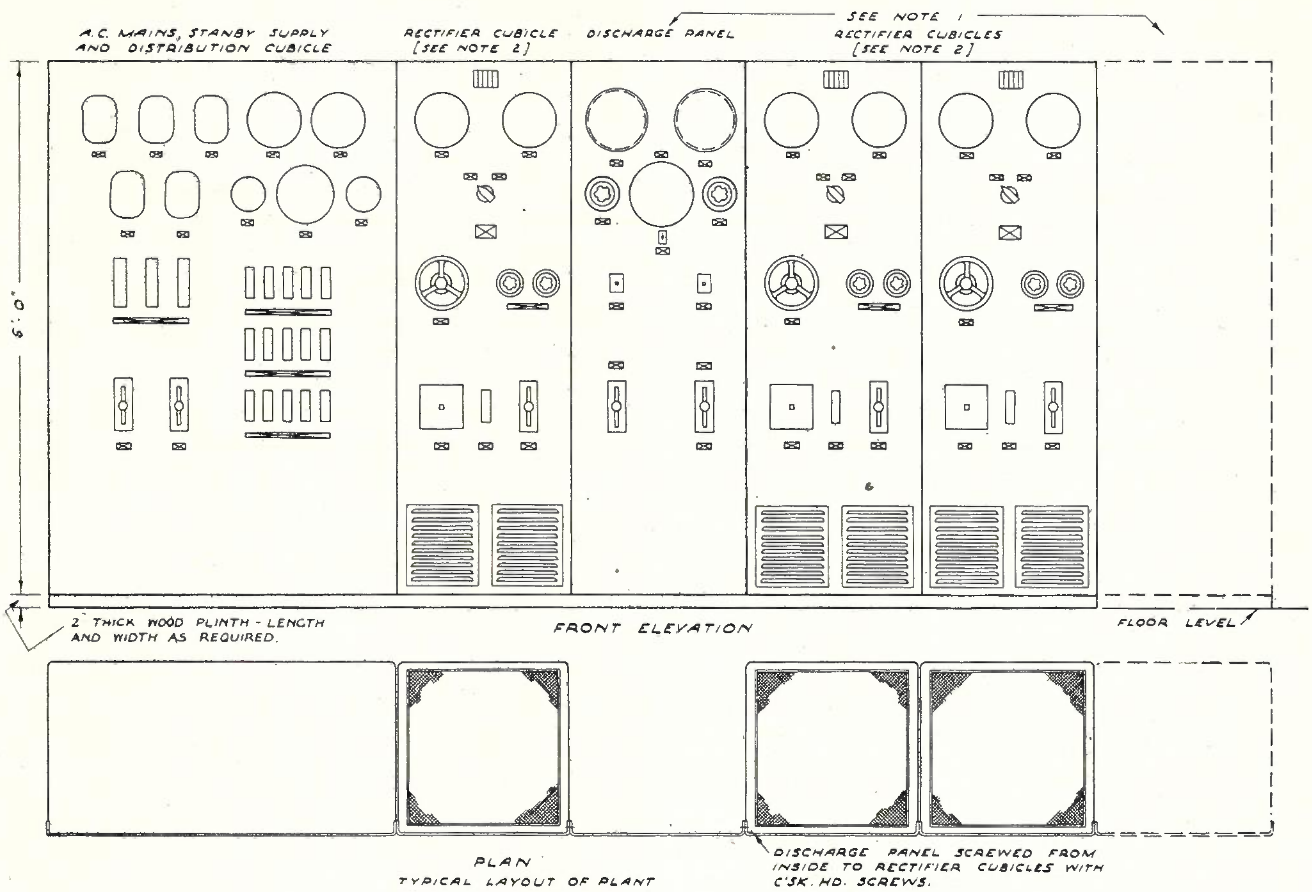

Fig. 6.—Typical arrangement of telephone exchange plant.
NOTE: 1. Position of Discharge Panel will depend on location of batteries.
2. Width and depth of Rectifier Cubicles will depend on rating of Rectifiers.

The maximum loading likely to be encountered at all telephone exchanges, with the exception of large city exchanges, is about 100 kVA, and on this basis a cubicle type switchboard of single design with a steel front panel, would cover all the normal requirements. The energy meters, indicating instruments, and stand-by diesel alternator switching arrangements could all be incorporated in the cubicle. A standard number of "ways" would be provided for main distribution, and the rating of the fuse cartridges would be determined by the loading and working conditions at any particular exchange. The overall design has to meet the various electricity regulations in all States. A typical A.C. cubicle of 75 kVA capacity, as used by another Government Department for incoming main supply, and incorporating the automatic changeover switching and controls for a stand-by diesel alternator is shown in Fig. 5.

The adoption of cubicle type switchboards has the advantage of lining up with other all steel cubicles now standardised in the Department for power rectifier plant. They are easy to install and can be located in almost any position without any special preparations, and are fully protected against accidental contact with live parts. The standard colour finish is light battleship grey. All exposed metal parts are finished in high grade chromium plate, and all indicating labels are in black with white lettering. Danger labels are in red with white lettering. Fig. 6 illustrates a typical arrangement of automatic exchange power plant, including the A.C. cubicle, power rectifiers and discharge board, all with steel front panels and dead front type switches. This layout is for 50 volt D.C. supply only. With combined 130 volt and 24 volt units appropriate rectifiers are used. The discharge panel may, however, in such circumstances, cater for the three D.C. supplies. A three feet panel is needed in such cases to accommodate the additional battery switches. The possibility of locating the complete power equipment in the same room as the communication equipment at telephone exchanges is being investigated, and Fig. 7 shows a proposed layout of power plant in such a location.

Stand-by Plant

An essential part of any supply authority's policy is that of continuity of supply, and prior to World War II, considerable progress was being made in providing a service free from interruption under normal working conditions. During the war

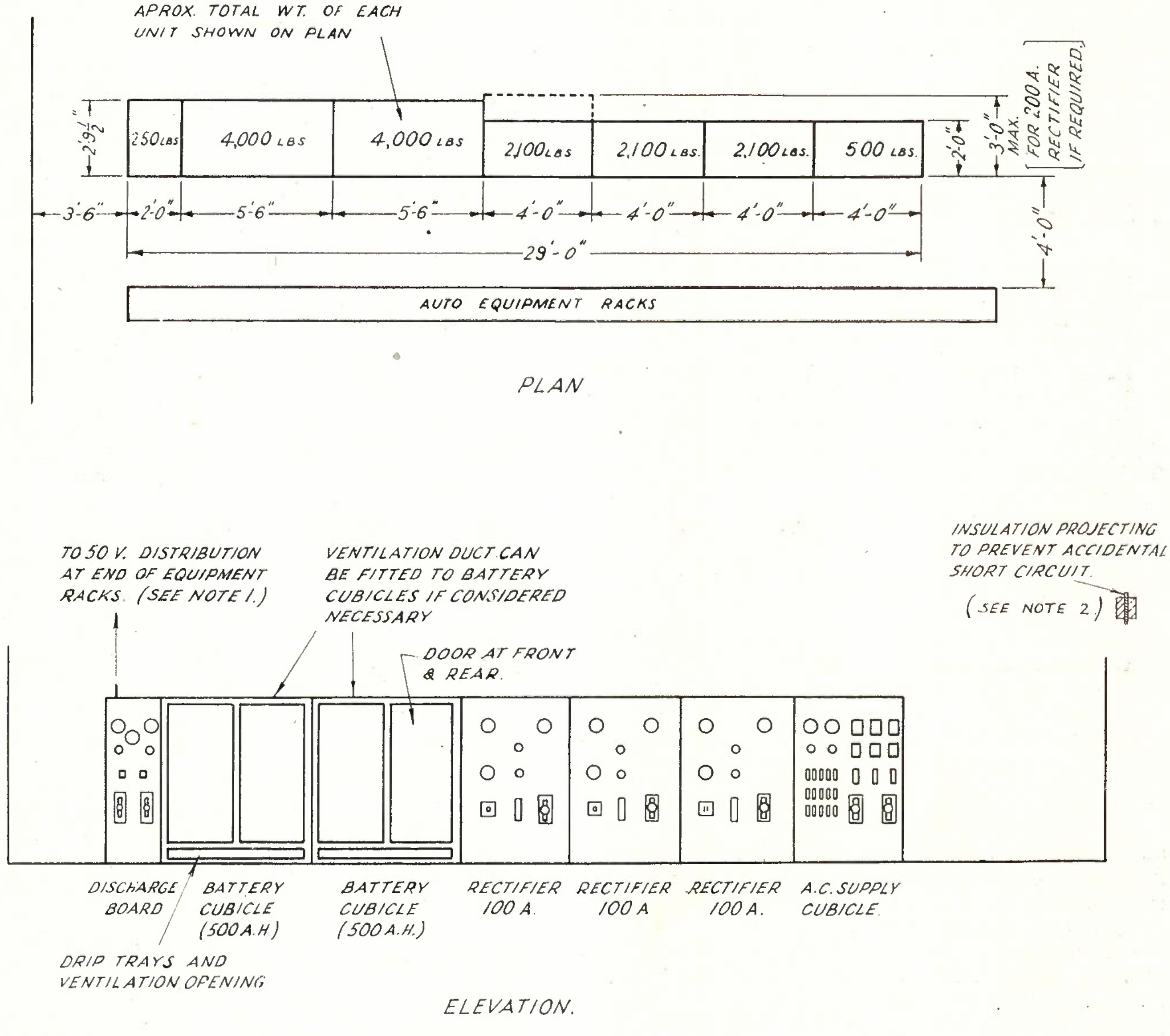

Fig. 7.—Typical layout of power plant in same room as communication equipment.

Notes: 1. When Busbar is at opposite side, panel layout is reversed.

2. Copper discharge bars can be placed together with insulation between, and can probably be operated at 1000 amps. per sq. in. instead of the present 500 amps. per sq. in., due to the short run.
3. Cable connections can be used for charging leads from rectifiers.
4. Charge and discharge arrangements under (2) and (3) give the ideal system for keeping electrical noise at a minimum.
5. Battery paralleling switch is provided on discharge board.
6. The A.C. cubicle includes metering and main distribution. Automatic change-over arrangements may also be provided is diesel alternator plant is installed.
7. The pasted plate cells have acid level indicators fitted. Hydrometer, topping-up device, etc., will be clipped inside cubicle.
8. Methyl Bromide or CO_2 fire extinguishing systems may be fitted to cubicles if considered necessary.

the shortage of materials, concentration of industry upon essential production, and other factors, severely curtailed power generation and distribution expansion, with results which need not be mentioned here. This state of affairs led to the installation of stand-by power plant in industry and at important communication centres, etc., where continuity of supply is essential for efficient working. This plant gives adequate reserve in case of war damage, industrial disturbances and other factors which may interfere with the commercial supply. At telephone exchanges in the past it was usual to rely on a large battery reserve to avoid loss of service due to supply failure, but with the great expansion in communication services the size and capacity of batteries required to give an ample reserve present a difficult problem in space requirements, maintenance and overall costs.

The continuous improvement which is being achieved in the reliability of the commercial supply under normal circumstances must be considered when deciding the most economical method of providing a reserve supply. It would seem feasible, therefore, to assume that any failures would tend to become less frequent and would only be of short duration except under abnormal conditions, and provision must therefore be made for the exceptional interruptions of long duration. On this basis prime mover generating plant with a small battery reserve is now considered the most efficient and economical method of providing a reserve supply to meet all the circumstances which may arise in the future. Such an arrangement gives a much greater reserve than with batteries alone, and at the same time results in considerable economies in space requirements. Diesel driven alternator plant is favoured in order to minimise fire risk and to give the most economical operation. Fully automatic start and stop plant, which responds to the cutting off and restoration of main supply in accordance with pre-determined time lags is preferable.

At continuously staffed exchanges employing stand-by alternators, and at other exchanges employing fully automatic stand-by plant, a battery capacity capable of carrying the load for approximately three hours at the estimated maximum drain at the ten year period should suffice. Such arrangements would, of course, keep the exchange working for a period much longer than three hours. Stand-by plant of sufficient capacity should be provided to carry the estimated exchange load at the ten year period. In computing this load some allowance is made for the more important auxiliary services such as lighting, skeleton lift service and essential tools.

A method of providing an uninterrupted supply in the case of mains failure without the use of batteries is of interest as it has applications in the telecommunication field. A continuously running synchronous motor with flywheel is connected in parallel with the incoming supply mains, and this motor is arranged for coupling to a prime mover through a magnetic coupling. A break in the mains supply causes the prime mover to start up, and when it reaches normal speed it is automatically coupled to the synchronous motor and this motor then acts as an alternator and generates the necessary supply for the station equipment. During the period from the mains interruption until the prime mover reaches normal speed, the synchronous motor acts as an alternator driven by the energy stored up in the flywheel. Although this method has not yet been applied in Australia, it has been used by some overseas administrations. A study of possible application to our plant is being made. A point of interest is that the machine running as a synchronous motor can be used for power factor correction.

The self-contained diesel alternator running at 1500 r.p.m. mounted on a rigid chassis suitable for floor mounting, is the type preferred for most of the Department's stand-by plant requirements. Such units are easy to install and can be moved readily from one point to another if so desired. For the larger stand-by plants and those units used for continuous running service, slower speed engines are preferred.

There are two general conditions of operation for stand-by plant:—

(a) Manual operation. Used at centres which are continuously staffed, and for portable sets which are kept in reserve to cover any instances where the installed plant fails to start or during overhaul periods.

(b) Fully automatic operation for starting at a predetermined time after failure of the normal mains supply and automatically switching back when it is restored. Used at unattended centres and centres which are not continuously staffed.

Under both conditions of working the design of the sets should be essentially the same, with the exception of the additional controls required for automatic operation.

In the majority of cases, self-contained units mounted on a rigid chassis do not require specially prepared foundations, when mounted on properly designed anti-vibration pads. This is a considerable advantage, as it is possible to put sets in service quickly without the need for preparing elaborate foundations. These mountings are designed to reduce the transmission of vibration from the apparatus, causing the disturbance to its supporting structure. One type of mounting consists of two concentric cylindrical metal parts with a pre-stressed rubber ring between them. The load is applied axially with the rubber in shear, and the metal parts are designed for fitting to the apparatus concerned. The outer member, which is completely insulated from the inner by the rubber ring, has a flange for floor mounting, and the inner member bore is for a fixing bolt. It must be emphasised that careful consideration is necessary in choosing the right type of anti-vibration mounting for each particular application in order to obtain the best results. Experience has shown that practically no vibration is transferred to the building if these pads are used. An additional precaution which is worth considering from the point of view of noise is the provision of acoustic treatment on the walls of the engine-room. Adequate ventilation of the engine-room must be provided as the thermal efficiency of a diesel engine is only about 30 per cent. and this

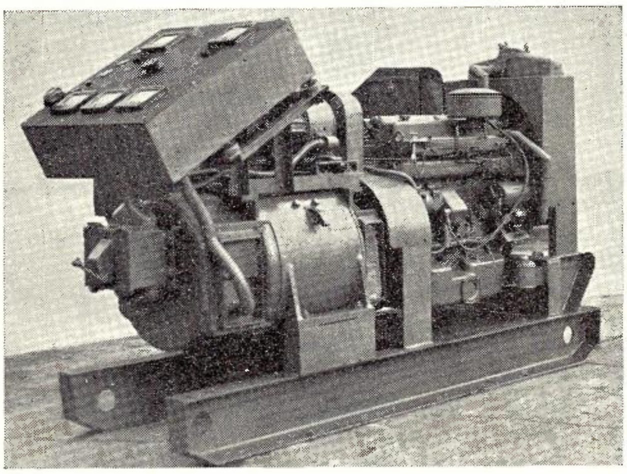

Fig. 8.—75 K.V.A. self-contained diesel alternator set with water cooling.

means that considerable heat must be dissipated from the area containing the standby plant. Figs. 8 and 9 show typical self-contained units of the water-cooled and air-cooled type respectively. The latter type has some advantages from a servicing point of view.

General Details. The engines are designed for operation in ambient temperatures between 25° and 120° F. They are totally enclosed and fitted with positive pressure system lubrication, and no moving parts should require lubrication by hand prior to the starting of the engine or whilst it is in operation. An efficient silencing system is fitted on the air inlet and the exhaust, and a suitable air cleaner is included on the intake. A lubricating oil filter is provided, and where necessary lubricating oil cooling it fitted. Electric starting is preferred on all engines. A pressure sensitive relay in the lubricating oil line and a thermostatic relay in the cooling water system are required for alarm operation and for shutting the set down if the oil pressure falls to a dangerous value, and if the cooling water temperature is excessive. The fuel service tank is of sufficient capacity for 24 hours' operation at full load. This tank is fitted with a float type oil level switch incorporating two sets of electrical contacts, one to be used to operate an alarm, and the other to shut the engine down before the tank is empty. One hour's operation on full load is the time interval between these contacts.

Electrical Requirements. In general, the alternator and exciter are fully protected against accidental contact with rotating or live parts, and the bearings are of the ball or roller type, grease lubricated and are efficiently sealed against dust. Automatic voltage control of the alternator output is provided, and the output voltage is controlled within plus or minus two per cent. of the specified value for any load between no load and ten per cent. overload. The self-regulating type of alternator with exciter is preferred, as this eliminates the necessity for a separate automatic voltage control regulator and, therefore, reduces maintenance. On manually operated sets the switchgear and control apparatus form an integral part of the set with provision for remote starting and stopping, and the extension of the various alarms to a supervisory position.

An elapsed hour meter is fitted so that it is an easy matter to arrange routine maintenance on a running time basis. The automatic switchgear and all the associated controls used on fully automatic equipment is contained in a floor-mounted cubicle which can be placed in a convenient position with other items of power equipment. As stated earlier in this article, under the heading "A.C. Switchboards," the most convenient arrangement is to combine all the A.C. incoming, main distribution and stand-by plant controls in one cubicle. The operation of the automatic changeover arrangements should be such that the failure of the normal supply on one or more phases shall, after an adjustable pre-determined interval, initiate the starting of the engine prior to an automatic changeover to the alternator supply. On the full restoration of the normal supply, a suitable adjustable interval should elapse before changeover to the normal supply and shut down of the generating set.

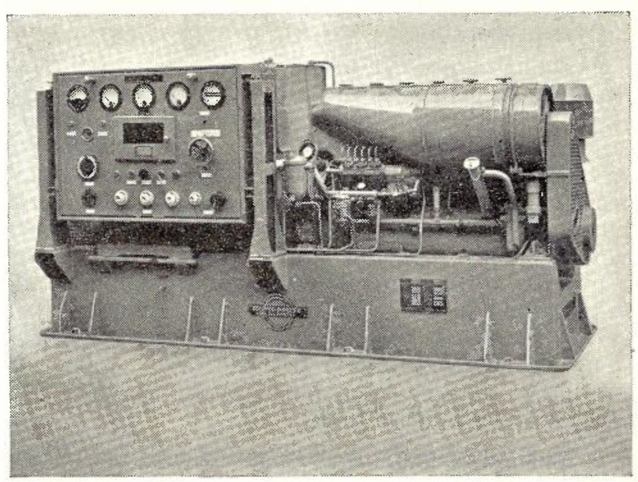

Fig. 9.—60 K.V.A. self-contained diesel alternator set with air cooling.

Precautions are taken to cover the following conditions.—

(i) Stopping the engine if the lubricating oil falls below a safe value.
(ii) Stopping the engine if the cooling water temperature rises to a value detrimental to the life of the engine.
(iii) Isolating of the starting circuit if the engine should fail to start within a pre-determined period.
(iv) The normal to stand-by changeover should not take place until the alternator output voltage is assured and failure of the alternator to generate shall prevent the changeover taking place.
(v) Pre-heating of the cooling water may be required at locations where the air temperature falls to a low value, to ensure that the engine is capable of quickly taking over the load without risk of piston seizure.

In order to keep the starting battery in good condition, the use of a two-rate charger normally connected to the supply mains is preferred to the method of using a dynamo driven by the engine. Under emergency conditions the rectifier would be connected to the alternator output.

Spares. In order to keep the quantity and number of spare parts down to a minimum it is essential that the types of engine generating sets used should be as few as possible. In general the spares should be located at some central depot where a complete record can be kept of their usage in order to determine any future requirements based on operational experience over a period of years. It is also essential that all the spare parts are readily available within Australia.

A.C./D.C. Conversion Plant

General. The type of conversion plant now being placed into service is of the static rectifier class. This type has practically replaced rotating machines for A.C./D.C. conversion work in all fields of electrical engineering. Examples are, traction, electrolysis, battery charging, high tension D.C., control circuit A.C./D.C. conversion, etc. The reasons for the use of the static type of plant are, of course, easier maintenance, smaller floor space requirements and the elimination of output circuit breakers. In addition, the capital cost of the plant is in general less than that for rotating machines.

Static Rectifiers. The static rectifiers which are used in the Department include copper oxide, selenium, mercury vapour, mercury arc and thermionic types. In addition, reports have been received that germanium rectifiers are under development although no complete details are yet available. One interim report stated that a water cooled rectifier using this material was capable of carrying 100 amps, using approximately a square centimetre area of rectifying surface.

Concerning the other types, the copper oxide unit has now practically been abandoned for power work and in the dry disc type, selenium rectifiers are generally adopted. Mercury vapour and mercury arc units are used in some fields which require higher voltages and they are useful for this purpose because of their high efficiency. The mercury arc rectifier at high voltages has an efficiency of up to 95 per cent. This efficiency falls off, however, at the lower voltages because the drop across the arc is approximately 20 volts, thus making it not very attractive in this field.

The selenium types in general use have facilities for controlling the voltage, both manually and automatically. The type of control may be selected by the operation of a suitable switch. The manual control is usually achieved by using a tap changer but may also make use of the saturable choke in combination with a suitable potentiometer. As far as the automatic control feature is concerned, the present trend is to use some form of saturable choke control in combination with either a thermionic or magnetic type amplifier. Although extensive use in other countries is made of the magnetic amplifiers for this class of service no actual experience has yet been obtained locally with this equipment. It is likely, however, that some will be introduced in the comparatively near future. The advantage claimed over the thermionic type is the absence of consumable parts in the equipment which are subject to replacement, such as valves.

The tendency nowadays from a physical make-up point of view is to enclose all the rectifier equipment within fire-proof metal containers. The small types are designed for either rack or wall mounting, whereas the larger ones are of the cubicle type for standing on the floor. All types have flame-proof wiring, and there must be adequate provision for room ventilation, as only convection cooled units are used. The floor mounted cubicle type rectifiers are designed to line up with the power switchboards, and are six feet high. For the sake of uniformity the width of the units is varied in multiples of six inches, depending upon the capacity. A maximum depth of three feet for the cubicle has been stipulated in order to facilitate maintenance attention within the cubicle from the rear of the unit. In this regard the units now being supplied are equipped with easily detachable rear covers and control amplifiers of the removable type equipped with plug and jack connections. The smaller cubicles such as the 10 and 20 amp. units are designed for front access. This allows them to be placed against a wall, thus saving floor space. A feature of the front panel of the latest units is that it is made of light gauge steel, which will be coloured light grey in contrast to the black sindanyo which was formerly used for this purpose. This change involves the use of dead front type switches.

The automatic control feature is designed to control the voltage of the equipment to a constant value within plus or minus one per cent. even though the output load may vary from 5 to 100 per cent., the frequency change plus or minus 3 per cent. and the A.C. mains voltage vary from plus 5 to minus 10 per cent. On battery floating rectifiers an automatic overload protection is also incorporated within the control device in order to limit the output current to the maximum rating of the rectifier in the event of the exchange load rising above this value. Under such circumstances the excess current would be taken from the battery. A study is being made of the possibilities of automatic switching in and out rectifiers to follow the varying exchange load and, in fact, a suite of such units is expected to be in service soon. This plant has facilities for automatic end cell switching. Fig. 10 shows a typical modern rectifier unit of the cubicle type alongside an A.C. cubicle.

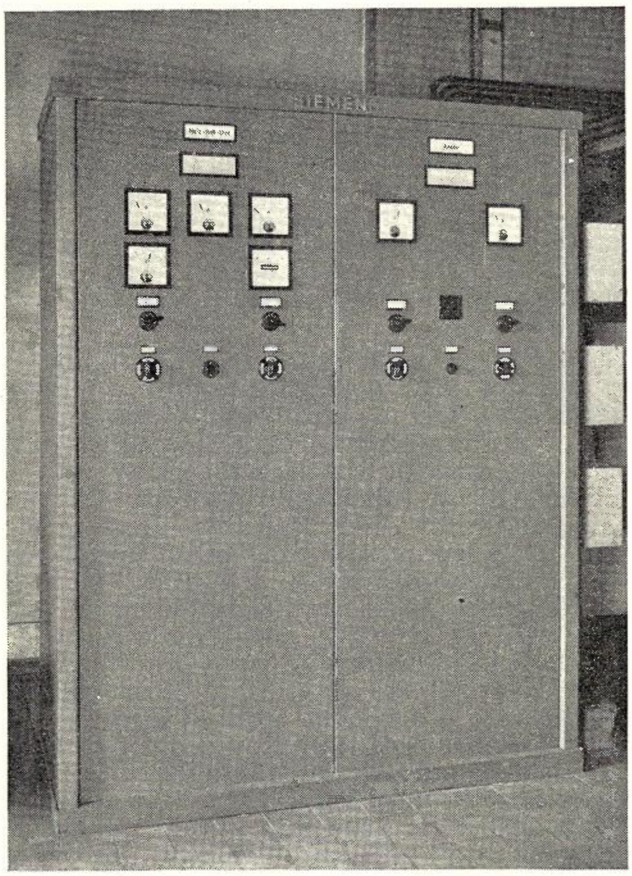

Fig. 10.—Rectifier unit and A.C. cubicle.

Rotating Machines. As indicated above, no more motor generator sets are being purchased for normal use. There will still be cases where they will need to be obtained for special services such as in locations where the local power supply is D.C. A type of motor generator set which has not been used very extensively in this country is the diverter pole machine. This machine is really a motor generator having automatic voltage regulation incorporated in the magnetic circuit in contrast to the standard type which uses a separate automatic regulator to control the output. Reports have also been received of a very high efficiency contact converter of the rotating machine type. This plant contains a synchronous motor which operates sets of moving contacts to rectify mechanically the A.C. supply input. Special reactors have been developed for use in conjunction with this unit in order to minimise the sparking at the contacts. Further information is being sought to ascertain whether these machines can be adapted for floating service. Present information is to the effect that they are very suitable for conversion work such as electrolytic processes which do not require floating batteries.

Batteries. In the early history of the Department the batteries used almost exclusively were of the open type which have Planté plates for the positives and box type for the negatives. In recent years there has been a tendency to swing towards the enclosed type cells, using positive and negative plates of the pasted type. The containers of these cells are usually of moulded hard rubber. Although the life obtained from the latter type of cell is generally not as long as that from the Planté cells there are several compensating factors. These include considerably cheaper initial cost, easier installation and replacement, more economical use of floor space and the avoidance of a spray laden atmosphere during periods of charging. Evaporation losses are also less for this class of cell.

At the moment the capacity of the largest battery in the enclosed type cell is 200 ampere hours. However, a 500 ampere hour cell has been developed recently and some of these units will be in service shortly. The plates of this cell have been designed specially so that the voltage will not fall off during the floating life of the battery to the same extent that is experienced with many of the existing enclosed type cells having lead antimony grids. These batteries take up much less space than the equivalent type of open Planté cell, and various types of stands, cupboards, cubicles and cabinets have been designed to accommodate the enclosed type batteries, depending on the location where they will be placed. The cabinets, for instance, have been designed to line up with equipment racks, and the cubicles have been designed to line up with rectifier and power cubicles. The latter design facilitates the provision of a combined battery and power room. Details of such a scheme, used by an overseas administration, are given in reference No. 7 in the Bibliography. A similar arrangement is being developed for use in Australia.

Some experience has been obtained in locating battery and power plant in the same room as switching equipment, and such experience has prompted a further examination of this field with the possibility that the need for battery and power rooms may ultimately disappear. Adequate ventilation must, of course, be provided in such cases to ensure that explosive mixtures, including hydrogen, are not enclosed within the cabinet. Precautions must also be taken to ensure that, during charging periods, corrosive acid spray is not thrown into the atmosphere where it may do some damage to equipment or cable. In the latter regard, the fact that the batteries are totally enclosed has a big bearing on minimising this risk. Fig. 11 shows a rectifier and battery cabinet asso-

Fig. 11.—General view, showing equipment rectifier and batteries in the same room. Rectifier and battery cabinet at extreme left.

ciated with equipment in the same room. Fig. 7 indicated in plan and elevation a typical power suite which it is proposed to develop for installation in equipment rooms. In passing, it is mentioned that investigations are being made of the possibilities of using nickel cadmium accumulator cells. These cells possess some advantages in that they do not have any corrosive fumes and give a longer life. However, their operating voltage is lower than that of the lead acid type, and the difference between the floating and discharge voltage is also somewhat greater. Experiments are also being undertaken for the use of the so-called dry type lead acid accumulator cells.

Concerning the operation of batteries the floating routine has, of course, been in use for many years. Various centres have used a different voltage of float and combined this with different practices concerning refresher charges, etc. Attempts have been made recently to standardise the procedures having in mind the different loading conditions and type of equipment which may be at the location under consideration. As a result of the investigations it has been decided that where two batteries are provided serving the same voltage they shall be floated in parallel. This lowers the battery impedance, and only half the drain is automatically taken from each battery in the event of a power failure, thus having the effect of increasing the capacity of the battery when on discharge under emergency conditions, and also providing a more effective short path for the lessening of electrical noise. The batteries are paralleled at the power switchboard to facilitate isolation of individual batteries for maintenance and charging.

A floating voltage higher than 2.3 volts per cell is undesirable as it results in overcharging. On the other hand a floating voltage below 2.06 volts results in the battery discharging continuously. The lower the floating voltage the more frequently will refresher charges be necessary, and the conditions approach those of charge-discharge working. Fluctuations in the floating voltage will render the conditions less ideal from the view-point of the battery. For a given percentage fluctuation, this effect tends to be more marked at lower than at higher floating voltages. Regarding the voltage question purely from the viewpoint of efficient battery operation the optimum floating voltage is between 2.24 volts and 2.30 volts per cell. At this figure sufficient trickle current flows to compensate for open circuit losses and the battery will always be maintained fully charged. Also, there will be no tendency for the cells to discharge while floating and normally no refresher charges or working up cycles will be necessary. (Small exchange meter batteries are floated in this voltage range.) This system has the practical disadvantage that there will be an appreciable margin between the floating voltage and the voltage at which the battery will take over the load in an emergency. Thus, if 23 cells are floated at 51.5 volts (that is, 2.24 volts per cell) the overall voltage at the beginning and end of a 9 hour discharge will be approximately 45.5 volts and 42.0 volts respectively. At higher discharge rates the voltages will be still lower.

To overcome this difficulty it becomes necessary either to add separately charged end cells which could be switched in during an emergency or alternatively, to increase the number of cells in the main battery and provide arrangements for feeding the load direct from a conversion unit at the normal equipment voltage whilst trickle floating the battery at a higher voltage with the aid of an auxiliary conversion unit. The battery could thus be retained at full capacity by using a higher floating voltage and provision made to automatically switch the battery across the load in the event of mains failure, without interruption to the equipment supply. This principle is employed overseas by some administrations and there is a plant on order which incorporates this arrangement.

If the batteries are floated at 2.06/2.10 volts per cell this is equivalent to maintaining the battery on open circuit. Partial discharges could occur during periods of appreciable low voltage. Monthly refresher charges are therefore essential to ensure that a reasonable battery capacity is always available. Test discharge cycles followed by full recharges should also be given every twelve months. This system has the practical advantage that it allows the battery to be permanently connected across the load with a minimum voltage drop between the floating condition and emergency discharge conditions. For example, if 25 cells are floated at 51.5 volts (2.06 volts per cell) the overall voltage at the beginning and end of the 9 hour discharge will be approximately 49.5 volts and 45.8 volts respectively.

In the case of cells floated at an intermediate voltage of 2.14/2.20 volts, open circuit losses during periods of low voltage may not be fully balanced although, if a steady voltage of 2.17 volts is maintained, the trickle charge current should in most cases be adequate to balance these losses. To guard against the effects of temporary fluctuations and variations in floating voltage, it is desirable to give refreshser charges at three monthly intervals and working up cycles every twelve months. This system of floating is used generally at smaller exchanges, P.A.B.Xs, R.A.Xs, etc., where only one 24 cell battery is provided. The associated rectifier output voltage may slope in such a way that the voltage of float at light load periods may somewhat exceed the 2.20 volts per cell. Under these conditions the refresher charges mentioned will not need to be given except under special circumstances.

Having in mind the above conditions, the larger exchanges will have two batteries. These will be of the 24 or 25 cell type, and due to the fact that it is proposed to limit the amount of battery reserve generally, there will be a tendency to increase the number of installations with 25 cell batteries. This is because of the discharge voltage question as discussed earlier. At exchanges with two 24 cell batteries they will be floated in parallel, at a voltage not lower than 2.1 volts per cell at the peak load. This will mean that during light load periods at night, due to the slope of the voltage output curve of the conversion plant, the voltage will rise to approximately 2.17 volts per cell. The refresher charges should be given every two months. Test discharges and, if necessary, working up cycles should be given every twelve months. At exchanges having two 25 cell batteries, these should be floated in parallel within the limits of 2.06 to 2.10 volts per cell for the main load periods of the day. During very light load periods the voltage may rise to a figure no greater than 2.12 volts per cell. Monthly refresher charges are necessary with this scheme. Yearly test discharges and, if necessary, working up cycles, are also a feature.

It is of interest to note that good battery life has been experienced under floating conditions using 2.17 volts as well as 2.1 volts per cell, as the nominal float voltage. In the former case, instances are on record where batteries are still giving service after fourteen years' use. In the latter category some batteries are still in use after sixteen years' service, although in the latter ten years tap water was used for topping up. An interesting recent development concerning topping up water is the use of chemical water purification units instead of the conventional water distilling units. Experience indicates that the chemical type produce suitable topping up water cheaper than the earlier type of "still".

Ringing Equipment. For the smaller exchanges, P.A.B.Xs, and R.A.Xs, ringing equipment of the relay vibrator type is generally used. Experience has indicated that an output of about seven watts can be obtained fairly reliably from such equipment. Use is made of a valve oscillator to produce the 400 c/s required for busy tone. Dial and ring tones are obtained from the ringing vibrator harmonics. For exchanges which require ringing current output of approximately fifteen watts and greater, the inductor tone type ringing machine is used. This combined unit consists of an alternator which produces the ringing current and an inductor type generator which produces the required tones. It has been the practice until recently to install one A.C. driven inductor tone machine in combination with a battery operated dynamotor where the ringing current output required is seventy-five watts or greater. Recent investigations have indicated that there are some advantages in using two dynamotors running off the battery in preference to this arrangement, and a future plant will be of this type.

Fig. 12 shows a standard ringer rack incorporating two dynomotors, control panel, etc., the whole unit being suitable for mounting within the exchange equipment room, preferably in the vicinity of the auxiliary equipment rack. As will be seen from the illustration, various indications are given to show which machine is in use, conditions of failure, etc. In addition, arrangements are incorporated on the panel for checking the voltage of the tones and ringer. A loud speaker with associated amplifier is incorporated in order that an audible appreciation may be obtained of the exchange tones. It is mentioned as a matter of interest at this stage that the standard ringing tone has recently been changed to 400/16-2/3 c/s. The reason for making this change was to facilitate the transmission of the ringing tone through trunk line circuits due to the comparatively poor transmitting qualities at the lower frequencies of some of the voice frequency repeaters.

D.C. Distribution. With the complete change over to rectifiers in lieu of generator sets for conversion purposes a considerable simplification has taken place in the D.C. control circuits in exchanges. Fig. 13, which indicates the present 50 volt power arrangements using rectifiers, shows

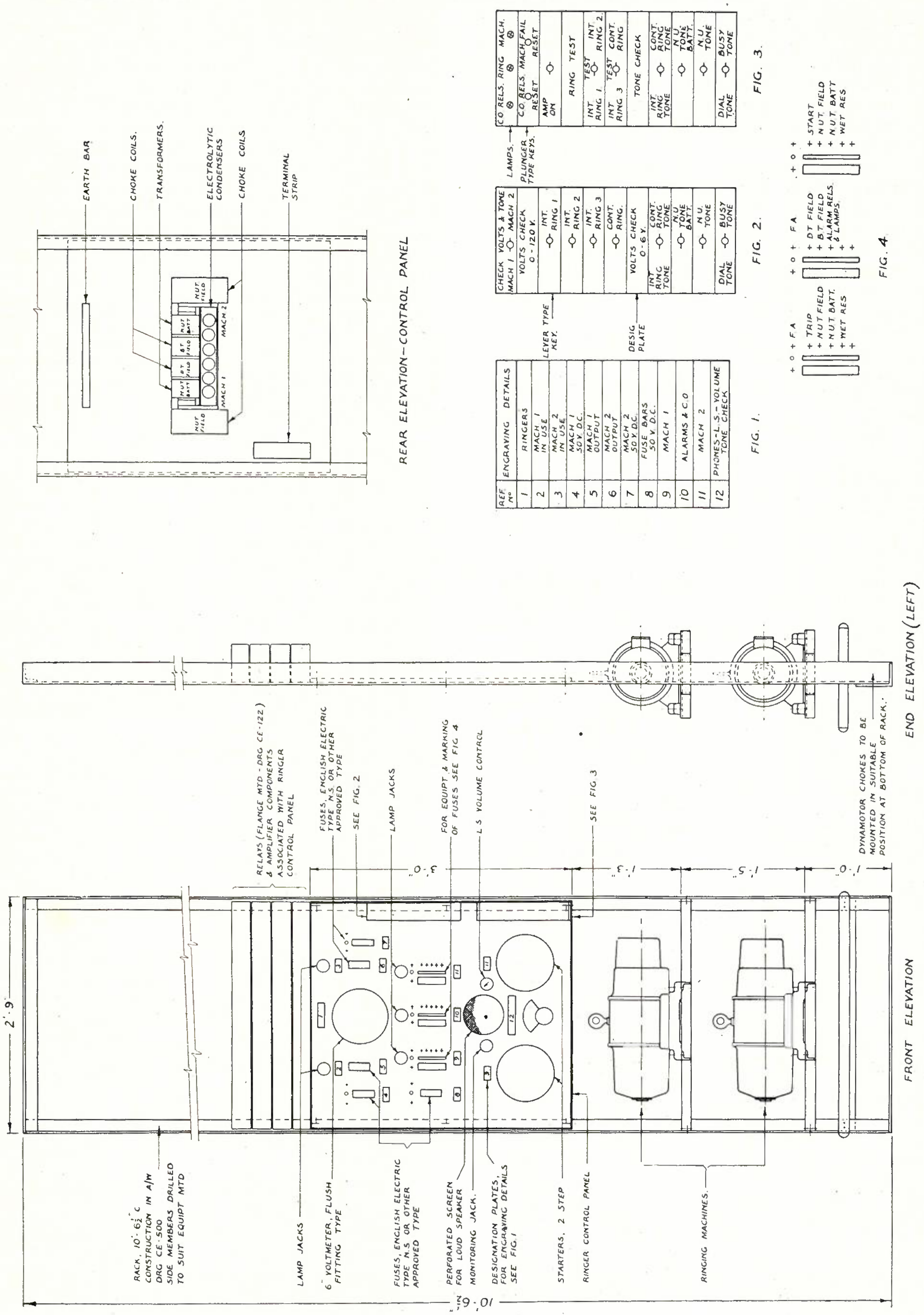

Fig. 12.—Layout of equipment on a typical ringer rack.

the simplicity of the main power circuit. It is the intention to use a steel discharge panel with dead front type switches thereon.

The problem of electrical noise generated by the automatic switching equipment and also by the power conversion plant and ringers has recently been given more detailed attention. Investigations have shown that noise generated by any of the foregoing plant may be prevented to a large degree from interfering with the transmission circuits by close attention to the power busbar and cable layouts. It has been indicated that the main contributing factor to such noise is the inductance of the leads between the battery and the conversion plant, and also from the equipment to the power board. This inductance may be reduced by placing the positive and negative leads as close together as possible and also by making the "runs" short. In this regard it would appear that in future multi-storey equipment buildings, which are usually situated in the capital cities, there will be some advantages in locating units of conversion and battery plant on the same floor as the equipment it serves, instead of the former practice of locating such plant on the ground or basement floor. This practice would decrease the inductance of the D.C. supply leads and also save in the overall cost of copper because under such circum-

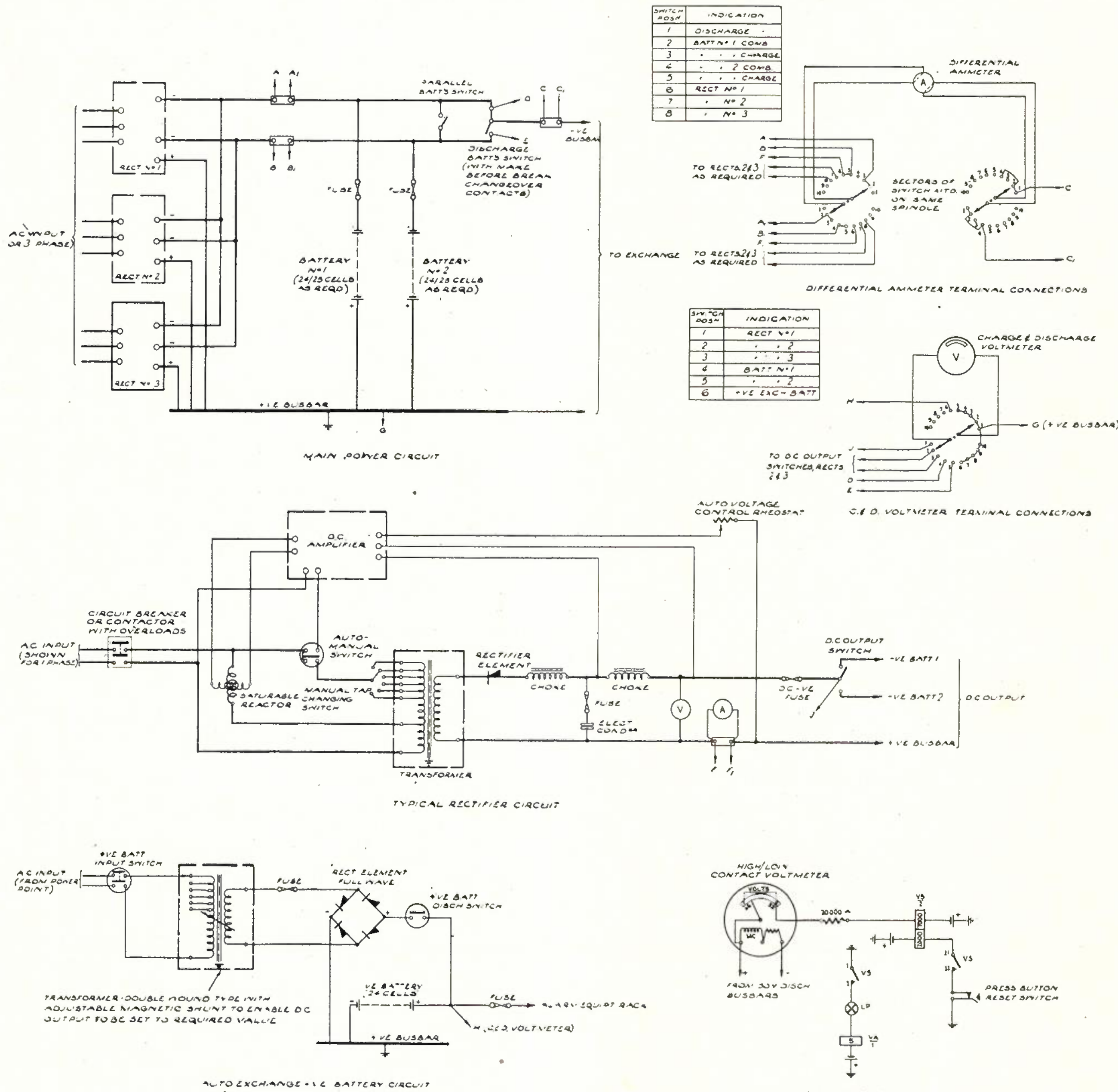

Fig. 13.—Schematic circuit of the 50 volt D.C. power circuit at exchange.

Notes: 1. Separate leads are to be provided for each battery.
2. Number and size of Rectifiers will be in accordance with requirements of particular installation.

stances 400 volts A.C. would be fed for the maximum distance between floors in lieu of the comparatively low D.C. 50 volts supply as has been done in the past.

The question of fuse provision and grading on the D.C. distribution is another matter which has been given some consideration recently. Use is already made in many exchanges of the high rupturing capacity type of fuse in this portion of the exchange power circuits. The usual arrangements in the equipment room for fusing have covered the provision of a 125 amp fuse serving several rack suites. A better arrangement may be to have smaller fuses with at least one per suite of racks. This would tend to give better localisation of faults and at the same time give more positive protection on earth faults by minimising the effect of high resistance in earth returns on rack frameworks, etc. Fig. 14 shows a photograph of a high rupturing capacity fuse with rack busbar connections, illustrating the comparatively simple

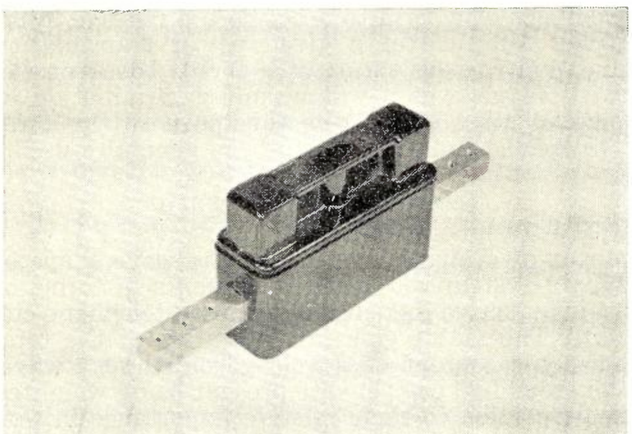

Fig. 14.—H.R.C. fuse and holder with rack busbar connections.

method of fitting this type of fuse for such a service.

Conclusion:

It will be realised from the foregoing that considerable developments have occurred in recent years in the power supply field. One of the reasons for the development is, no doubt, the amount of thought which has been concentrated on these problems and the factor which has caused this concentration to be given to the question is the fact that the public power supply position has been so precarious in recent years. By taking advantage of all of the developments which have occurred we can materially assist in achieving that overall aim of the engineer, namely, "efficiency with economy."

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ERRATA

"The Design of a Voltage Stabilised Anode Supply for 230 volt D.C. Mains Operation," Vol. 9, No. 1, 1952, page 28. The titles to Figs. 6 and 7 should be reversed.

"Examination No. 2906, Engineer Natural Science," Vol. 9, No. 1, June, 1952, page 63. The formula for Young's Modulus should read: $Y = FL/eA$.

SOME ASPECTS OF POWER INTERFERENCE TO TELEPHONE CIRCUITS

W. E. Weaver, B.E., A.M.I.E., Aust.

A considerable expansion of the power distribution networks in this country has taken place in recent years, and further developments in the transmission of power over wide areas are expected in the future. These developments emphasise the need for a more technical approach to the problems associated with the prevention of interference to aerial wire communication circuits, which may be caused by the disturbing influences of power circuits.

In this paper, it is proposed to give a broad outline of influences which, in general, can be expected to exist in proximity to power lines, and of their effect on telephone communication circuits in the production of noise. Some thought is given to measures designed to overcome these effects. Consideration is also given to conditions affecting the safety of men required to work on telephone routes erected in close proximity to power lines, where these are subject to fault disturbances.

Generally speaking there are eight components of induction which must be taken into consideration in studying the inductive effects of power distribution systems on communication circuits. It does not necessarily follow that all of these components will be important and it may be found that one or more may have a controlling influence on the amount of noise induced in a telephone circuit.

These components can be grouped under **direct metallic circuit induction** from—

1. balanced currents
2. balanced voltages
3. residual currents
4. residual voltages

which produce in the exposure section, induced E.M.F's across telephone circuit pairs, and **indirect metallic circuit induction** from—

5. balanced currents
6. balanced voltages
7. residual currents
8. residual voltages

Indirect metallic circuit induction is produced by the action of longitudinal circuit induction in all the wires of the line on such unbalances as may be present in the telephone circuits. The latter may be either self unbalances such as high resistance joints or unbalanced leakage, or due to mutual inductance or capacitance unbalances to other wires of the line or to ground.

The effects due to balanced currents and voltages are not usually of serious concern and may be almost entirely eliminated by co-ordination of power and telephone construction over exposure sections involving transposing of conductors in power and telephone circuits. The chief influence factors controlling induction are therefore those which arise from residual currents and voltages.

Noise Induction in Telephone Circuits

The amount of noise induced in telephone circuits by power transmission lines is determined principally by:—

(a) The separation between the power and telephone power lines.
(b) The length of the exposure.
(c) The coupling inductance.
(d) Wave shape.
(e) Voltage.
(f) Current.

With the factors indicated under (a), (b) and (c) fixed by constructional considerations, the wave shape of a power circuit voltage and current becomes the controlling influence in the production of noise. This condition necessitates the employment of a term to describe the relative interfering influence of a given power transmission line, and the derivation of a factor based on the wave shape, which will permit determination of the inductive effect. For this purpose the term "Telephone Influence Factor", is generally used.

Telephone Influence Factor

The Telephone Influence Factor (T.I.F.) is a means of evaluating or rating the wave shape of supply system voltages and currents in terms of their inductive influence on exposed telephone circuits. The factor gives an indication of the total harmonic content of a voltage or current wave, the individual components present being weighted in proportion to their relative importance in contributing to noise on exposed telephone lines. The T.I.F. of a voltage or current wave is the ratio of the square root of the sum of the squares of the weighted R.M.S. values of all the sine wave components (including in alternating waves both fundamental and harmonics) to the R.M.S. value of the complete wave.

The frequency weighting used in determining the T.I.F. is derived from the relative interfering effects of different single frequencies in a telephone receiver, the characteristics of the transmission path between the trunk circuit terminals and the receiver of the telephone subscriber's set, and the variation with frequency of the inductive coupling between the power and the telephone circuits. These do not include telephone circuit unbalance but, except for certain types of apparatus, circuit unbalance is independent of frequency. Where unbalances are not independent of frequency the T.I.F. may not be a reliable index to the influence of the power system current or voltage.

The T.I.F. at any given frequency (f) may be expressed mathematically as follows:—

$$\text{T.I.F.}_{(f)} = KP_{(f)}.\ (I_R/I_L)M \qquad (1)$$

where K = a constant

$P_{(f)}$ = the relative interfering effect of a noise current of frequency f in a telephone receiver.

I_R/I_L = ratio of receiver current to that in the line to which the subscriber's set is connected.

M = factor representing coupling between the power and telephone circuits.

In deriving the revised weighting curve, M has been assumed to be directly proportional to frequency. If this factor is assumed to be unity at 1050c/s, the peak of the curve of the relative interfering effects, the value of M at another frequency f is f/1050.

Then, $T.I.F._{(f)} = KP^1_{(f)}.\ (f/1050)$ .... (2)

Where $P^1_{(f)} = P_{(f)}\ .\ (I_R/I_L)$ .... (3)

Calculations and tests indicate that satisfactory correlation between readings made with the old and new weightings would result if a peak value (k) of 12,000 were assigned to the new weighting characteristics. The expression then becomes—

$T.I.F._{(f)} = 12000\ P^1_{(f)}.\ (f/1050)$ .... (4)

The relative interfering effects of single frequency line currents $P^1_{(f)}$ used in deriving the T.I.F. weighting curve are as follows:—

f (c/s)	$P^1_{(f)}$	f (c/s)	$P^1_{(f)}$	f (c/s)	$P^1_{(f)}$
180	.0073	1080	.97	1980	.155
300	.060	1140	.85	2100	.146
360	.090	1260	.55	2220	.139
420	.123	1380	.347	2340	.134
540	.202	1440	.288	3000	.115
660	.298	1500	.257	5000	.0084
720	.363	1620	.211		
780	.457	1740	.184		
900	.707	1800	.174		
1020	.995	1860	.168		

Calculation of T.I.F. from Harmonic Analyses

The value of the T.I.F. can be readily calculated if the various component frequencies in the wave are known. The procedure is as follows:

1. Multiply each component frequency by the corresponding weighting factor shown by the curve in Fig. 1.
2. Square each of the products.
3. Obtain the sum of the squares.
4. Extract the square root of this sum.
5. Divide by the R.M.S. value of the current or voltage wave in question.

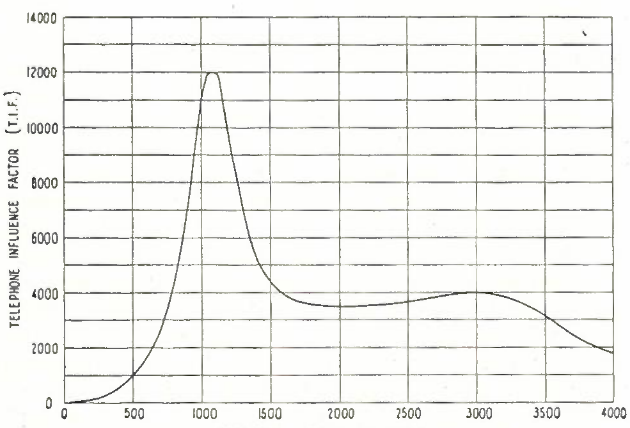

Fig. 1.—Frequency weighting characteristic for T.I.F. measurements.

The quantity obtained in (4) gives what is known at the I.T. or Kv.T. product. The following example illustrates the process as applied to a 60 c/s current wave:—

Frequency c/s	Current amperes	Weighting factor	Product (2) x (3)	Square of (4)
1	2	3	4	5
60	11.0	1	11	121
180	.6	15	9	81
300	.3	205	62	3,840
540	.02	1250	25	625
900	.04	7270	291	84,700
1500	.02	4400	88	7,740
1620	.015	3900	59	3,480
				100,587

The square root of 100,587 gives 317 as the I.T. product; dividing by the R.M.S. value of the current gives 28.8 for the T.I.F.

It is probable that the T.I.F., as calculated for the representative current wave in the preceding paragraph, would be an average value for a normal power circuit, and, subject to the provision of reasonable separation for the exposures involved, would be satisfactory from an interference aspect. On some circuits the T.I.F. value may be appreciably greater without undue interference being caused to parallel telephone circuits owing to the smaller values of the other components affecting the total noise. Roughly the inductive influence of an average transmission line, as regards balanced voltages, is proportional to the fundamental frequency voltage, and, in general, averages about 20.

A determination of the inductive influence of any power circuit will enable the total induced longitudinal noise in a parallel telephone circuit to be calculated for the exposure conditions, taking into consideration the exposure length and the coupling inductance for magnetic induction and the voltage ratios for electric induction. The metallic circuit noise within an exposure has a definite relation to the total longitudinal noise based on the constructional features of the telephone circuits. This is employed in the determination of the effective metallic circuit noise, which is expressed in noise units.

Referring to the American noise measuring set the maximum permissible metallic circuit noise on voice frequency circuits is approximately 30 db above reference noise level of a 1000 c/s tone 90 db below 1 milliwatt, and, on this basis, the noise calculated as above, should not exceed 250 noise units.

In the consideration of inductive effects it is usual to employ special terms to define the influence factors. These are—

(i) The I–T product, which is the product of R.M.S. amperes and the T.I.F. and is used as a measure of the inductive influence of a given current.

(ii) The Kv–T product (product of R.M.S. kilovolts and T.I.F.) is used as a measure of the inductive influence of a given voltage.

From the results of investigations in the U.S.A. it may be concluded that the most important factor in the influence of power distribution circuits involved in exposures at roadway separations is the wave shape and magnitude of the ground-return current I.T. This is held to be practically always true in exposures to the main power line or whenever several miles of power line extend beyond exposure. For exposures near the end of a line or at any point along a short single phase extension, the noise in a telephone circuit will usually be controlled by the wave shape and magnitude of the residual voltage Kv.T.

Ground Return I.T.

The power circuit components controlling the magnitude of the ground return I.T. depend to some extent on the power distribution arrangements, for example:—

(1) In the case of circuits isolated from ground or grounded at one point only, the ground return I.T. is practically all harmonic charging current. It is, therefore, a function of—
   - (a) The operating voltage.
   - (b) The impressed voltage wave shape.
   - (c) The extent and arrangement of the metallically connected three phase and single phase portion of the system.
   - (d) Those effects of loads which modify the voltage wave shape.

(2) In the case of multi-grounded neutral circuits the ground return I.T. is contributed to by—
   - (a) Harmonic charging currents.
   - (b) Harmonic components of the load currents.
   - (c) Harmonic components of the transformer exciting currents.

In the latter case the tendency is for the charging current component to be controlling on the longer and higher voltage circuits, and for the load and exciting currents components to be controlling on the shorter lower voltage circuits.

The magnitude of the ground return charging current at any frequency depends on the voltage impressed on the ground return circuit and on the impedance to ground of the circuit, neglecting loads. It also follows that the amount of ground return charging current resulting from a given residual voltage depends to a large extent on the frequency of the impressed voltage and the circuit length. The maximum current results when the circuit length is such that series resonance (at quarter wave length) occurs at the particular frequency controlling the wave shape of the residual voltage.

Residual Voltage Kv.T.

Residual voltages appear on power systems operated isolated from ground, as a result of the action of the balanced voltages on the unbalanced impedances to ground of the phase conductors. On isolated systems of limited extent the series impedance of the line conductors may be neglected and residual voltages may be considered to be dependent only upon the balanced voltages and the direct capacitances to ground of the conductors.

Formulae giving residual voltages in terms of phase to phase voltages and the direct capacitances to earth, and based on the usual conception of residual voltage as the vector sum of the voltages to ground on the conductors, may therefore be derived. A three phase circuit perfectly transposed and without single phase extensions would give zero residual voltage, but it is calculated that an untransposed three phase circuit with one single phase extension of equal length would give a ratio of residual voltage to balanced or phase to phase voltage of 0.34, series impedances and propagation effects neglected. In more extensive isolated systems the series impedances of the lines should receive consideration. Under some conditions certain frequency components may be considerably amplified by the effects of resonance between line inductance and capacitance.

On three phase systems operating with grounded neutral, residual voltages may (a) be impressed directly upon the system as in the case of generated triple harmonics, or (b) arise as a result of unequal impedance to ground of the line conductors and connected loads. Where a system is supplied from a delta-star connected transformer bank no residuals can be directly impressed at the point of supply. However, a residual voltage will frequently appear at the supply point due to the residual current in the circuit acting on the impedance to ground of the supply transformer, the residual current in these cases being the result of a combination of the effects of unbalances (such as unequal lengths of single phase extensions connected to each phase) and harmonics generated in loads and transformers connected phase to neutral.

The voltage wave shape of any system may be affected to a considerable extent by the loads connected to the circuits and for this reason it is convenient to separate the loads into those types which are not sources of harmonics (passive loads) and those which generate harmonics. In the case of passive loads, where the impedance of the source is relatively high (for example, where a line is fed from a small capacity transformer) the connected load may appreciably reduce the harmonic voltages appearing on the line. However, where the inductive reactance of the source and the capacity reactance of the line approach resonance at the frequency of one of the harmonics present in the impressed voltage, a greatly increased harmonic voltage on the line can result from the condition of resonance at no-load.

Loads which generate harmonics and are connected phase to neutral to multi-grounded circuits, contribute directly to the harmonic residual voltage. Three phase loads of this type, however, can result in residuals only indirectly through their effects on the balanced wave shape. They can contribute balanced components which may act on system unbalances to produce residuals.

Effect of Power and Telephone Transpositions on Inductive Interferences.

Telephone Transpositions involving the interchange of pin positions by the conductors at the transposition point (the exposure conditions at the point of transposition being otherwise uniform) may be said to cause a phase change of 180 degrees in the metallic circuit induction in a telephone circuit. Telephone transpositions have no effect on longitudinal induction because this type of induction takes place in the circuit composed of the telephone wires in parallel as one conductor and the earth as the other. They do, however, tend to reduce the components of indirect metallic induction due to the action of longitudinal induction on circuit unbalances, insofar as the balance of the telephone circuit is improved by the transpositions. Transpositions in telephone circuits in exposed sections should, however, be thought of from a power co-ordination viewpoint as a means of reducing only the direct metallic induction from either balanced or residual currents and voltages.

Power transpositions also have a neutralising effect due to the change in phase of the electric and magnetic field of the balanced voltages and currents respectively, which accompanies a change in the relative positions of the power wires. In a single phase circuit this change is 180 degrees, analagous to the change effected by a transposition in a telephone pair. In a three phase circuit, where a transposition is made by changing the positions of each of the three-phase wires, the phase change is 120 degrees. Two such transpositions are necessary to obtain maximum neutralisation of the inductive fields from the balanced components. (In any section of power line two evenly spaced three phase transpositions will ensure that each phase conductor occupies each of the respective phase conductor positions for equal distances. Such a section of power line is usually termed a "barrel"). Corresponding changes in the phase of induction in the exposed telephone circuits are dependent upon the uniformity of the exposure conditions.

The usual method for co-ordinating power transpositions with telephone transposition schemes is the one by which the power transpositions, when required, are located opposite "neutral points" in telephone transposition layouts. When so installed they should be considered as directed toward reducing only the **longitudinal circuit induction** (and hence only the indirect components of metallic circuit induction) from balanced currents and voltages. Their effect on direct metallic induction will be small on the average, as theoretically, in an ideal case of absolutely uniform conditions, the induction between neutral points of the telephone transposition scheme would be perfectly neutralised. In a practical situation, because of unavoidable irregularities, the installation of properly co-ordinated power transpositions would probably result in an increase in the direct metallic induction in some telephone circuits and a reduction in others.

For this reason power transpositions installed by this method cannot be expected to effect substantial reductions in the total noise from an exposure unless—

1. The longitudinal circuit induction from the balanced components is large compared with that from residual components. In such cases a 5 to 1 reduction may be obtained in the longitudinal circuit induction.
2. The indirect metallic circuit induction arising from the action of this longitidunal induction from balanced components is an important part of the total noise from the exposure.

Residual components of a power circuit act as if they were caused by voltages impressed on the phase wires of a power circuit taken in parallel, and are not materially affected by rearrangement of the phase wires. Consequently induction caused by a given amount of residual current or voltage is not affected by power transpositions.

However, power transpositions provided both within and outside exposures, that is throughout the length of a power circuit, can effect appreciable reduction of the residual currents and voltages in a power system which result from the action of the balanced voltages and currents on unbalances caused by the power circuit configuration. Such an arrangement would have valuable possibilities for situations where there are not present other sources of residual currents and voltages such as on direct inter-station or main distribution feeders.

Measures Necessary to Eliminate or Reduce Interference from Power Circuits.

It is not practicable to specify definite requirements for the construction of power distribution lines, and it, therefore, becomes the responsibility of the power authorities in this country to take such measures as are necessary, either in the design of generating equipment and distribution plant, or in the construction of transmission lines, to prevent interference to communication circuits. Generally, a wide separation of routes is sought, but, except for extra high tension routes, construction of parallel routes at normal roadway separation is often unavoidable. The coupling at these separations has a relatively high value and special measures are usually necessary where high potentials are involved.

All trunk telephone circuits are, for crosstalk reasons, well transposed, and, providing balanced conditions are maintained, these transpositions take care of most direct metallic induction, but, as explained, have little effect on longitudinal induction. Power authorities are therefore required to limit longitudinal induction by the control of harmonic residual currents and voltages. This may not require transposing of power conductors, but over sections of parallelism and exposure, transpositions are usually considered advisable to reduce interference from the balanced components.

Longitudinal Induction at Fundamental Frequency under Fault Conditions on High Voltage Power Lines.

In the foregoing consideration of the induction from power circuits, only the effects of harmonic frequencies in the production of audible noise have been treated. Induction at fundamental frequencies, particularly under earth fault conditions on the power circuit, can produce excessive longitudinal voltages over adjacent telephone wires, with resultant severe hazard to communication plant and to personnel engaged in the operation and maintenance of communication circuits.

The International Consultative Telephone Committee (C.C.I.F.) has specified in the Directives (Rome Edition, 1937, revised at Oslo, 1938), that the limit of the longitudinal electromotive force induced in telecommunication lines as a result of earth faults on neighbouring electric power lines should be 430 volts. This limit has been recognised generally as the value which would be calculated under the most favourable conditions for maximum fault current flow. It is known that the C.C.I.F., following on suggestions by international representatives of the power producing and distributing authorities, is at present studying this particular question to see if it would be possible to increase the limit of 430 volts.

In examining this proposition, the First Study Commission of the C.C.I.F. in its Summary Report, issued at Geneva, 10th-20th October, 1950, has indicated that arguments in favour of the proposal can be held to be valid only for certain very high voltage lines of first class construction and having up-to-date protection equipment. It has also indicated that the request to raise the limit cannot be considered unless it is recognised as possible to determine complementary arrangements for protection of personnel and plant, to be carried out on the power lines and the telecommunication circuits. Further, it pointed out that such arrangements, varying in accordance with the degree of exposure to danger and the working conditions of the telecommunication circuits, cannot be adopted in a general manner, but that study is necessary in each particular case having regard to the danger which might arise in that case.

The conclusion of the First Study Commission, as reported in Document 12 of the C.C.I.F., 1950-1951 1st C.E. is stated to be: "That there is no case for the adoption generally of an increase to a value of over 430 volts of the limit of the longitudinal electromotive force induced in a telecommunication line as a result of earth faults on neighbouring lines." Document 12 also states that it seems reasonable to agree to an increase under certain conditions in those cases where it is impossible to keep the induced longitudinal electromotive force lower than the defined limits, as contained in the text of Section 235 of the Directives, Chapter VIII, paragraph 29, "Danger". Each particular case should, however, it is stated, be the object of special study in order to ascertain the solution which overall is the most reasonable and most economic, taking into account such circumstances as: the standard of mechanical construction of the power line; the probability of earth faults on this line and the efficiency of protection of this line against earth faults.

In pursuance of this matter the First Study Commission is proposing to the XVIth Plenary Assembly that a study be made of the possibility of relaxing the existing rules as regards the conditions of proximity to telecommunication lines for electric power lines fulfilling the following conditions:

1. Good quality of mechanical construction.
2. Extreme rarity of earth faults.
3. Maximum duration of short circuits as small as possible.
4. Specially efficient protection in the case of earth faults.

Although the trends indicated by the foregoing suggest that some relaxation of the present limits for induced longitudinal voltages in telecommunication circuits may be accepted in some cases without increasing the risk of serious injury to workmen, or of damage to plant, it is obvious that the present limits should, as far as practicable, be observed, and that only where it is impossible to do this under the conditions obtaining should the value of the induced voltage as determined by calculation in accordance with accepted formulae, be permitted to exceed 430 volts. In those cases very high quality of mechanical and electrical construction and specially efficient protection on the power line would be necessary.

The requirements to be met for the limitation of the induced longitudinal voltage under fault conditions in the power circuit need to be related to specific factors which must be considered in some detail for each separate installation. The main factors associated with the question are:

1. Maximum earth fault currents under the worst conditions, that is, the conditions most likely to produce the maximum current.
2. Separation of the power and telephone circuits.
3. Length of the exposure for each value of the separation where this is variable.
4. Resistivity of the soil.

Maximum earth fault currents are generally calculated for conditions of zero earth contact resistance with one phase wire earthed and all other wires assumed open at the far end. Actually, it may be expected that if the other wires on the power pole line were earthed at one end, or alternatively they were connected to the other two phases of a three phase generator, they would provide a measure of screening against electric field induction; earthed at both ends they would provide a considerable degree of screening against magnetic field induction. It should be noted, however, that the electrically-induced voltage is proportional to the voltage on the interfering line, while the magnetically-induced voltage is proportional to the interfering line current; and further, that the electrically induced voltage will be nearly independent of the length of the exposure, while the magnetically induced voltage will be proportional to the length of the exposure.

In the case of earth faults on a power line the magnitude of the fault current and the length of the exposure will invariably control the amount of induced electromotive force appearing on neighbouring telecommunication circuits. To afford effective screening, the remaining wires on the power route would need to be earthed at both ends, and in practice this rarely occurs. It is necessary, therefore, to calculate the maximum fault earth currents without any allowance for screening effects.

This proposition does, however, suggest that a satisfactory means is available for the limitation of the induced longitudinal voltages in telecommunication circuits where adequate separation between power and telephone pole routes is not obtainable over a particular exposure section. The erection of an additional conductor on the power pole line, with cross sectional area approximately equal to that of the transmission conductors and the permanent earthing of the conductor at each end of the exposure section, would be necessary. Similar measures if taken in respect of the telephone pole route would also tend to limit the building up of excessive voltages on the communication conductors.

The value of the maximum earth current arising from an earth fault on a power line is determined from a consideration of the reactance in the distribution circuit, including cables where provided, and in the transformer or generating equipment supplying the line. Depending on the values of line and equipment reactance, the fault current may vary for a fault at different points along the line, the fault current being a "maximum" for a fault occurring at the supply end of the line, and a "minimum" for a fault occurring at the far end of the line.

Normally, where there is general parallelism throughout the length of the route, the greatest longitudinal induction will take place when the fault occurs at or beyond the end of the exposure which is distant from the supply end. This is particularly true when the portion of the power line which is involved in an exposure is at the end of a long transmission line or is an extension of a distribution system which has its source of power located at a considerable distance. Under these conditions the value of the fault current is not likely to vary appreciably for faults occurring at different points in the exposure section. Generally it may be said that the amount of magnetic induction is directly controlled by the length of the exposure, the relation being linear.

For a given uniform separation between a power pole line and a telephone pole line the total induced longitudinal voltage on the telephone wires, based on calculated values of a maximum earth fault current in a 50 c/s power circuit and the measured earth resistivity in the locality, may be determined from the following expression:

$$E = 0.552 \text{ m. l. i.}$$

Where E = induced voltage in volts.
m = mutual inductance of the power and telephone conductors in millihenries per 1000 yards.
l = exposure in miles
i = fault current in amperes

and the constant $0.552 = 2\pi f \times 1.76 \times 10^{-3}$

The value of the mutual inductance for the relative separation between the pole routes and for the resistivity of the earth can be obtained from the curves shown in Figs. 2 and 3, which are based on Pollaczek's formulae.

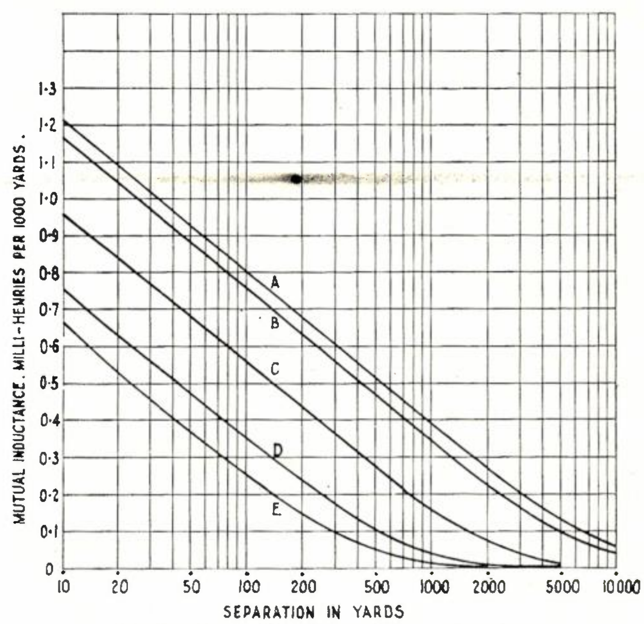

Fig. 2.—Mutual Inductance between two lines.

When earth resistivity is above 300,000 ohms-CM³ use curve A.
When earth resistivity is between 30,000 and 300,000 ohms-CM³ use curve B.
When earth resistivity is between 3,000 and 30,000 ohms-CM³ use curve C.
When earth resistivity is between 1,000 and 3,000 ohms-CM³ use curve D.
When earth resistivity is below 1,000 ohms-CM³ use curve E.

Where there is not complete regularity in the separation between a power pole line and a telephone pole line, the total value of the longitudinal voltage on the telephone wires can be determined more accurately by summation of the component amounts of induction over the sections of varying separation along the route. For this purpose it would be necessary to substitute for the factor m.l. in the above expression, the following term:

$M.L. = m_1 l_1 + m_2 l_2 + \ldots$ etc.

where $m_1 l_1$, $m_2 l_2$ are the values of mutual inductance and length for each section in the exposure.

Then $E = 0.552$ M.L.i.

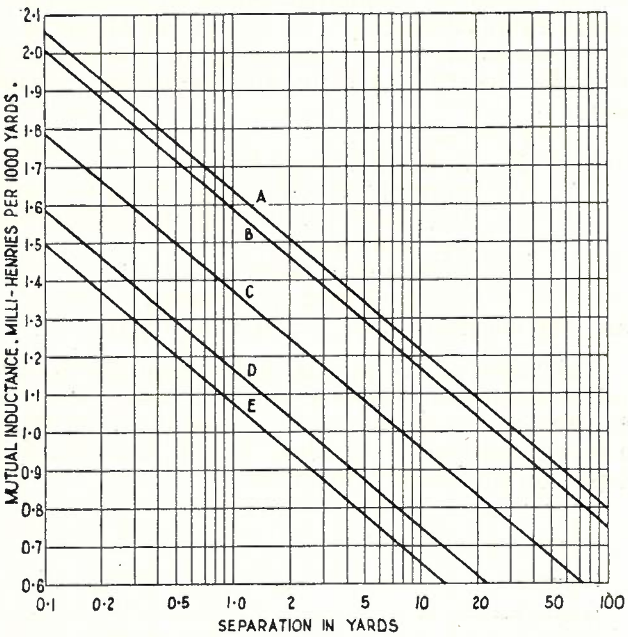

Fig. 3.—Mutual Inductance between two lines.

When earth resistivity is above 300,000 ohms-CM³ use curve A.
When earth resistivity is between 30,000 and 300,000 ohms-CM³ use curve B.
When earth resistivity is between 3,000 and 30,000 ohms-CM³ use curve C.
When earth resistivity is between 1,000 and 3,000 ohms-CM³ use curve D.
When earth resistivity is below 1,000 ohms-CM³ use curve E.

When it is evident that the total induced longitudinal E.M.F. under fault conditions on the power circuit will exceed the present limit of 430 volts specified by the C.C.I.F., a reduction in the value of this E.M.F. may be obtained either by increase of the separation of the pole routes or by limitation of the earth fault current. The amount of pole route separation, or alternatively the value of the maximum permissible fault current necessary to limit the induced E.M.F. to 430 volts, can be determined by substitution of the fixed value of either in the expression above. For example, if the separation of the routes cannot be increased,

i = permissible fault current

$= 430/0.552\ ML = 1370/ML$ amps

or where a reduction in the fault current is not feasible, the expression can be put in the following form:

$M = 1370/Li$ millihenries per 1000 yards.

from which a value of the separation required between the routes can be obtained by use of the curves in Fig. 2 or Fig. 3.

The advantages of providing adequate separation in the first instance are twofold. As well as ensuring freedom from disturbance of telephone channels under normal operating conditions, such provision would permit some flexibility in power circuit switching and distribution arrangements without having serious effects on the longitudinal induction over telephone circuits under fault conditions. The provision of special protective equipment and fault-current limiting devices in the power circuit may also be obviated.

Conclusion

The foregoing is designed to cover the general considerations affecting the question of interference to telecommunication circuits by neighbouring power circuits, and to give some indication of the requirements for avoidance of adverse noise effects and for the protection of telecommunication staff and equipment.

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CONSTRUCTION ASPECTS OF THE SEYMOUR-BENDIGO POLE ROUTE

V. Quirk

Introduction

The existing telephone traffic between Melbourne and Sydney is carried by an open wire pole route of approximately 575 miles in length, generally following the main railway line through Albury, Wagga, Yass and Goulburn. At present there are operating on the route nine 12-channel systems (eight Sydney-Melbourne, one Sydney-Canberra and one Melbourne-Canberra) and a maximum of twenty-four 3-channel systems, mainly used for intra-state traffic. This represents the maximum carrying capacity for through circuits.

In anticipation of this stage, plans had been prepared for the provision of additional circuits by means of a new pole route between Seymour, in Victoria, and Bathurst, in New South Wales, pending the installation of a direct Sydney-Melbourne underground cable. The pole route, which is now nearing completion, passes through the large country country centres of Bendigo and Echuca in Victoria and Deniliquin, Jerilderie, Narrandera, Wagga, Temora, Young and Cowra in New South Wales, and, in addition to providing interstate circuits, enables substantial traffic relief to be given to these and other centres in northern Victoria and mid-western New South Wales. The open-wire route connects to existing 24 pair 40 lb. star quad carrier cables at Bathurst and Seymour, from which points the open-wire circuits are extended to Sydney and Melbourne respectively by cable carrier systems.

Because of the long distances involved the pole route was designed on the basis of maximum 12-channel carrier system capacity, a typical pole plan being shown in Fig. 1.

Accommodation of the twelve 12-channel systems on the three major trunk arms required intensive transposing of the pairs, and at the same time it was necessary for the pole spacing and wire sags to be maintained within close tolerances. In the present paper a description is given of the construction of the Seymour-Bendigo section, which is typical of the route as a whole.

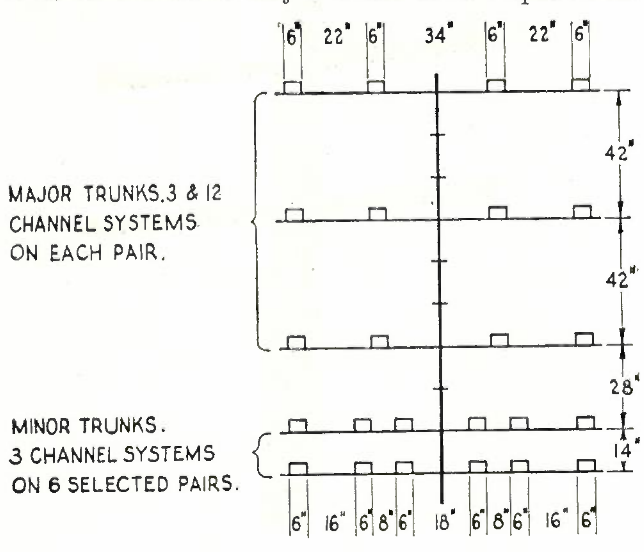

Fig. 1.—Pole Plan, showing ultimate number of pairs.

As shown in Fig. 2, the pole line, which is 56 miles in length, crosses the Goulburn River at Seymour, proceeds across country to Heathcote, and then follows the Kilmore-Bendigo highway, via Axedale, to Bendigo. Except through the Heathcote forest, where bush fires are a danger and steel H-beams are used, the poles are wood. For the steel beam construction 6" x 5" H girders are used for the normal pole height of 28 feet with 8" x 6" H girders where higher poles are required at road crossings, etc. Initial requirements were for four pairs of wires and as an additional four pairs were planned within two years, two pairs have been erected on each two arms in one and four positions on the pole, thus simplifying the subsequent erection of the additional pairs. In order to confirm the suitability of the transposition design for the route, a test E-section 6.4 miles in length, and including the twelve pairs of wires on the three 12-channel arms, was erected at the Bendigo end of the route. A general view of this test section is shown in Fig. 3, a close up view of a typical transposition pole being shown in Fig. 4. The following worst values in db of far-end and near-end crosstalk to 143 kc/s were obtained from all combinations of the twelve 12-channel pairs.

	Far-end	Near-end
Minimum	64	45
Average	74	57

Preliminary Work

Construction of new aerial trunk routes suitable for the operation of multi-channel carrier circuits involves consideration of the following:—

(a) choice of route,
(b) layout of route and preparation of field books,
(c) procurement and storage of material.

These matters must be attended to well in advance of commencement of the actual construction work.

Choice of Route: In the selection of a new route, three possible alternative locations need to be considered, namely:—

(a) along a public road,
(b) in a railway reserve,
(c) in private property and Crown land.

The railway reserve has the advantage of enabling shorter poles to be used because the minimum clearance of the lowest wires above ground for routes erected in a railway property is 8 feet, compared with 12 feet on public roads. This results in a lower capital cost and in greater ease in procurement of poles. Also, there is usually a

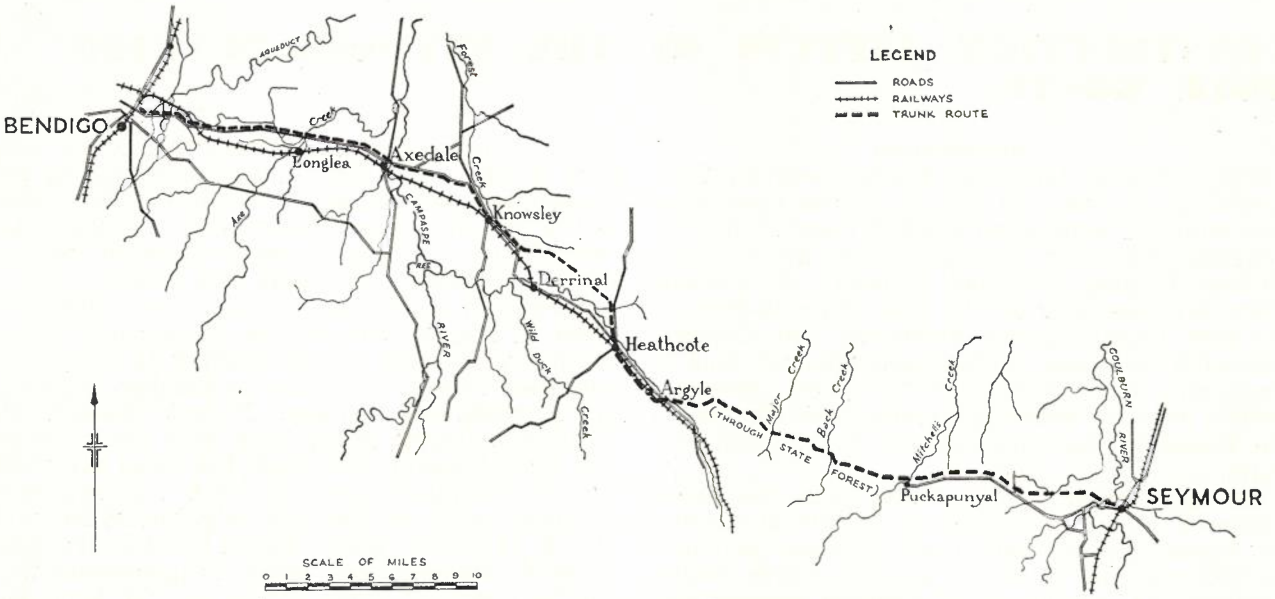

Fig. 2.—Location of aerial route between Seymour and Bendigo.

minimum of clearing. A disadvantage is that there is often difficulty of access both for construction and subsequent maintenance, in that a railway line is often some distance from good roads. The reserve itself is seldom suitable for motor traffic, particularly in the wet season, and it is often necessary to use pole trains and railway trolleys for transport.

Construction on public highways has the advantage of easy access, but often has a number of serious drawbacks. Chief of these is generally the necessity for extensive clearing. Many roads have trees growing over the full width between the carriageway and the fence line. Apart from any aesthetic considerations the cost of clearing is a major item, the felling, cutting up and stacking of timber and the burning of debris accounting for an appreciable proportion of the labour costs. The possibility of alterations to road alignment must also be taken into consideration. The presence of power lines restricts the selection of road routes, and often results in costly alterations to power construction to maintain adequate clearances between trunk and power lines, particularly at vehicular crossings.

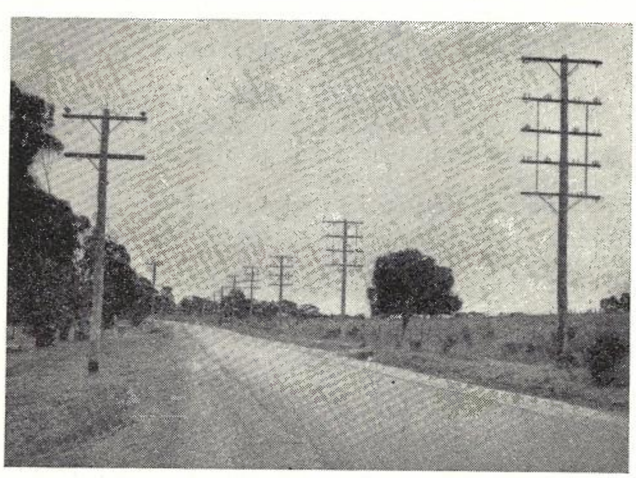

Fig. 3.—General view of test section on Seymour-Bendigo route, near Bendigo.

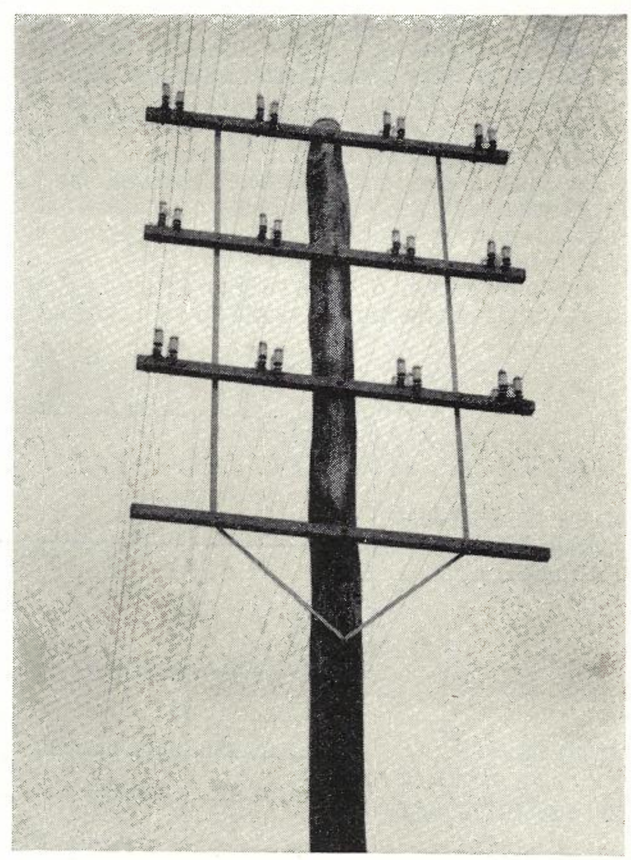

Fig. 4.—Transposition pole on test section on Seymour-Bendigo route, near Bendigo.

The route on private property combines some of the advantages and disadvantages of the roadway and railway routes. The private property route is generally more accessible than the railway route, but less accessible than the roadway route. On the whole clearing in private property is much less of a problem, but difficulties arise from possible damage, and from interference with the rights and activities of the owner. This is particularly so where the land is cultivated, as poles and stays present an obstacle to the cultivation and harvesting of crops. In addition, in wet weather private property often involves serious problems of access for construction and maintenance work, due to the bogging of pole hole borers and trucks.

The Seymour-Bendigo route provides examples of all the various route locations, including Crown land. The latter includes a military reserve at Puckapunyal, but consists mostly of the State Forest at Heathcote, where steel beam poles were used because of the fire risk. The standard clearing of 40 feet on each side of the pole line was provided, as shown in Fig. 5, but fortunately the

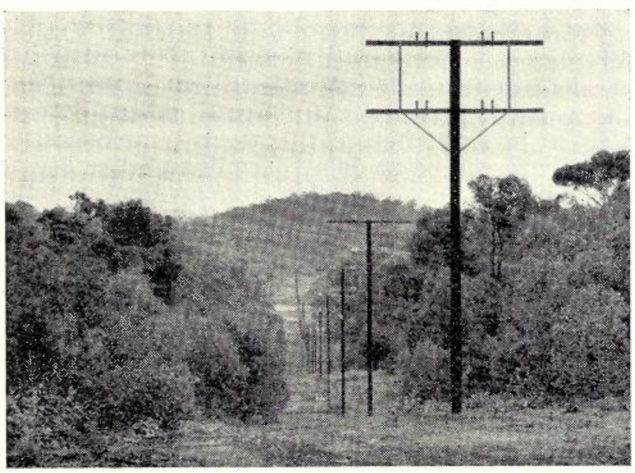

Fig. 5.—Seymour-Bendigo route, showing extent of clearing.

forest is of red ironbark, which is not a particularly tall tree and the amount of clearing was not excessive. Due to the unsuitability of much of the land for cultivation in the sections where it was necessary to construct the line on private property, it was practicable to construct most of the pole line 40 feet inside the fence line, resulting in a considerable saving in clearing costs and the avoidance of public criticism which might result from the cutting of trees along the roadway.

Where a route parallels a fence line, the separation from the latter is governed mainly by the clearing necessary and the overall width of the road reserve. Other factors which need consideration are the location of all ground stays and the presence of any power parallels. The usual margin on public roads is 5 to 10 feet, on private property 20 to 40 feet, whilst the location on railway reserve is affected by the height of the pole line, because of possible damage to the railway rolling stock should a pole fall over. The extent to which clearing was reduced by erecting the route on

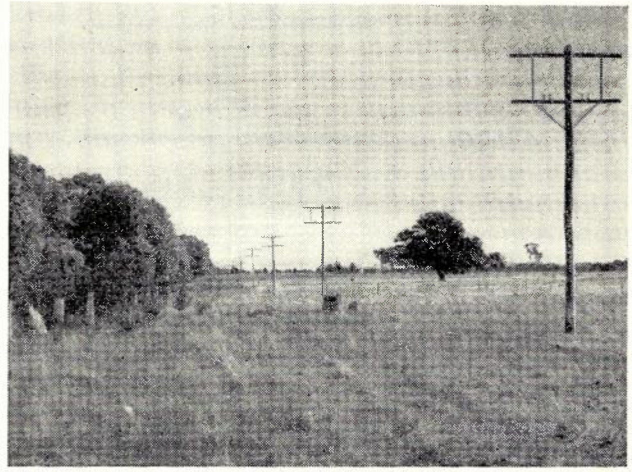

Fig. 6.—Seymour-Bendigo route on private property.

private property instead of along the road is shown in Fig. 6. A view of the route crossing the Campaspe River is shown in Fig. 7.

When the general location of the route has been decided upon, consultation is necessary with all public bodies and private citizens affected, and wayleaves and other matters determining the exact location and the construction of the route must be attended to.

Layout of Route and Preparation of Field Books: As soon as the final location of the route is fixed, any necessary clearing is done using a bulldozer where possible. This simplifies the work of the survey party, which makes an accurate measurement of the route, locates pole positions with wooden pegs, and takes levels for grading purposes. During the survey field notes are prepared, which, with the pole sizes as determined later from grading sheets prepared in the office, staying data, and any special provisions decided

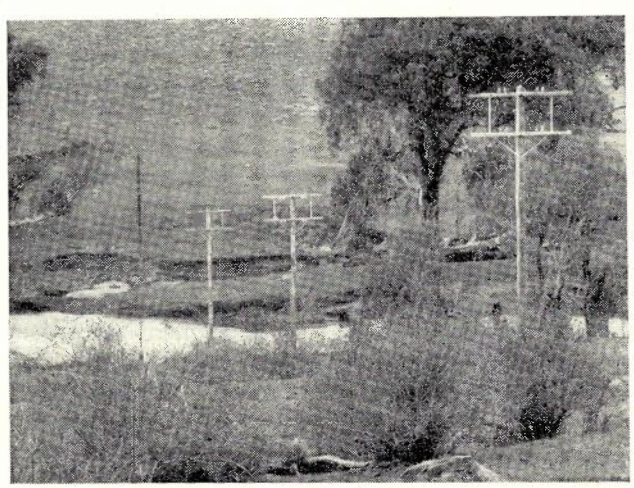

Fig. 7.—Campaspe River crossing at Axedale.

upon by the Engineer in charge of the work, are used to prepare the field book. See Fig. 8. As several copies are required and the time taken to prepare them by hand is considerable, a trial was made of photostat copies printed and bound by the Drafting Section to form field books similar to the standard book. These have been successful, but a further improvement has been effected in in the Trunk Planning Division by use of the Fordigraph process. This is a duplicating process in which various coloured inks can be used. The latest field books are cheaper and faster to produce, and have the great advantage of being printed in colour. They are similar in size and quality of paper to the standard field book, and have strong manilla covers. The usual number of copies prepared for a job is six.

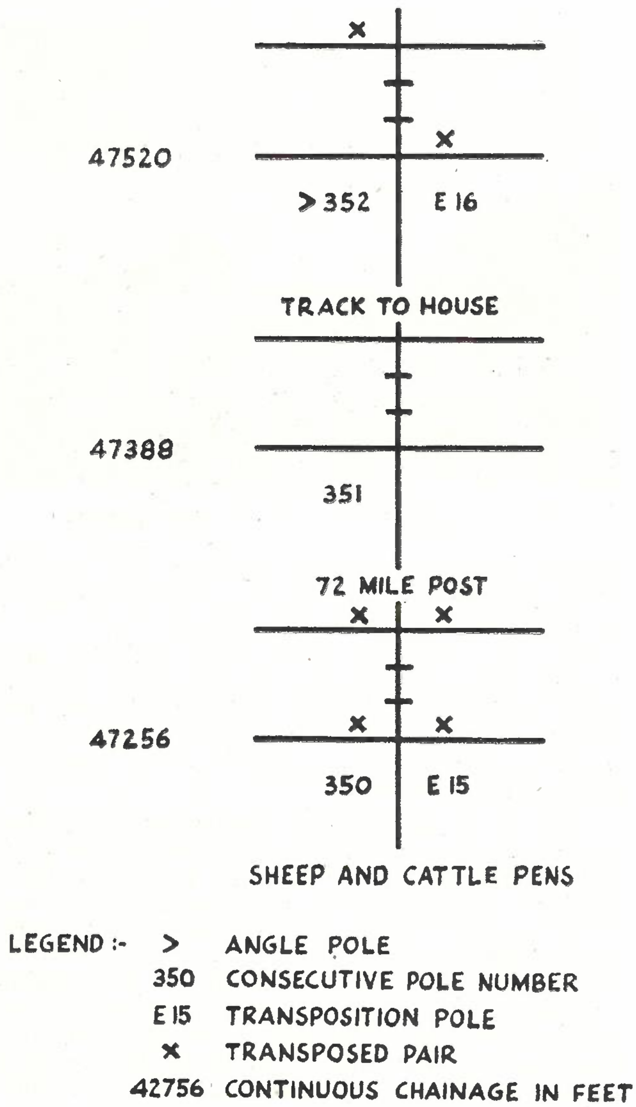

Fig. 8.—Field Book—typical sheet.

NOTE.—A covering sheet would be prepared for each field book, indicating generally the work to be carried out. In this case the work consisted of erecting 4 pairs of 200 H.D.C. wires in pin positions 1.3-1.6 and 4.3-4.6. Where only the basic pole layout is shown as for pole 351, the wires would be erected in the correct pin positions, but would not be transposed.

In the field books the poles are numbered consecutively, as well as in accordance with the transposition scheme, to correspond with the numbered pegs set up in the field by the survey party. The pegs are made of jarrah or red gum, and are approximately ten inches long. Angle pegs are made of 3″ x 3″ timber and painted red. Pegs for straight line poles are of 2″ x 2″ timber, painted yellow for transposition poles and white for other poles. Where transpositions occur at angle poles a yellow peg is placed alongside the red peg. Identification of the survey pegs in this manner and indication in the field books of all prominent land marks, and features including mileposts, gates, houses, dams, etc., as well as pole chainage, simplifies the task of the line parties when work commences, and minimises the possibilities of mistakes in laying out poles and subsequent fitting of transpositions. In addition to pole and transposition identification numbering, pole heights, pole plans, description of work to be done, and the geographical identifications, power crossings are included in the field books. The last item is of assistance in ensuring that standard clearances are effected, and in taking safety measures during the running of wire.

Procurement and Storage of Material: Orders for material are placed as early as possible and arrangements made for storage at points along the route. It is essential to have all material available or in sight before the work commences, so that there will be no delay once line parties are on the job. The most suitable arrangement for the storage of matcrial is to have huts erected at line depots along the route so that material can be accepted and stored as it becomes available. Poles are delivered to pegmarks, or to dumps along the route and laid out from there. Huts have recently been obtained which are particularly suitable for the storage of material on large jobs. They are made of angle-iron frames bolted together, and covered with corrugated iron sheets attached to the frames with metal screws and clips. The roof is of the gable type. The whole unit is simple and speedy to erect and dismantle, and presents no difficulties in transport. Two sizes are in use, 20′ x 10′ and 8′ x 10′.

Construction Work

When the preliminary work has been completed the route pegged, field books prepared, material including poles procured, and accommodation arranged for staff, the actual work of construction commences. The first consideration is the laying out of poles to pegmarks. On the Seymour-Bendigo job the wooden poles were tank creosoted at Rushworth, and delivered straight to peg marks by Departmental pole trailers, the officer in charge at the creosote plant being provided with a field book showing peg numbers and corresponding lengths of poles, so that poles could be loaded for economical laying out along the route. Where poles are delivered by rail to sidings, a mobile crane has proved most useful in loading the poles to pole trailers for delivery to peg marks. Immediately the laying out is proceeding satisfactorily, parties are put on to the work of arming the poles and fitting transposition plates. As far as practicable all fittings are placed on the pole whilst it is on the ground.

With the modern post-hole borer poles can usually be erected complete with arms and plates, thus effecting a saving in time. This type of borer lifts the pole as well as boring the pole hole, and has a long boom enabling it to grip the average pole well above its centre point, to allow for the shift of the centre of gravity towards the head due to the weight of the arms and plates. Another type of borer, which has no lifting mechanism, has been used on the Seymour-Bendigo route for boring stay holes. When used for poles it has been worked in conjunction with a winch truck fitted with sheer legs. One party follows behind the borer uprighting the poles and filling in and ramming. A separate party attends to the stays. One man follows the pole erecting party stencilling the poles. The work is so organised that the erected poles have been fitted with stays when required, and allowed to settle as long as possible prior to the commencement of wiring work.

Before wire is erected the section of route is checked to ensure that all poles are upright and stays are tight. Wires are erected and tensioned in ½ to 1 mile sections, the weight method, described in the paper "New Method of Regulating Aerial Wires," by C. H. Hosking, in the June, 1951, issue of this Journal, being used for tensioning. Eight wires are strained at the one time. Where practicable, the wires are laid out in groups of four from wire reels mounted on a wire trailer or on the tray of a motor truck. A wire reel hav-

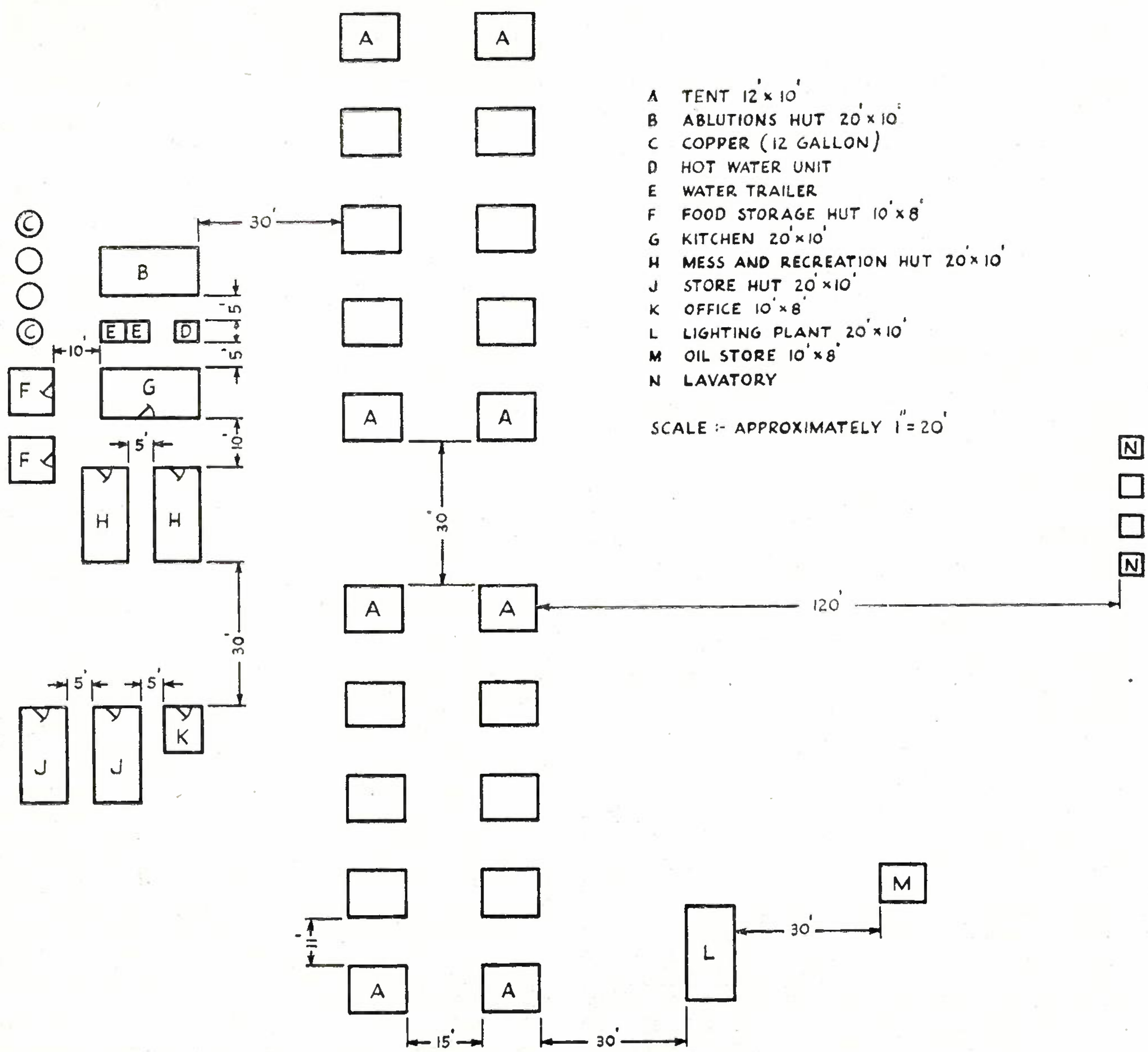

Fig. 9.—Large Line Camp—Layout.

ing an automatic braking device has recently been developed and simplifies the work, provided care is exercised at angles in the route. In this type of reel, the wire running off in a straight line holds a spring-loaded brake off the rim of the wire reel by means of the tension in the wire. Should slack develop, the tension is released and the brake operates until the wire is again under tension. An equal number of wires are strained on each side of the pole in the one operation, in order to maintain an even pull on the pole and arms.

Camps for Large Construction Parties:

Many large trunk works are now carried out by camping parties because of the difficulty of obtaining suitable accommodation in towns near the work. Camps should be located as near as possible to the route, and so that the maximum distance of travel in any one direction is approximately 15 miles. A camp would then cover 30 miles of route. Other considerations, such as proximity to water and power, fuel supply and drainage will affect the final location of camps. Sleeping accommodation is provided by 10′ x 12′ tents with wooden flooring. The tent is fitted up for two men, and has two steel stretchers, mosquito nets where required, one table and two camp chairs. A large portable hut approximately 20′ x 10′ is provided for messing and recreation. The hut is furnished with tables and camp chairs, a heating stove and wireless.

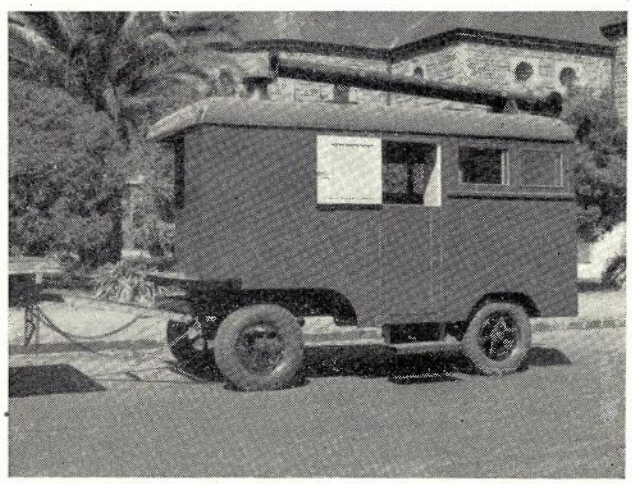

Fig. 10a.—Portable Kitchen—General View.

Kitchen arrangements consist of a trailer kitchen, and a small fly-proof hut to act as a pantry and to accommodate refrigerators. The kitchens are four-wheeled trailers with steel panelled bodies converted from surplus army "Wiles Cooker" vans. A wood fire or oil-burning stove is installed at one end, and the kitchen has both a solid and fly-wire door, a sliding panel in the roof, and fixed and sliding windows along the sides. All such openings are protected by fly-wire screens. Cupboards, shelves and drawers are fitted around three sides of the kitchen. The tops of the cupboards act as benches and also carry a stainless steel tank. A water tank is fitted between the stove and the sink. The oil-burning stove is the

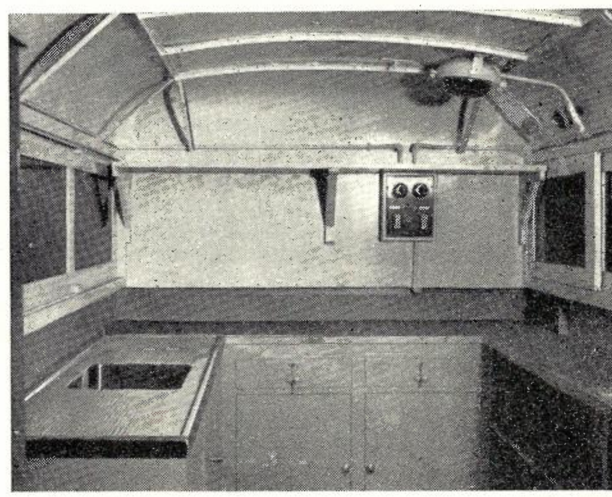

Fig. 10b.—Interior, showing steel sink, cupboards and bench, and electric light and power points.

type in which oil and water drip from separate tanks on to a hot plate, the preliminary heating of the plate being effected by allowing the oil to drip at a fast rate on to burning paper or wood chips. When the plate is heated, the oil rate is reduced and the water tap turned on. Oil and water taps are adjusted to give a clear, intense heat. The portable kitchen is a prefabricated wooden hut with similar fittings to the trailer kitchen. However, as it is not on wheels it is necessary to erect and dismantle it each time a camp is moved.

Lighting is normally provided by means of a 55 volt step down transformer where power is available. Where commercial power is not available eight six-volt car batteries are used, these being charged from a petrol generator set. Washing and bathing are catered for by means of a hot water service, wood or coke fired, and an ablutions hut, containing showers, baths and wash troughs.

Where a town water supply is not available the camp is pitched if possible near a river, and the water is pumped into a large water tank for distribution around the camp. Kitchen, ablutions hut and hot water service are grouped together to economise in piping, and for convenience. The mess hut is placed close to the kitchen. The camp office, a portable hut, is also included in this group. Beyond these buildings the tents are placed in rows, and beyond these again is the lavatory block. Earth drains are dug where necessary to dispose of surface water. Cleanliness is essential in a camp, particularly in hot weather, and all kitchen refuse is disposed of without delay. In some cases local farmers are prepared to cart away kitchen refuse, otherwise it is buried, use being made of the post-hole borer.

To reduce the number of flies present during the summer months, blow-fly traps are placed in suitable locations around the camp. Catering, recreation and general camp matters are placed in the hands of a camp committee usually consisting of five members of the staff, including the Line Inspector and the cook. The Department provides the services of a cook for camps of ten or more men, with one or more assistants for camps of twenty men and over. Members of the camping party make their own arrangements regarding catering.

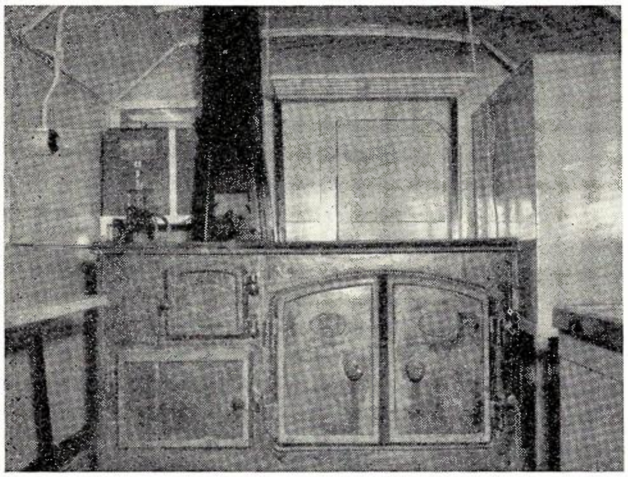

Fig. 10c.—Interior, showing oil stove and water storage tank.

A large camp of approximately forty men requires a regular staff of four, one to assist the Line Inspector on clerical duties and camp organisation, a cook, cook's assistant, and one on general duties around the camp. During weekends and on holidays a member of the camping party is rostered for a 24-hour period for camp protection duties. Such a camp covers an average area of half to one acre, and comprises twenty 12 feet x 10 feet tents, mess hut, trailer kitchen, store huts, ablution hut, hot water unit and portable lavatories. There are 94 distinct items of equipment, the total number of items being in the vicinity of 1400. A typical large camp layout is shown in Fig. 9 and three views of the portable kitchen are given in Figs. 10a, 10b, 10c.

Conclusion:

Trunk aerial construction using large parties has created a number of problems in organisation of staff, equipment and material to carry out the work speedily and without waste effort, and the experience gained on the Seymour-Bendigo route has been invaluable in meeting similar problems on other large works.

THE BUTTINSKI

A. Westmore and B. Edwards

The handset No. 3 or "buttinski" is a piece of testing equipment used extensively throughout the Department by technicians and linesmen. It is generally similar to the ordinary handset except that a dial is incorporated behind the receiver. The body consists of two main sections and is hollow to accommodate a choke coil, capacitor, switch, press button and wiring. The circuit is shown in Fig. 1.

Arising from difficulties in obtaining overseas supplies, the Departmental workshops, Melbourne, was requested to submit tooling and production costs with a view to local manufacture. At the same time there was a need for redesign because the body of the buttinski was of aluminium, which was in short supply, the transmitter inset and receiver were of a type not available locally, and the inclusion of a choke coil in an improved circuit was required. This redesign was carried out jointly by the Drafting and Design Sections attached to the workshops and the following article gives a brief description of the design and production problems involved.

DESIGN OF BUTTINSKI

Factors influencing the design.

Electrical—Insulation of components from the body and from each other.

Weight—Strength, balance, appearance, finish, comfort of handling, etc.

Maintenance

General Usages—In exchanges; outdoor technicians; subscribers' premises; linemen (poles, manholes, etc.).

Wear and Tear—The buttinski is used in a variety of places and in general handling, transport by tool bag, truck, etc., is subjected to general wear and tear, indicating that a strong material is required in the body.

Material—The material decided upon to best suit the foregoing conditions was a fabric-filled thermo-setting plastic, because:

(a) It covers the electrical problem in that it is itself an efficient insulating medium.
(b) It can be moulded to any desired shape and a high gloss finish can be obtained.
(c) It requires no maintenance.
(d) Use of a phenol-formaldehyde base with a fabric filler gives a high tensile strength, is resistant to shock, and allows a relatively thin wall section, thus keeping down weight.
(e) Being a thermo-setting plastic, it has high dimensional stability and does not warp under extreme temperature changes.
(f) Allows the use of standard receiver inset and earpiece, transmitter inset bowl fittings and mouthpiece.

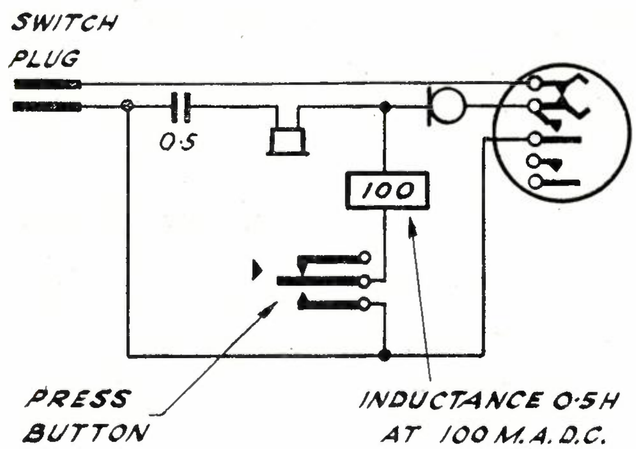

Fig. 1.—Buttinski circuit diagram.

Component Parts—To reduce tool costs to a minimum and to effect standardisation of parts with the ordinary handset, it was decided to use, as far as possible, parts already being manufactured at the workshops or available from stores.

These parts were:—
(a) Transmitter inset No. 13 (workshops).
(b) Fittings—(i) contact springs (stores).
(ii) combined contact plate and cleat (stores).
(c) Receiver inset No. 1L (workshops).
(d) Ear-piece No. 18 (workshops).
(e) Mouthpiece, Army type which is considerably stronger in design than the commercial type.
(f) Dial No. 10 (stores).
(g) Cordage (stores).
(h) Switch springs (workshops).

Parts not available and therefore needing design were:—
(k) Capacitor.
(l) Choke coil.

General Aspects of Design

Appearance.—An endeavour was made to keep the appearance similar to a handset insofar as maintaining correct modal positions of the mouth and ear-pieces, which the previous type did not do. At the same time a more comfortable hand-grip and press button was provided.

Number of pieces.—The body must necessarily consist of more than one piece to accommodate internal components and wiring. The previous type consisted of three, thus needing three dies, but it was found practical to use only two pieces in the new design. (See Fig. 2.) One half accommodates the transmitter inset and receiver, the cavities and mountings being similar to those in Handset No. 184. This half also houses in the handle the switching unit and coil. The other half houses the dial and capacitor and has a protecting flange for the dial, a feature that the previous type lacked.

Housing of Components.—As the previous type housed a capacitor and switching unit only, the additional space required for a coil presented a difficult problem. The external periphery of the handle being determined by the hand grip, the internal space is determined by the thickness of wall. A compact spring set was adapted from the No. 302A switch springs mounted in a position so that the push button is convenient to the users hand grip. The button is locking or non-locking as desired when using. The space left was too small to accommodate any existing type of coil or capacitor, therefore new types were designed to suit the requirements of the circuit and yet fit in the space available. The coil is held between built-up lugs in the handle, and room for the condenser was found in the rear chamber of the transmitter inset cavity.

Dial Mounting.—The dial casing incorporates three lugs, two of which have embossed pips designed to slide in slots in the normal mounting ring, and the other is tapped to provide locking. These lugs are "set" to provide a close fit in slots and through continual setting, eventually snap off. The design, therefore, was considered to be rather weak. It was decided to mould threaded holes in the body opposite these lugs and use a screw with a flat end and a hole up the centre to take the pip, using a spring washer behind the

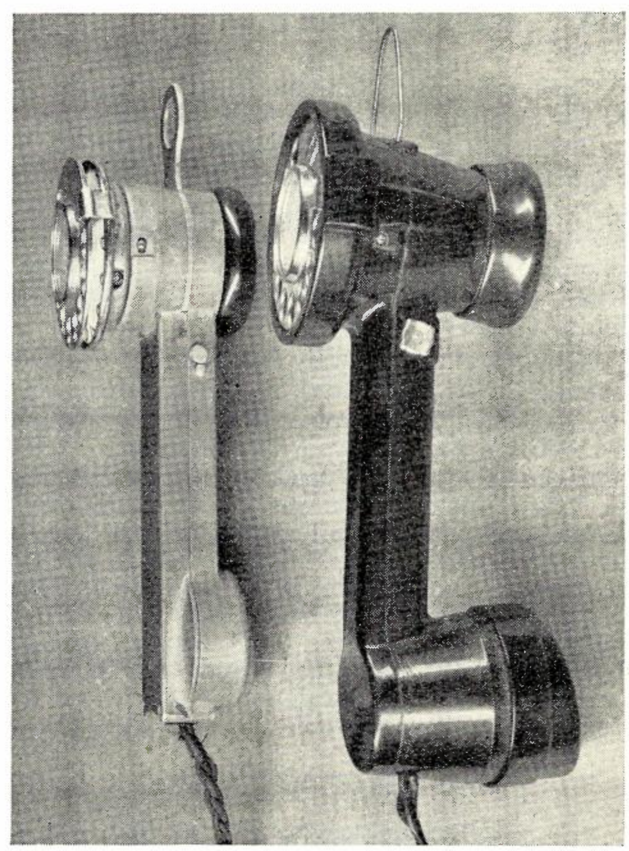

Fig. 2.—The new fabric filled phenol-formaldehyde body (compression moulded) and the old aluminium body (die cast).

head, which is recessed flush in the body. The lugs are now held firmly by the face of the screws instead of "floating" in a slot.

Hanger.—To reduce shock on the bakelite walls a flexible wire hanger is used. In the meeting faces of each half is moulded a semi-circular groove in which the wire is held when the halves are clamped together.

Assembly.—Internal means are provided for holding the two halves of the body together. In the half housing the dial, and at the transmitter end, two brass screws are moulded in. These extend through holes in the bottom wall of the transmitter cavity in the other half and are fastened with a spring washer and nut. The studs also serve in conjunction with a fibre plate to clamp the capacitor in place.

At the dial end a brass strap is moulded in the walls and fits into a seating provided in the other half. Screws passing through holes in the strap and into tapped inserts in the seating complete the fastening. Cordage wiring to terminals and components is completed with the two halves "laid open". With the hanger placed in position, the halves are then fastened together as described above. The dial, transmitter inset and mouthpiece, receiver inset and earpiece are attached to complete the assembly, a sectional view of which is shown in Fig. 3.

DESIGN OF MOULDS

Consideration of Design.

The main considerations influencing the design of the moulds are:—

(a) Type of press to be used (direct compression, angle, injection, etc.)
(b) Type of heating (electric or steam).
(c) Type of mould required (solid cavity or split cavity).
(d) Moulding pressures.
(e) Bulk factor.
(f) Types of steels.
(g) Method of construction.
(h) Machinability.
(i) Holding and loading of inserts.
(j) Loading of powder.
(k) Flow and venting.
(l) Opening and closing of moulds.
(m) Extraction.
(n) Shrinkage allowances and mating of halves.
(o) Accessories for moulding (guides, slides, knock-out plates, etc.).

Drawings.—Mould drawings are very involved in that the article itself has to be drawn "in reverse" and separated into inside and outside views on the top and bottom forces respectively. A multiplicity of views and details are needed for the toolmaker and in all, 26 sheets of drawings were required. In addition, dimensioning in conjunction with shrinkage allowances is exacting. Shrinkage varies with the bulk, shape and section of the moulded articles and with the type of powder used. This must be allowed for to ensure perfect mating of the two mouldings. A typical mould drawing is shown in Fig. 4.

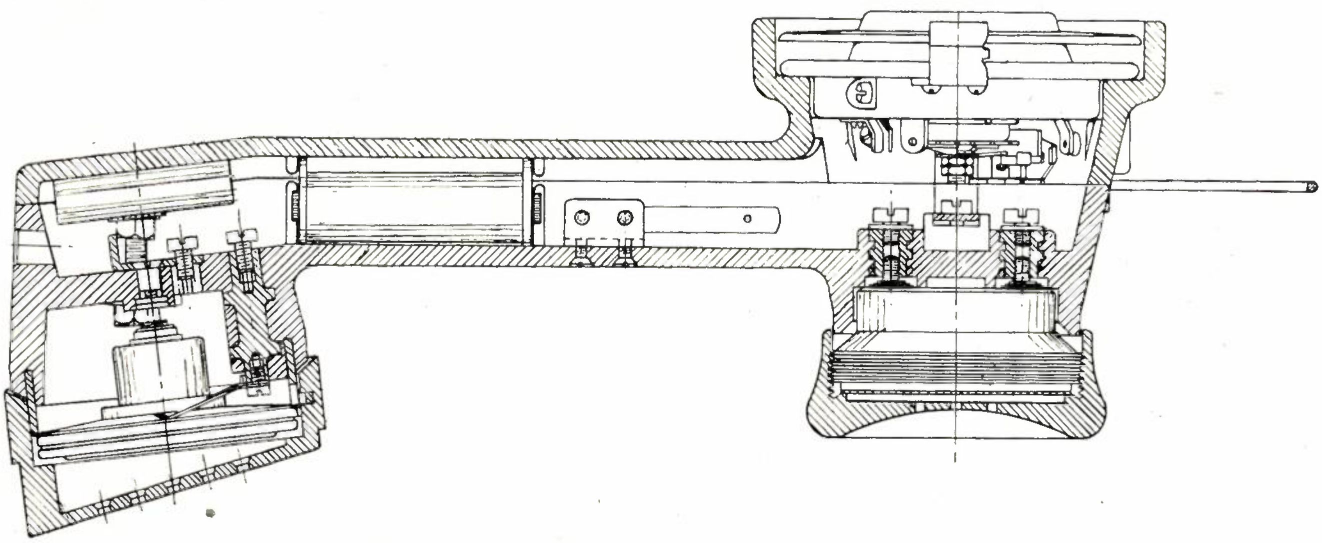

Fig. 3.—Sectional side elevation of Buttinski, wiring not shown.

Strength.—Owing to the high pressure required for moulding fabric filled plastics, substantially built moulds are needed. These may be obtained by careful selection of material and by method of construction.

Materials.—Several different types of material may be required. The main body and cores require a steel which will not "crush" beneath the hardened skin under continued high pressures. Other parts, due to their shape or section, may require a steel which will not warp when hardened. Core pins, due to the work they do, require a very tough steel.

Construction.—Greater strength is obtained from constructing from a solid forging than by fabrication, and although it entails difficult "set

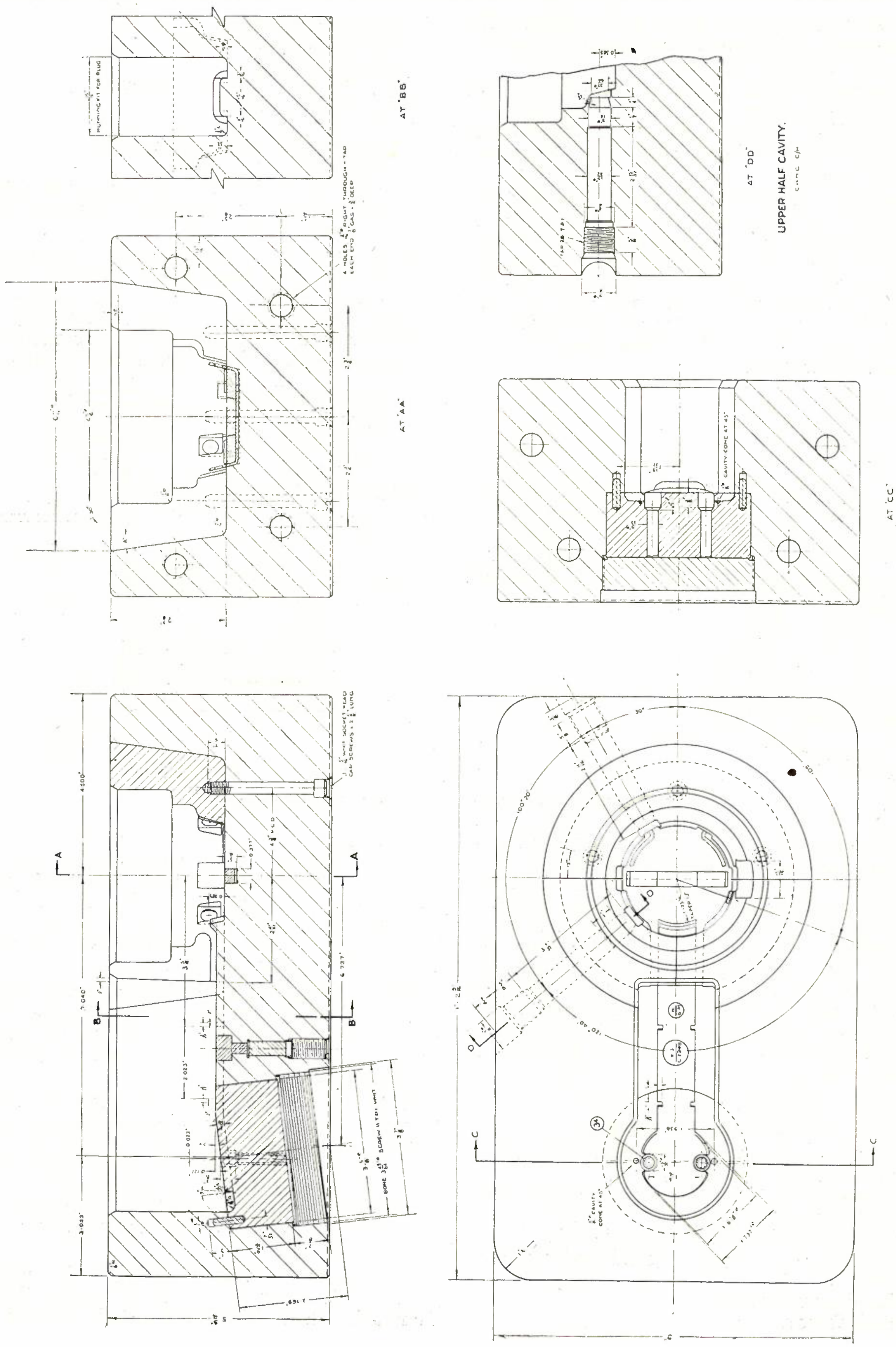

Fig. 4.—Typical mould drawing.

ups" and intricate machining it is offset by less maintenance and longer mould life. This principle has been adopted in the buttinski moulds.

Bulk Factor.—The fabric-filled powder has a bulk factor (loose to moulded volume) of 6 or 8 to 1, varying with grade of filler, therefore a deep loading chamber is required. Incidentally, the walls of this chamber serve as an efficient guide during the closing of the press.

Type of Heating.—As both steam and electricity heated presses will be available from time to time, the moulds have been constructed to suit either.

Tool Making.—Owing to the complexity of the moulds and the machining operations, and so that the toolmaker could have direct access to the draftsman and Supervisor, Design Section, it was decided to make the moulds at the workshops. This was possible because of the modern precision machines existing in the toolroom. All dimensions were obtained directly by indexing on the machines. Several special milling cutters, taps, "D bits" broaches, etc., were required. A wooden model of the buttinski was made to supplement the drawings, and so allowed a better comprehension of the problems involved.

Terms.—The top half or plug of a mould, that is, the half which is attached to the head of the press and which enters the cavity, is known as the "top force". Similarly, the bottom half or cavity is known as the "bottom force". These terms are used throughout the article.

Construction of Moulding Die for Dial-housing Half.

The chief factor influencing the type of mould for this half was extraction. Simple top and bottom forces could not be employed because of the dial protecting flange overhanging the handle, thereby preventing withdrawal of the top force. A direct split cavity bottom force could not be used because of undercuts required to form bosses for recessing the heads of the dial holding screws. In the final design a section of the cavity involving the over-hanging flange was split, the remainder being a cavity machined from the solid. The types of material used were:—

(a) Top Force—Nickel chrome (C.H.N.C.) steel forging, case hardened.

(b) Bottom Force—Nickel chrome (C.H.N.C.) steel forging, case hardened.

(c) Split cavity ring—Vibrac V.30 (pre-heat treated).

(d) Cores—Nickel chrome (C.H.N.C.) bar stock, case hardened.

(e) Core pins—tool steel, hardened and tempered.

(f) Insert holders—Nickel chrome (C.H.N.C.) bar stock, case hardened.

(g) Screws—socket head cap screws, high tensile steel.

Top Force.—The base of the top force and the plug forming the hand grip is machined from a solid forging measuring 16" x 8" x 6". The plug for the dial cavity is a separate unit, let into the base, and held from the back by screws. The transmitter end running off on an angle, required a special angle jig being cast to hold the moulds at the required angle during machining. A typical set up on a turntable of a vertical milling machine is shown in Fig. 5.

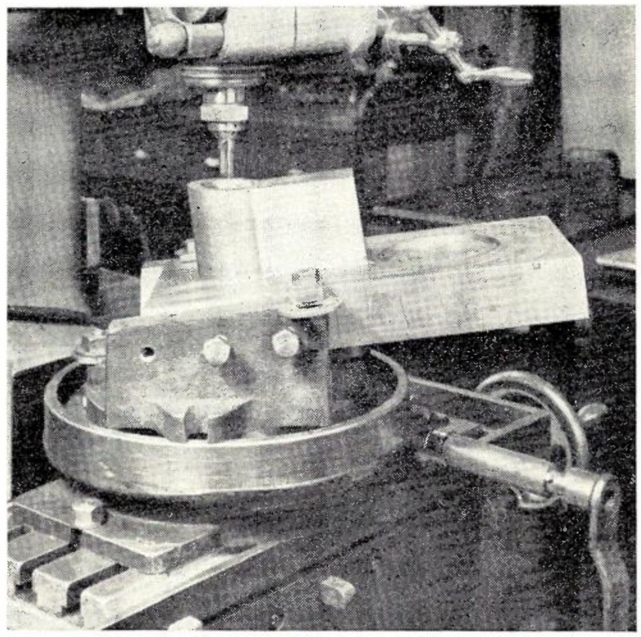

Fig. 5.—Dial Housing Component. Top force "set up" in vertical miller.

Bottom Force.—The cavity of a mould is usually the more complicated piece because it carries the majority of cores, core pins and inserts, and this case is no exception. The main block is a forging measuring 16" x 10" x 6". One end is bored to take the split ring which forms the dial housing. This ring is made up of a full half-section and two quarter sections initially dowelled and sweated together to form a unit while machining. Owing to its peculiar section and its liability to warp when hardened, it is made of Vibrac V.30 preheat-treated, which made it extremely difficult to machine, tipped tools being necessary.

The half section is permanently held in the main block and the two quarter sections, which form the undercut section of the flange and part of the handle, are loose. When extracting, these pieces come out with the moulding and are removed on the bench. The brass clamping strap is held in a slot across the bottom of the cavity, being covered again by three loose blocks, leaving only the ends to be moulded into the walls protruding. The blocks come out with the moulding and are then removed. Moulding of the threaded holes for the dial holding screws necessitated side cores. These are screwed in the main block on the same pitch as the moulded thread and pass right through the split ring into the cavity, seating against the top plug when the mould is closed. On extracting they have to be screwed right out to allow the quarter sections to be removed.

At the transmitter end of the cavity the vertical core has to finish at the same angle as the plug.

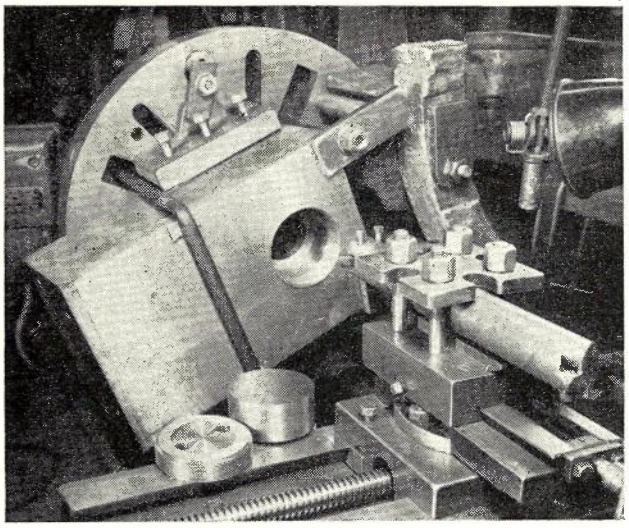

Fig. 6.—Dial Housing Component. Bottom force—boring "false bottom seating.

To obtain this a false bottom is let in on the angle from the back. Fig. 6 shows the block set up on the angle jig on the face plate of a lathe. The bore is finished and the block to form the false bottom and the screwed "holding in" plug are in the foreground. The two screws moulded in this end are held in extractable sleeves let into the false bottom. On extraction the sleeves come out with the studs and are then screwed off. Fig. 7 shows the completed mould. The bottom force has a quarter section and one strap covering block removed.

Accessories and Extraction.—The top force is attached to a mounting plate which, in the case of electric heating, is screwed directly to the top platen of the press. The bottom force is attached to a mounting plate which rests on the bottom platen. For extracting, rotatable guides mounted on angle iron extensions are fastened to the sides of the bottom platens. The mounting plate carrying the bottom force is brought forward in the guides clear of the platen and the whole is swung over. Knock out pins attached to a plate are then employed to extract the moulding and quarter sections. Fig. 8 shows the mould in the press with moulding and sections removed and bottom force back again on the platen. The holes seen in the ends of the mould pass right through and are required for steam heating.

Construction of Moulding Die for Transmitter and Receiver Half.

The factor influencing the type of mould for this half was the transmitter bowl. As it is tapered outwards towards the top, a direct vertical extraction is prevented, and a split-cavity mould was needed. The type of press is determined by:—

(i) **Electric Heating.**—Direct compression. Provision of a centre plate is needed for the closing of the split cavity.
(ii) **Steam Heating.**—Angle press, that is, direct compression with a side ram for the closing of the split cavity. The mould is designed for either.

The types of material used were:—
(a) Top force—Nickel chrome (C.H.N.C.) steel forging, case hardened.
(b) Bottom force—Nickel chrome (C.H.N.C.) steel forgings, case hardened.
(c) Cores—Nickel chrome (C.H.N.C.) bar stock, case hardened.
(d) Core pins—Tool steel, hardened and tempered.
(e) Insert holders—Nickel chrome (C.H.N.C.) bar stock, case hardened.
(f) Centre plate—45 ton steel, heat treated.
(g) Mounting blocks—45 ton steel, heat treated.
(h) Hangers—Nickel chrome (C.H.N.C.) steel, case hardened.
(i) Screws—socket head cap screws, high tensile steel.

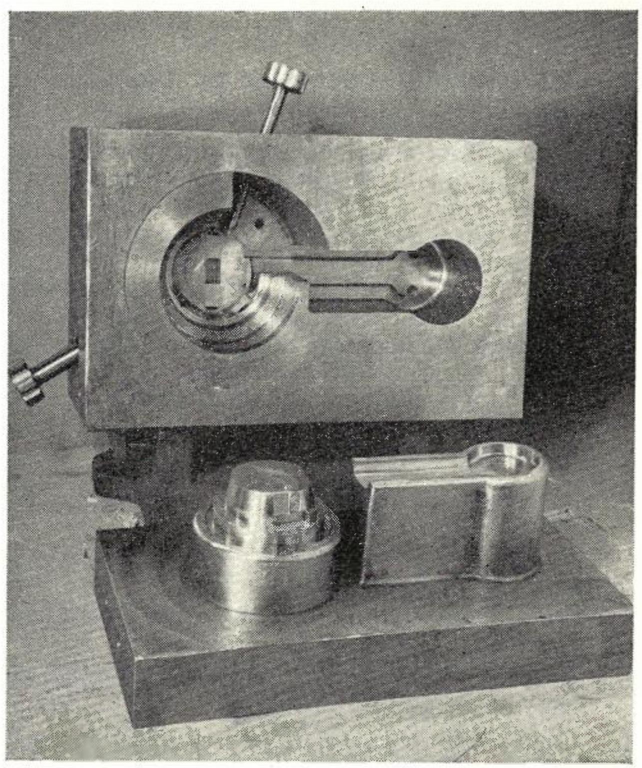

Fig. 7.—Dial Housing Component. Top and bottom forces—complete mould.

Top Force.—The top force consisted of one solid piece machined from a forging measuring 14″ x 7″ x 6″. At the receiver end a slot has been cut across the plug and a piece let in and held from the back to form the seating for the holding down strap moulded into the other half. There are four inserts required at this end of the moulding and, if moulded in, would have to be held on the plug. It is simpler and quicker in handling, therefore, to mould holes for them with core pins and press the inserts in immediately the mould is opened. Shrinkage of the material when cooling is sufficient to hold the inserts tight.

An intricate piece of work on the "land" of the plug was the machining from the solid of the raised portions to form the grooves for housing the wire hanger. The angle jig was again employed to machine the transmitter end. Fig. 9 shows the completed top force. The four holes on the side are for steam heating.

Bottom Force.—This was machined from two forgings measuring 14″ x 6″ x 4″, which were dowelled and held together by plates for machining as one unit. The outside walls are tapered outwards towards the bottom to provide positive clamping by the centre plate. The bore is carried through at each end, the top side being the loading chamber and cavity, and the under side takes the cores for the transmitter and receiver inset cavities.

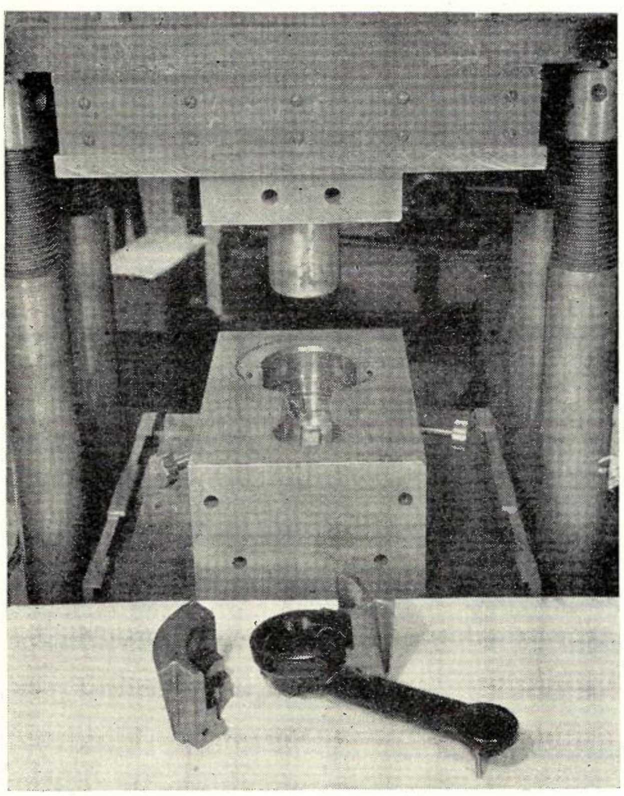

Fig. 8.—Dial Housing Component. Top and bottom forces "set up" in moulding press.

All inserts are moulded in and are carried on pins let into the transmitter cavity core piece. Side cores are provided to mould the holes for the press button and cord entry. The mouthpiece mounting ring is located on the transmitting core piece, and a groove is cut in the bore to clear the

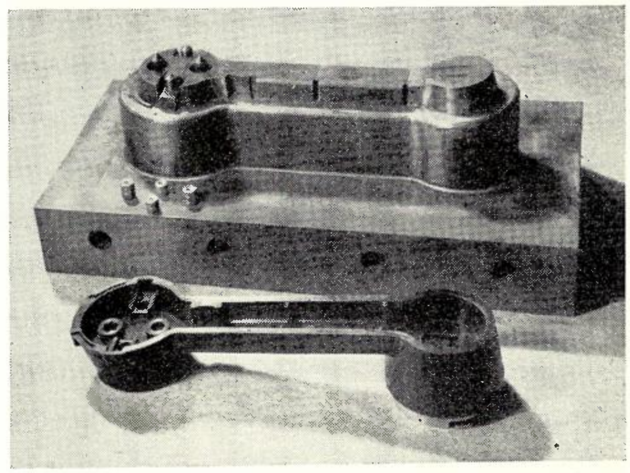

Fig. 9.—Transmitter and receiver housing component. Top force—completed.

three off-set portions. One side of the cavity only is shown in Fig. 10. The cores are carried on locating pins on a detached block which in turn is located on a strip fastened to the mounting plate.

Accessories

Centre Plate and Hangers.—These were machined from a forging of 45-ton steel. To eliminate possibility of warping, it was pre-heat-treated and machined in that state. Four seatings are fabricated and welded to the sides. These, in conjunction with four hangers screwed into the top

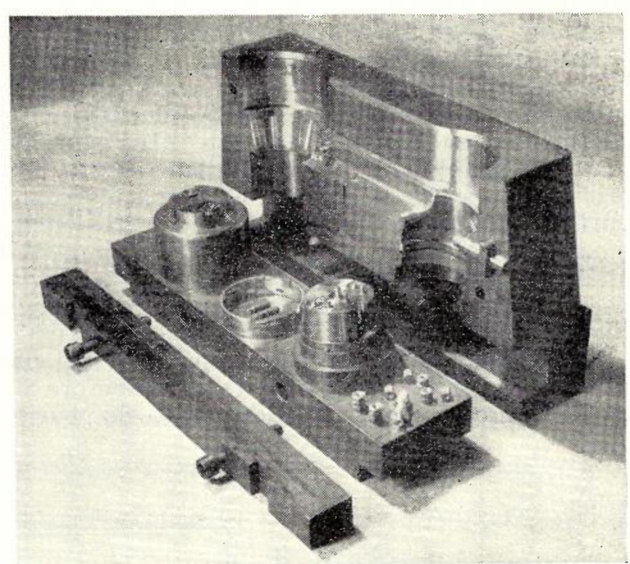

Fig. 10.—Transmitter and receiver housing component. Bottom force—split cavity and components.

mounting plate, serve as a closing stop when mould is closed. The hangers limit the travel of the centre plate when the mould is opened. The springs provide the initial pressure on the plate to clamp the split cavity together; the closing stop provides the final pressure. Fig. 11 shows the assembly in the press in the closed position.

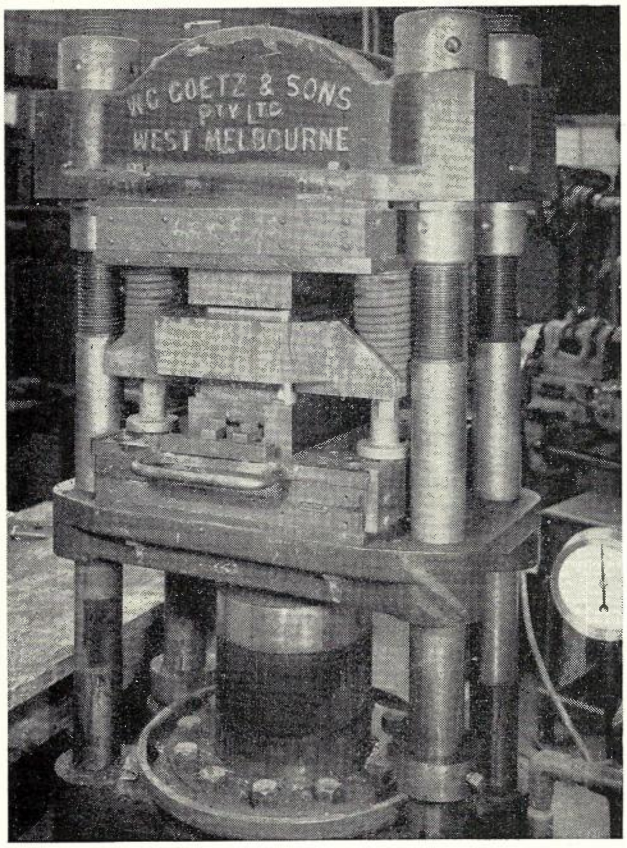

Fig. 11.—Transmitter and receiver housing component. Press "set up" —moulding position.

Extraction.—When the mould is opened the bottom force and centre plate come away together to the limit of the hangers. The bottom force then continues to the end of the stroke of the ram. The mounting plate carrying the bottom force is then brought forward on slides and the split cavity opened, leaving the moulding on the cores on the mounting block. The inserts are pressed in at this stage. The moulding and cores are lifted off as one unit and the cores are removed on the bench. Fig. 12 shows the mould in the opened position.

Trial Mouldings.—To check on all sizes, fits, mating, etc., trial mouldings were run before the moulds were hardened. In addition, a cold pouring plastic known as "Formit" was utilised during machining as a check on mating sizes. The dial side mould having been made first, several trial mouldings were run. When the cavity of the receiver side mould had been machined it was heated and filled with "Formit" which on setting has the same shrinkage as the moulding material used. This not only checked mating sizes, but checked the mating angles at the transmitter end as well.

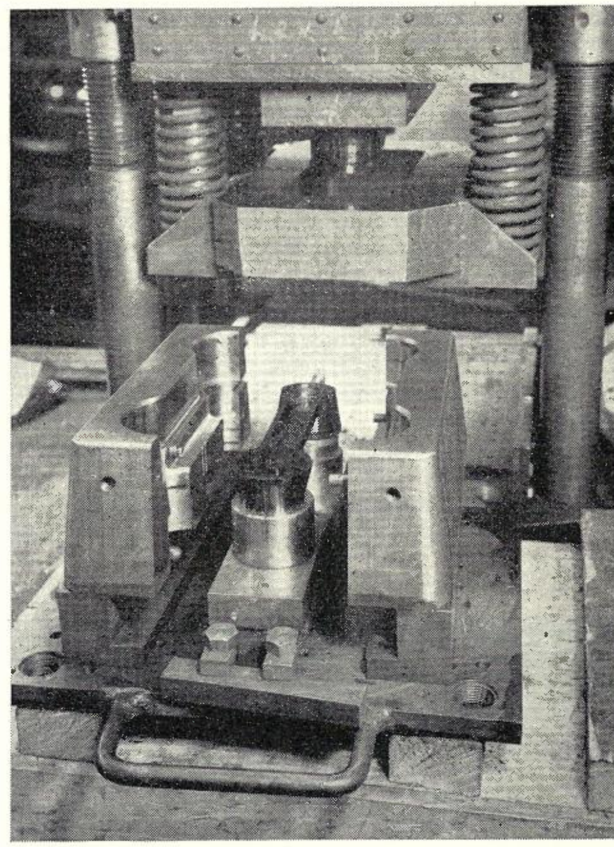

Fig. 12.—Transmitter and receiver housing component. Press "set up" —extracting position.

Hardening.—When a mould is case hardened a skin is formed which has to be removed and the moulding surfaces polished. Owing to the complex nature of the surface of these moulds, this was not practical, so the surfaces were polished while machining, and the finished mould was "bright hardened". This is done in a special furnace and on removal the surfaces retain their original polish.

Plating.—The final operation is to chrome plate all moulding surfaces. The higher the quality of plating the higher the finish on the moulding.

INTER-CHANNEL INTERFERENCE IN MULTICHANNEL CARRIER TELEPHONE SYSTEMS

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Introduction.

Interchannel interference or crosstalk in multichannel carrier systems is well known in communication engineering, but so far no method of measurement has been standardized internationally. With the increasing use of multi-channel systems, a need has arisen for a simple method of measurement, giving accurate results capable of reproduction. A number of methods have been used and are being used, but none of these appear to be entirely satisfactory.

One method which, because of its simplicity, is frequently used, is to transmit sine waves simultaneously on one or several channels, and to measure by means of a db-meter the interference appearing at the output terminals of channels on which there is no transmission. This method of measurement will not result in "true" figures of interchannel interference, unless a very large number of measurements are carried out at different frequencies, and "average" figures worked out by long and laborious calculations. The method is, however, often useful when comparing the performance of identical systems.

Another method of measurement employs human speakers instead of sinewave oscillators, but is otherwise as described above. This method gives figures directly related to the quantity of audible interchannel interference, but it has the disadvantage that conditions of test cannot be reproduced accurately.

One of the best methods appears to be one recommended, but not agreed upon, by the C.C.I.F. and used by the Swiss Telephone Administration (1). The method is similar to the methods mentioned above, but employs instead of a sinewave oscillator or a human speaker, an oscillator producing a complex wave consisting of the frequencies 100, 200, 300, . . . c/s. The complex wave simulates to a certain degree "steady" speech, and the figures obtained are, therefore, related to the quantity of audible interference. The frequencies 100, 200, 300 . . . c/s are of certain defined relative amplitudes and phases. A similar type of oscillator has been developed in England (2).

Theory of Interchannel Interference.

Interchannel interference in its broad meaning could include interference by crosstalk between channels of different carrier systems operating on the same route. However, only interference between channels of the same system will be considered here. This type of interference may be due to one or more of the following causes:—

(i) Non-ideal filter characteristics, that is, there is some attenuation in the pass-band, and the attenuation is not infinite in the stop-band.

(ii) Unwanted products of modulation, including harmonics and intermodulation products in non-linear elements and units, such as amplifiers, filters, etc.

(iii) Undesired couplings.

Each of these causes will now be considered separately:—

Non-ideal Filters: Interchannel interference due to lack of suppression in filters may be determined from the attenuation versus frequency curves of the filters involved. The relationship between the input level to the disturbing channel and the interference output from the disturbed channel is linear, so that, for instance, a 3 db increase of input level causes a 3 db increase of interference level. Similarly, if several channels are disturbing, an increase of 3 db of all input levels causes a 3 db increase of interference level in each of the disturbed channels.

This type of interference is often due to lack of suppression in that part of the stop-band nearest to the cut-off frequency, and occurs, therefore, mainly at the extremes of the channel frequencies. In carrier telephone equipment with suppressed carriers, the interference will generally appear at the voice frequency terminals of the disturbed channels as an unintelligible complex wave.

Unwanted Products of Modulation: These include harmonics and intermodulation products in amplifiers, etc.

If a single sine wave frequency is applied to a non-linear element, harmonics will be produced. If two single frequencies, each a sine wave, are applied simultaneously to the same non-linear element, harmonics of each of the two will be produced, and in addition the two frequencies will intermodulate, whereby a number of "foreign" frequencies called intermodulation products will be produced.

As all components, including resistors and condensers, are not perfectly linear, harmonics and intermodulation frequencies will occur in any multichannel system and may cause interference between channels.

An exact mathematical treatment of harmonics and intermodulation products is difficult, but some useful information may be gained by a study of a simple case, in which second and third order harmonics and intermodulation products only are considered. It should be noted that this simplification is not very often permissible in practical cases.

Consider, for instance, an amplifier, and assume that the relationship between input voltage V_1 and output voltage V_2 is given by the expression:

$$V_2 = C_1 \cdot V_1 + C_2 \cdot V_1^2 + C_3 \cdot V_1^3 \quad \text{.... ....} \quad (1)$$

and assume further that two single sine wave frequencies with amplitudes a and b and frequencies f_1 and f_2 are applied simultaneously to the input terminals, that is:

$$V_1 = a . \sin \omega_1 t + b . \sin \omega_2 t \quad \text{.... ....} \quad (2)$$

where: $\omega_1 = 2\pi f_1$ and $\omega_2 = 2\pi f_2$.

Substituting equation (2) in equation (1),

$$V_2 = C_1\{a\,.\,\sin\omega_1 t + b\,.\,\sin\omega_2 t\}$$
$$+ C_2\{\tfrac{1}{2}(a^2+b^2) - \tfrac{1}{2}a^2\cos 2\omega_1 t - \tfrac{1}{2}b^2\cos 2\omega_2 t + ab\,.\,\sin(\omega_1+\omega_2)t + ab\,.\,\sin(\omega_1-\omega_2)t\}$$
$$+ C_3\{(3a/2)(\tfrac{1}{2}a^2+b^2)\sin\omega_1 t + (3b/2)(\tfrac{1}{2}b^2+a^2)\sin/\omega_2 t - \tfrac{1}{4}a^3\sin 3\omega_1 t - \tfrac{1}{4}b^3\,.\,\sin 3\omega_2 t - \tfrac{3}{4}ab^2\sin(\omega_1+2\omega_2)t - \tfrac{3}{4}ab^2\sin(\omega_1-2\omega_2)t - \tfrac{3}{4}a^2b\sin(2\omega_1+\omega_2)t - \tfrac{3}{4}a^2b\sin(2\omega_1-\omega_2)t\} \quad \text{....(3)}$$

From equation 3, the frequencies and amplitudes in the output voltage V_2 may be tabulated as shown:—

Frequency	1st Order	2nd Order	3rd Order
D C		$C_2\,.\,\frac{1}{2}(a^2+b^2)$	
f_1	$C_1\,.\,a$		$C_3\,.\frac{3}{2}(\frac{1}{2}a^2+b^2)$
f_2	$C_1\,.\,b$		$C_3\,.\frac{3}{2}b(\frac{1}{2}b^2+a^2)$
$2f_1$	$C_2\,.\,\frac{1}{2}a^2$		
$2f_2$	$C_2\,.\,\frac{1}{2}b^2$		
f_1+f_2	$C_2\,.\,ab$		
f_1-f_2	$C_2\,.\,ab$		
$3f_1$			$C_3\,.\,\frac{1}{4}a^3$
$3f_2$			$C_3\,.\,\frac{1}{4}b^3$
f_1+2f_2			$C_3\,.\,\frac{3}{4}ab^2$
f_1-2f_2			$C_3\,.\,\frac{3}{4}ab^2$
$2f_1+f_2$			$C_3\,.\,\frac{3}{4}a^2b$
$2f_1-f_2$			$C_3\,.\,\frac{3}{4}a^2b$

Without knowing the values of C_1, C_2, C_3, f_1 and f_2, the following information may be obtained from this table:—

(i) There are four harmonics. The amplitudes of the harmonics of f_1 do not depend on the amplitude of f_2, and vice versa.

(ii) There are six products of intermodulation, that is, components involving both f_1 and f_2, and the amplitudes of the intermodulation products depend on the amplitudes of both f_1 and f_2.

(iii) The second and third order harmonics increase with the squares and cubes respectively of their fundamental, so that, for instance, an increase of 1 db of the fundamental will cause an increase of 2 db and 3 db of the second and third order harmonics respectively.

(iv) If f_1 and f_2 are of equal amplitude, that is $a = b$, the amplitude of the second order harmonics will be equal to half the amplitude of the second order intermodulation products, or in other words, 6 db lower. Similarly, the amplitude of third order harmonics will be $20\ .\log_{10}3 = 9.5$ db lower than the amplitude of the third order intermodulation products.

(v) If the amplitudes of f_1 and f_2 are both increased for instance by 1 db, the amplitudes of second order harmonics and intermodulation products are increased by 2 db, and in the case of third order by 3 db.

Speech waves have been found to consist of a fundamental with rapidly varying pitch and 10 to 20 strong harmonics. Consequently the parts of a multichannel system common to several channels may handle a large number of frequencies simultaneously, and the number of unwanted harmonics and intermodulation products may, therefore, be great. Some of these unwanted frequencies may fall in frequency bands allocated to other channels, and will thus cause interference between channels. Interference of this nature normally appears at the voice frequency terminals of a channel as an unintelligible complex wave.

Undesired Couplings: Interchannel interference may be caused by various types of undesired couplings, such as electromagnetic coupling between transformers, coils and resistance spools, or elec-

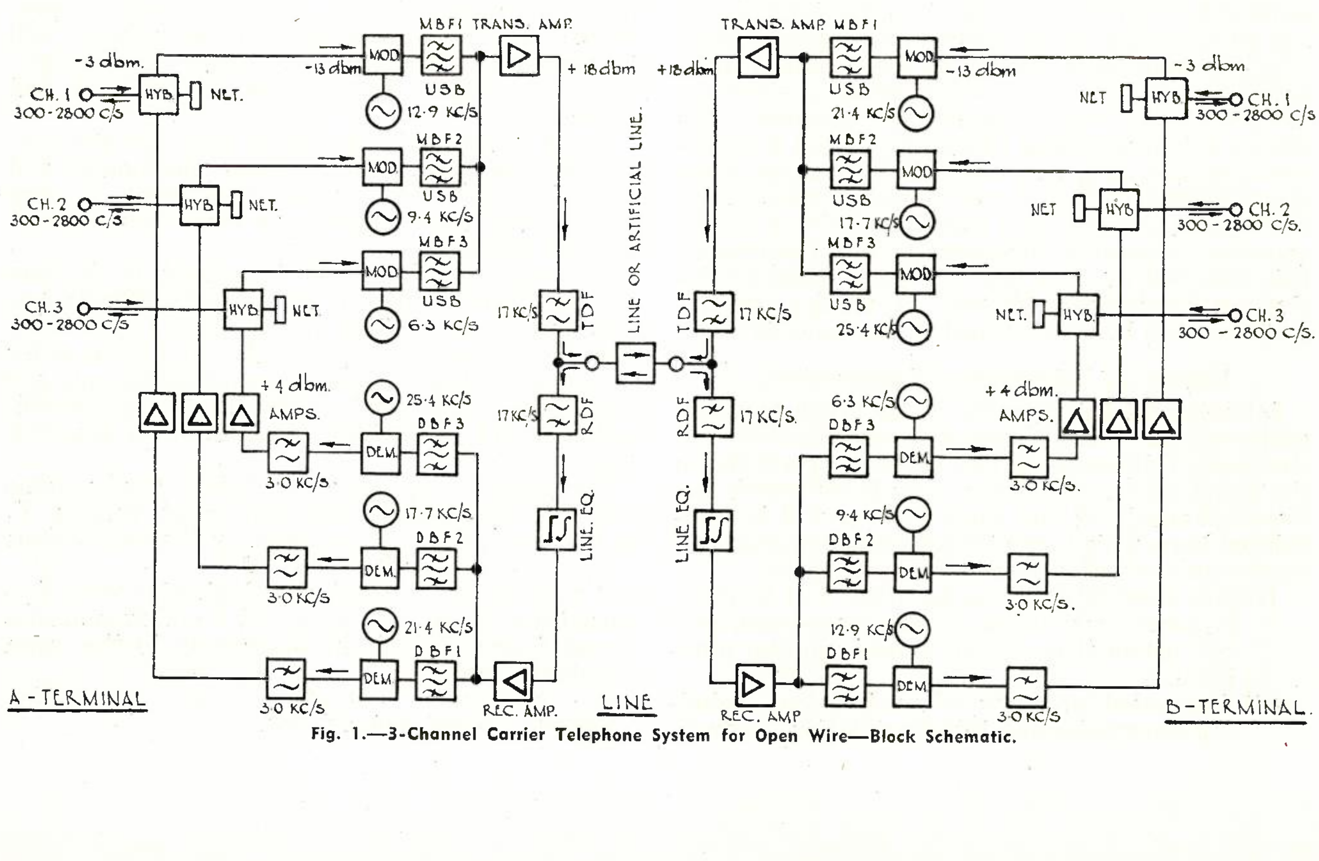

Fig. 1.—3-Channel Carrier Telephone System for Open Wire—Block Schematic.

trostatic coupling due to insufficient screening. Other types of couplings are caused by impedances common to several channels, such as, for instance, the impedance of common power supplies, common earth-wires, common bias circuits, and common carrier frequency generators.

Interference due to undesired couplings in a well-designed system will be small compared with the interference mentioned under the first two headings. Interference due to couplings between voice frequency paths will normally be intelligible.

Interchannel Interference in a 3-channel Open Wire Carrier Telephone System.

In order to illustrate and clarify the foregoing sections, the specific case of a 3-channel open wire carrier telephone system will be dealt with in further detail. Fig. 1 is a block schematic of the system. The frequencies and line-up levels are those normally used by the Department.

Interference due to non-ideal filters: Fig. 2 shows a typical case of spill-over from one channel into another channel.

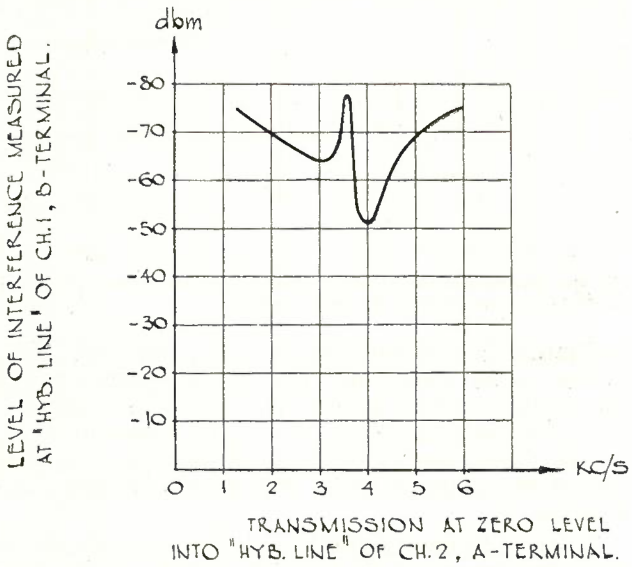

Fig. 2.—Interference between Two Channels due to lack of Suppression in Filters.

Interference due to harmonics and intermodulation products: It has been shown previously that the levels of harmonics and intermodulation frequencies increase more rapidly than the levels of the fundamentals. It may, therefore, be expected that these frequencies will be produced predominantly in the units handling the highest relative levels, that is transmit amplifier, directional filters, receive amplifier and line. Harmonics and intermodulation frequencies from the transmit amplifier will give rise to near and far-end interference. The near-end interference is countered mainly by the attenuation in the stop-band of the transmit directional filter, and is, in most cases, less than the far-end. Harmonics and intermodulation frequencies will be produced in the receive amplifier when this handles power received from the far terminal, and the interference will, therefore, be far-end.

Harmonics and intermodulation frequencies produced by the directional filters will give rise to both near-end and far-end interference. The reason for this is that each filter consists of several sections, in each of which harmonics and intermodulation frequencies are produced. Referring to Fig. 3, which shows a block schematic of a

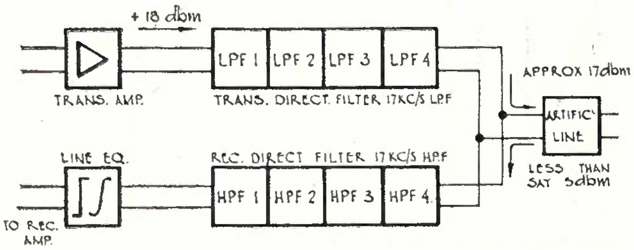

Fig. 3.—Directional Filter, 3-Channel System, A Terminal.

set of directional filters and its adjacent units, together with the approximate nominal levels, it will be seen that the sections LPF 1-4 and HPF 4 are exposed to levels in the order of + 17 dbm. HPF 1-3 are exposed to considerably lower levels only. The highest levels of harmonics and intermodulation products are, therefore, likely to be produced in sections LPF 1-4 and HPF 4. Unwanted products in the frequency band below 17 kc/s will be attenuated by the receive directional filter before they enter the receive amplifier of the terminal. The products below 17 kc/s transmitted to line are not suppressed by the 17 kc/s low pass receive directional filter of the far terminal, and they appear finally as far-end interference. Unwanted frequencies in the band above 17 kc/s produced in sections LPF 1-3 will be attenuated in LPF 4 before they reach the line side of the directional filters. From there they may enter either the line, in which case they will be suppressed by the receive directional filter of the far-end terminal, or they may pass HPF 1-4 and appear as near-end interference. The greatest amount of near-end interference may, however, be expected from sections LPF 4 and HPF 4, as the unwanted frequencies produced in these occur at a point of low relative receive level, and are not attenuated by any filter section before they enter the receive amplifier.

For this reason sections LPF 4 and HPF 4 are often made with mica capacitors and air-cored coils, if iron or dust-cores of very high quality are not available. It may be mentioned that filters do not produce odd-order products only, as might have been expected, but also an appreciable amount of even-order products. This phenomena is caused by a "magnetic bias" of cores, set up for instance by the magnetic field of the earth or by DC-currents in adjacent circuits.

Fig. 4 shows harmonics and intermodulation frequencies produced in a 3-channel carrier telephone system, with the simplifications that second and third order products only are considered, and

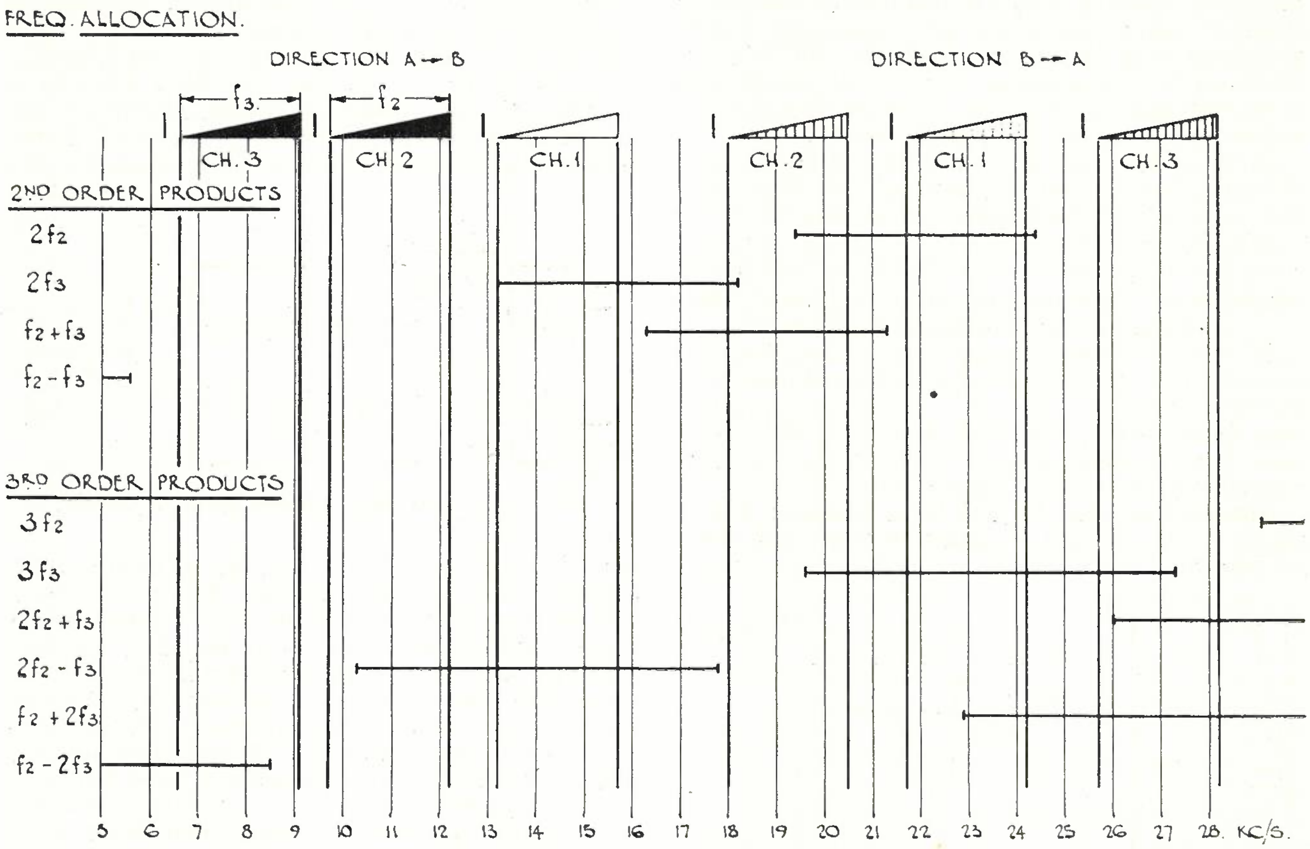

Fig. 4.—Frequency allocation of 3-channel carrier telephone system, type U, and intermodulation products when single frequencies are transmitted on channels 2 and 3 in A-B direction (one single frequency transmitted on each channel.)

that single frequencies, instead of complex speech waves, are transmitted within the frequency bands of channels 2 and 3 in the A to B direction. Similar graphs may be drawn for other combinations of transmission.

Interference due to undesired couplings: The varieties of undesired coupling are many, but in well designed systems the interference caused by such couplings has proved to be of very little significance.

Measurement of Interchannel Interference.

Although such problems as intermodulation in group-modulators, or the variation with frequency of intermodulation have not been discussed, it will be appreciated that the problems of interchannel interference are so many and so different, that the safest way to obtain figures for the amount of interchannel interference in a carrier system, is to measure them on the complete system, under conditions simulating as accurately as possible the conditions under which the system may work.

The method employing human speakers appeals, because the figures obtained express directly the quantities of disturbances obtained under working conditions. The irregularity of speech, however, makes it an inconvenient source of energy for objective transmission measurements. An important step toward objective measurements is, therefore, to find a reproduceable and well-defined source of energy. The usual source, a sine wave oscillator, is not suitable for this purpose. The source to be used must provide a complex wave simulating human speech as closely as possible, with the exception that the output power must be of less irregular nature than speech, so that meters of ordinary types will give a "steady" indication.

As already mentioned a speech wave consists at any given moment of a fundamental and its harmonics. The frequency of the fundamental, and, therefore, also the frequencies of its harmonics, change rapidly, and the entire voice-frequency band may, therefore, have been covered in the course of very short time, that is, in less than a second. A good substitute for speech should, therefore, produce a complex wave consisting of all frequencies in the voice frequency band. In order to simulate "average" speech, each of the frequencies produced by the substitute should appear at the output of the substitute at a level corresponding to the "average" level of the same frequency in human speech or, in other words, the power versus frequency characteristic of the substitute should be identical with the "average power" versus frequency characteristic of speech. This applies under the assumption only that the telephone apparatus used is "linear", that is, that the conversion of acoustical energy to electrical energy is independent of frequency over the voice-frequency band, and that the electrical power output is proportional to the acoustical power input. This assumption is not quite correct for telephone apparatus in general use today, but a considerable improvement in linearity, perhaps at the cost of some of the conversion efficiency, is visualised. For this particular purpose the telephone apparatus will be considered as a linear device, and the source to be substituted for a speaking subscriber should have a power versus frequency characteristic equal to that of speech.

A source of energy which may be easily adapted to satisfy the above requirements is "thermal noise". The power versus frequency characteristic of thermal noise may be flat over a very wide frequency band, and the required power versus frequency characteristic of the substitute may be obtained by the insertion of a suitable weighting network. Thermal noise, however, is of very low power, and it is more convenient to use sources of higher power in order to reduce the amount of amplification required. Experiments show that the voltage between two electrodes of a gas tube, operated from D.C.-supplies, in addition to the DC-component, contains a frequency spectrum of the same type as thermal noise, that is with a flat power versus frequency characteristic, but of much higher power than thermal noise.

Fig. 5 shows a circuit schematic for the gas tube and a block-schematic of a thermal noise generator with weighting arrangement, for convenience referred to as "noise generator" only in the following. To prevent overloading, a 65-20,000 c/s resistance-capacitance band pass filter is inserted in front of the 35 db amplifier, reducing the band of frequencies applied to the input.

Fig. 6 shows the attenuation versus frequency characteristic and the components of a 1500 ohm weighting network. The frequency response of the weighting network corresponds fairly well with a distribution of "average" speech power, taken as a mean for men and women, published by the Bell System (3), and also with the weighting used by the Swiss Telephone Administration in their complex-wave oscillator. The power versus frequency characteristic measured at the output terminals of the noise generator is identical with the attenuation characteristic of the weighting network over the frequency band 100-15,000 c/s, and corresponds consequently to the distribution of "average" speech power.

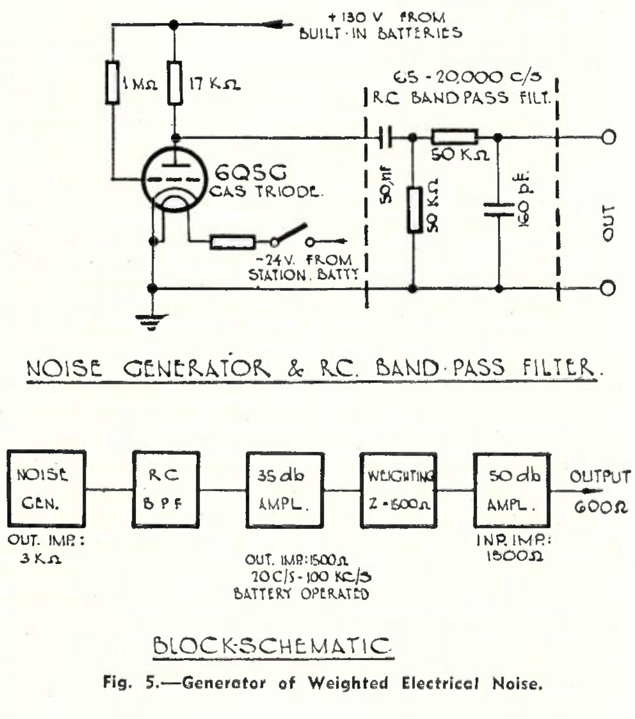

Fig. 5.—Generator of Weighted Electrical Noise.

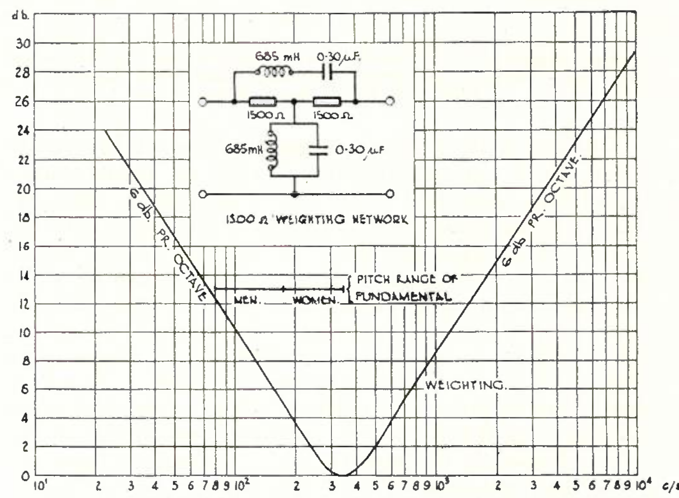

Fig. 6.—1500 Ω Constant Impedance Weighting Network.

The output level of the noise generator is adjustable by means of a gain control in front of the second amplifier, and is, unless otherwise stated, quoted in terms of its RMS value. The RMS value may be found by means of a suitable thermocouple meter, but it is interesting to note that it may also be found by adding 0.5 db to the reading on a linear rectifier meter such as the Australian Post Office transmission measuring set, or by adding 5 db to the reading on a Western Electric type 2 B noise test set with F.I.A. line weighting. If measured with a psophometer in accordance with the C.C.I.F. 1949 recommendations, it is estimated that a figure of 4-5 db should be added.

The "normal" distribution of peaks of thermal noise with time, together with the distribution of speech peaks for 1, 4, 16 and 64 speakers is shown in Fig. 7 (reproduced from Bell Laboratories Record, November, 1939) (4). It will be seen that the ratio in decibels of observed to RMS voltage for thermal noise is practically identical with the curve for 64 speakers. The similarity between the noise curve and the speaker curves becomes less pronounced as the number of speakers decrease, but even so there is a considerable similarity between the distribution of noise peaks and the peaks for one speaker. The thermal noise is seen to be less "peaky" than voice voltage from one speaker, or in other words the noise voltage is more regular.

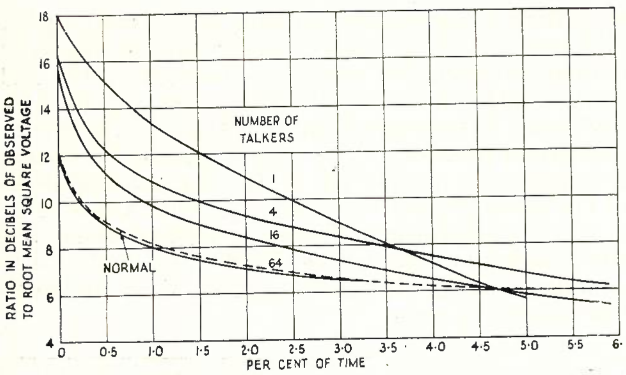

Fig. 7.—Voltage distribution of the voice currents from a group of talkers approaches a normal distribution more closely as the number of talkers increase. (Extracted from Bell Laboratories Record, Nov., 1939, Vol. XVIII, No. 3, page 82.)

In line with a fairly general trend, it is considered that the permissible levels of interference should be specified in terms of its peaks. Employing a noise generator as an interfering source instead of speakers, the noise voltage should consequently be adjusted so that its peaks are of same magnitude as the peaks of speech voltage. To simulate those of the peaks occurring 1% of the time, it is necessary, see Fig. 7, to employ an RMS noise level 5 db above the speech level, in which case both the ratio in db of observed noise voltage to RMS speech voltage, and ratio of observed speech voltage to RMS speech voltage exceed 13.5 db over 1% of the time.

Existing specifications for carrier equipment specify that the speech levels used for interference tests shall be 4 db below Reference Telephone Power (R.T.P.) at a point of zero relative line-up level. R.T.P. has been found by Holbrook and Dixon (5) to correspond to an R.M.S. speech level of very nearly + 2 dbm, and the R.M.S. speech level for interference tests is, therefore, –2 dbm. The R.M.S. noise level to be used for interference tests should consequently be + 3 dbm at a point of zero relative line-up level.

The interference appearing at the voice frequency terminals of any channel should be, and is in most cases, unintelligible. It is, therefore, justifiable to measure the interference level with a psophometer, in accordance with the latest C.C.I.F. 1949 recommendations. Measurements of interchannel interference in the past have usually been made with psophometers or other types of noise measuring set, and the above proposal is, therefore, in principle not new.

General Conditions of Tests.

In some cases in the past, when tests on carrier equipment have been performed in a laboratory, it has been the practice to use an attenuator as "artificial" carrier line, and by-pass the line-equalisers. It is pointed out that this may lead to erroneous results because the attenuator has a flat frequency response against the sloping response of a line; the gain in the receive path of the terminal will, therefore, differ in the two cases and so will the near-end interference. It is, therefore, most desirable that an artificial line, with characteristics resembling as far as possible an "ideal" physical line, be used for interference tests in a laboratory. The artificial line should preferably be screened, and the intermodulation frequencies produced in it should be of negligible magnitude.

In all cases the equipment should be lined up to the prescribed levels and if 2/4 wire terminating sets are associated with the equipment, the hybrids should be balanced by terminating all hybrid nets and hydrid lines in 600 ohms.

In order to obtain true interference figures, the basic noise level at the voice frequency terminals of the equipment should be reduced to a level considerably below the interference level. In case of laboratory tests it has been found not difficult to obtain basic noise levels as low as – 85 to – 90 psophometric dbm, provided battery supplies are filtered suitably. For equipment working on actual lines, it may be difficult to reduce the basic noise sufficiently to measure interchannel interference levels directly, but it is often possible to "guess" the interchannel interference levels fairly accurately by comparing the basic noise level and the level of basic noise plus interference.

Performance Requirements for 3 Channel Systems.

On the basis of existing specification figures for noise, crosstalk and interference together with the results of tests performed, it is considered that systems operating on a line free from interference and without repeaters should meet the following performance requirements:—

(i) The "basic noise" at any voice frequency testjack, that is the noise when no channels are active, should not exceed –65 psophometric db at a point of zero relative line-up level, provided that the noise content of the power supplies does not exceed the specified limits.

(ii) With a noise generator, of 600 ohms output impedance and furnishing an R.M.S. level across a 600 ohms load 3 db above the appropriate nominal line-up level, connected to the transmit terminals of any one channel, the near and far-end crosstalk in any other channel, together with the basic noise, should not exceed – 58 psophometric db at a point of zero relative line-up level. Where crosstalk exists, speech tests should be performed, and all crosstalk should be found to be unintelligible under all conditions of test.

(iii) With two noise generators connected as above to any two channels, the interference in the third channel, together with the basic noise, should not exceed – 58 psophometric db at a point of zero relative line-up level.

In support of the testing method described, it is worth mentioning that the interference figures obtained have been reproduced after an interval of weeks by independent tests. Most of the figures obtained during second tests were within 1 db of the original test figures, and in no case has a difference greater than 2 db been observed.

For comparison purposes corresponding interference figures were measured, using speakers as interfering sources. The differences between corresponding figures obtained in successive speech tests were frequently in the order of 10 db, and as much as 20 db has been experienced.

The difference between figures obtained from tests using speech and from tests using noise generators is usually less than 5 db, which is as good as may be expected, considering the difference between figures obtained in successive speech tests.

Testing of Systems with a Large Number of Channels.

For a system with N channels it may be seen that the number of possible interchannel near and far-end crosstalk measurements is 4.N.(N–1).

The number of possible near and far-end interference tests, assuming n channels are activated all in one or the other of the two possible directions is 4. [N!/(N–n)! n !]. (N–n).

Table 1 shows for some typical numbers of channels the number of crosstalk and interference measurements possible in accordance with these formulae, and the estimated working time required for two persons to carry out the tests and record the results, using noise generators as interfering sources, and having at their disposal multiway switches by means of which the noise generators may be switched to any of the channels of one terminal. The time quoted does not include any preparatory work or trouble shooting, and is based on the time taken to perform measurements on a 12 channel open wire system under laboratory conditions.

Number of Channels	3	6	9	12	17	24	34
Number of basic noise readings	6	12	18	24	34	48	68
Crosstalk—Number of readings .... Working man-hours	24 —	120 —	288 —	528 —	1,088 3	2,208 6	4,488 13
Interference, two channels activated —Number of readings .... —Working man-hours	12 —	240 —	1,008 3	2,640 7	8,160 20	24,288 65	71,808 190
Interference, three channels activated —Number of readings .... —Working man-hours	0 —	240 —	2,016 5	7,920 20	38,080 100	170,016 425	742,016 1,900

Number of channels — N.
Number of basic noise readings — 2N
Number of crosstalk readings — 4N (N–1)
Number of interference readings –4[N! /(N–n)!n!] (N–n) where
Number of channels activated – n

Table 1.—Number of Readings and Estimated Testing Time for Noise, Crosstalk and Interference.

It will be seen from the table that it is quite practicable to test all crosstalk possibilities for any type of system installed so far in Australia. Full interference tests with two or three channels activated are also possible for systems with up to 12 channels, which is the greatest number of channels in use on open wire systems.

Some cable systems, however, have more than 12 channels, but as the two directions normally are carried by two separate cables, and the equipment is normally identical for the two directions, it appears feasible to reduce the interference measurements to cover all possibilities of far-end interference in one direction only, thus reducing the number of interference measurements by a factor 4. In the opposite direction a limited number of tests should be made for comparison purposes. By such a reduction of the number of interference readings, it appears quite feasible to test the interference on, for example, a 34 channel system by using only two activated channels.

If a particular type of equipment has previously been tested fully, the tests on subsequent deliveries may be limited to cover only a certain number of representative tests for comparison with the results of the type test. If time or other circumstances prohibits full testing of a new type of equipment, tests may be performed by selecting certain combinations of active channels to give expected maximum interference into other channels. The channels to be selected depend on the frequency allocation and design of the equipment, and must, therefore, be selected for each type of system. Useful information for such selections is given in some of the articles mentioned under references.

Economic and Practical Advantages of Noise Generator Testing.

Reference to Table 1 reveals that the average time taken for one reading is about 11 seconds. It is thought that the introduction of automatic or semi-automatic switching of noise generators between channels, effected for instance by uniselectors, and the recording of interference levels exceeding a certain maximum limit only would reduce the testing time required to about one-fifth or less of the times quoted in Table 1. Even without such refinements, the testing man-hours using noise generators as interfering sources is thought to be considerably less than one tenth of the man-hours required for the same number of speech tests.

The speed with which noise generator testing is performed makes it practical to test systems with a much greater number of channels than possible with speech testing. The results of noise generator testing may be reproduced with great accuracy anywhere in the world, and the conditions of tests can be easily defined. The results of noise generator testing agree with the average results of speech testing.

Conclusion.

It has been assumed throughout the article that the channels are carrying speech when the system is in service. If a channel is not carrying speech, but used, for instance, for an 18 or 24 channel voice frequency telegraph system, 2 V.F. signalling or 1,000/20 c/s signalling, conditions will be different. It may be anticipated, however, that equipment showing the best performance when tested with noise generators or speech will also give the least interchannel interference when used for V.F. telegraph or signalling. It should be noted that it is desirable from an interference point of view that V.F. telegraph and signalling levels should be as low as possible, and a separate investigation of interference when one or more channels are used for such purposes is desirable.

The first noise generator tests as described above were performed in November, 1950, and since then the method has been used with very great advantage for comparative measurements. Such tests have also proved extremely useful for the detection of equipment faults causing crosstalk and/or interference.

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POSTAL ELECTRICAL SOCIETY OF VICTORIA

Annual Report, 1951-52.

During the 1951-52 year the customary lecture programme was arranged, and members were able to hear talks by Mr. F. Kempson, of the Melbourne Technical College Radio School, Messrs. W. R. Treloar, K. W. Macdonald and J. S. MacGregor. In addition, on 2/7/51, a team of five speakers gave short talks on five subjects of general interest.

We continue to be indebted to the authorities of the Radio School, Melbourne Technical College, for the use of the Radio Theatre for these talks, as well as for help in the preparation of film strips and services of a projectionist.

The response to previous appeals for articles has enabled the Board of Editors to partially overtake the lag in publication of the Journal. Further assistance by any member with the submission of additional articles, to one of the Sub-Editors or Editors would be appreciated.

The circulation of the Journal, while not quite as high as in previous years, continues at some 2400 copies. Overseas subscribers in the United Kingdom, New Zealand, South Africa, Malaya, Cyprus, Pakistan, India, United States, France, the Netherlands, Denmark, Sweden, Finland, Poland, Switzerland, Lebanon and Egypt, are now receiving the Journal.

Notwithstanding Departmental subsidies during recent years the continually rising costs of publication of the Journal have necessitated action to increase the subscription. It is now contemplated that the annual subscription should be 10/-.

The Committee expresses its thanks to the authors of articles, members of the Drafting Staff, who have freely given a good deal of time and effort in preparing diagrams and illustrations for the Journal, and to those members who have assisted in the collection of subscriptions and distribution of Journals during the past year.

TELEPHONE EQUIPMENT CIRCUIT DRAWING PRACTICE

K. J. H. Hall

Introduction

The basic principles adopted for the preparation of schematic and routed schematic circuit diagrams for 2000 type equipment in the Postmaster-General's Department drawing offices is taken from the established practices observed by all English and Australian manufacturers supplying telephone equipment to the Australian Post Office. This practice is comparatively new to the Department, and the aim of this article is to illustrate the main principles of the methods used, including the following aspects:—

(a) Procedure.
(b) General rules.
(c) Detailed wiring rules.
(d) Circuit drafting.

While dealing specifically with circuit diagrams for telephone equipment purposes, the methods outlined are also applicable to other types of equipment, such as telegraph, long line equipment, etc.

Before dealing with the above aspects it may be well to define what is meant by the terms "Schematic Diagrams" and "Routed Schematic Diagrams".

Schematic Diagrams: A diagram which is prepared primarily to illustrate the operation of a circuit is known as a schematic diagram. Before the advent of, and many years after, the introduction of automatic switching, it was considered necessary, when preparing circuit diagrams, to draw the contacts of each relay alongside the symbol for the relay coil. However, as the circuits grew in complexity, it became increasingly difficult to readily understand the operation or follow out a particular function of the circuit. A system was therefore evolved of coding the relays and contacts so that the coils and contacts could be dissociated and placed at convenient points on the diagram. Such diagrams are known as "detached contact" diagrams to distinguish from the earlier "attached contact system". This method of layout not only shows the separated functions, but results in considerable simplification of the diagrams. This will be readily apparent if schematic circuit diagrams are compared with similar circuits drawn according to the older method, in

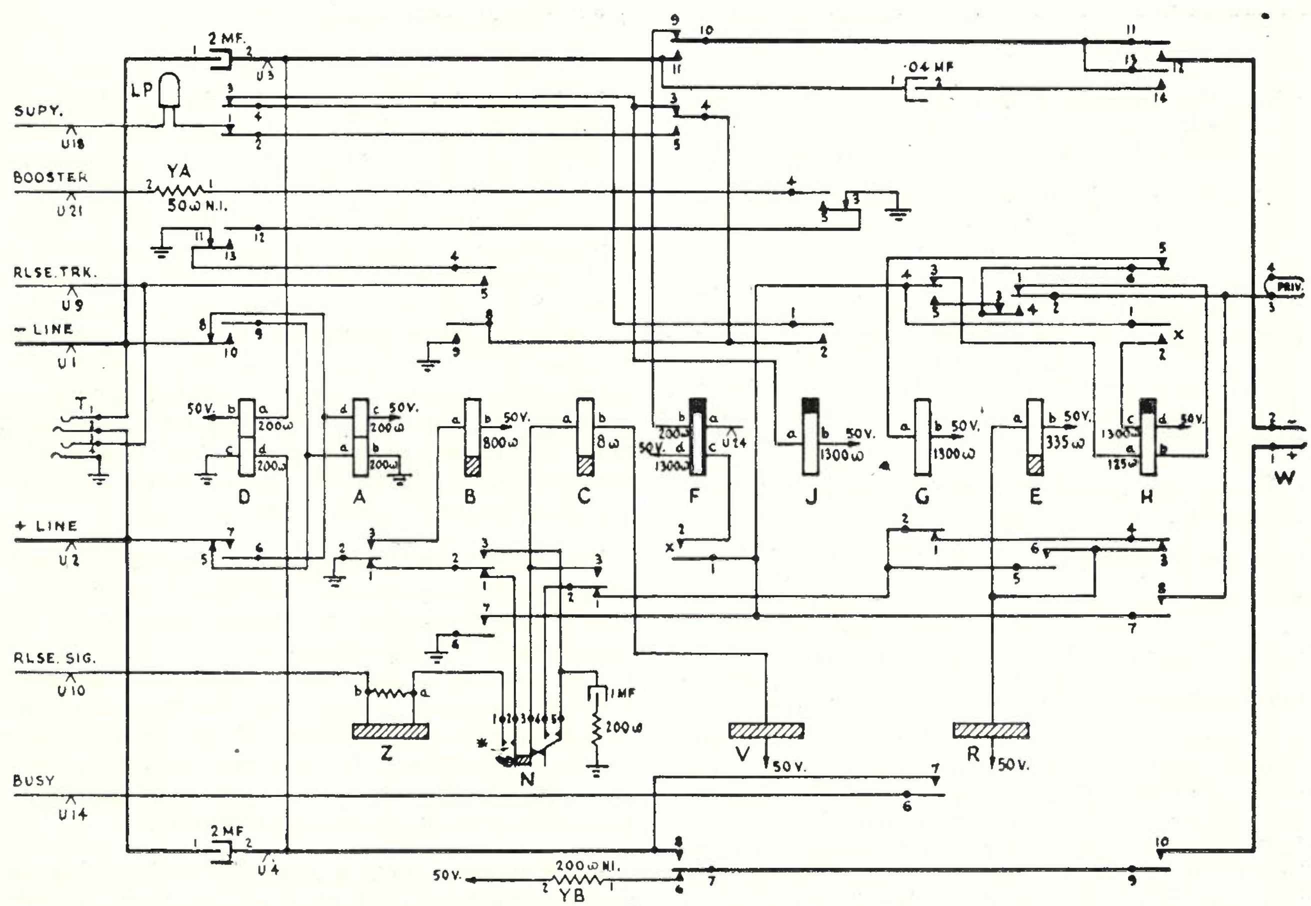


Fig. 1.—Final Selector Circuit drawn with the "attached contact" method.

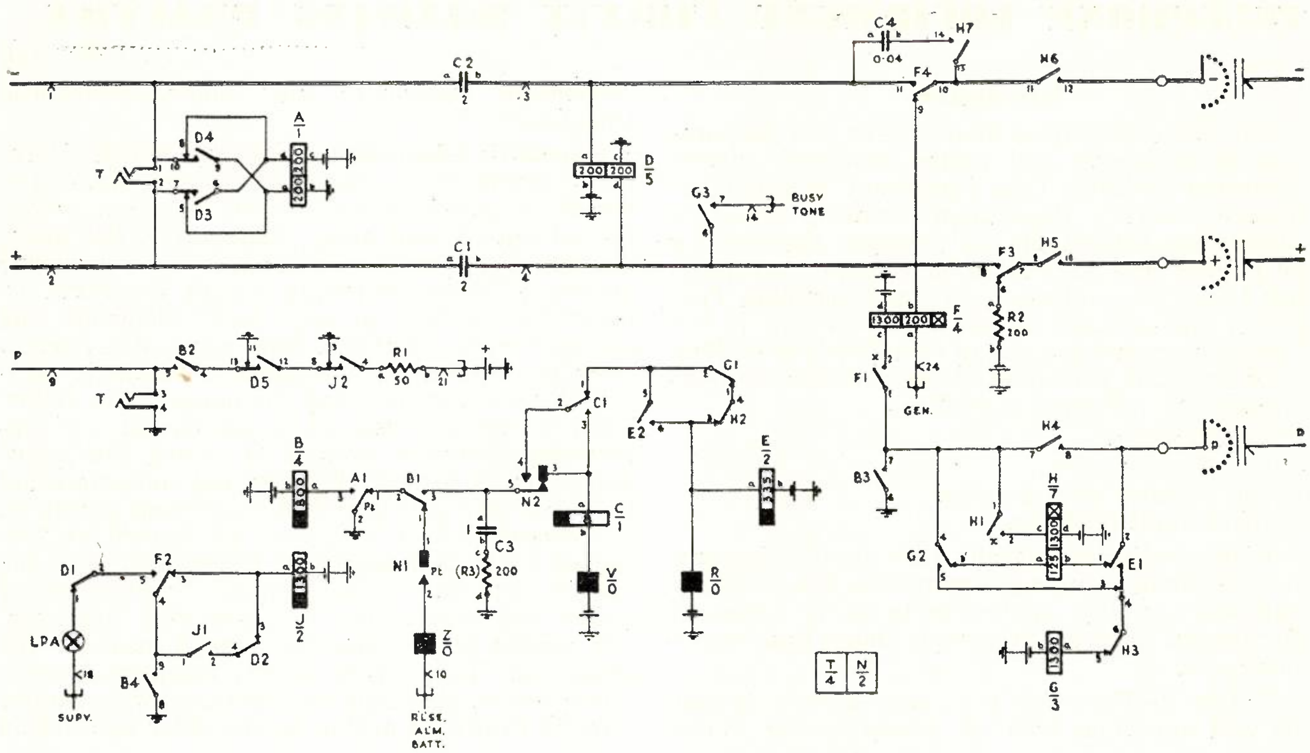


Fig. 2.—Final selector circuit drawn with the "detached contact" method.

which the contacts of each relay are directly associated with the relay, thereby necessitating many crossed lines and a complicated drawing.

Fig. 1 shows an "attached contact" diagram of an earlier type of final selector employing horizontal type relays, and Fig. 2 is the same circuit drawn with the "detached contact" system. Fig. 3 is included to show a compromise or later version of the "attached contact system". It is interesting to compare Fig. 2 with Fig. 4, which is the A.P.O. standard 200 line, final selector, ordinary. This circuit is drawn on sectional paper which will be explained later.

Under the detached contact system a relay is designated by a combination of a letter and a figure, for example, $\frac{A}{3}$, or $\frac{B}{4}$. The letter indicates the relay and the figure shows the number of contact units. Where a relay coil is used as a retard without contacts, it is designated by a code letter and the figure 0 below the line, e.g., $\frac{R}{0}$. As stated above, relay contacts, which are shown in their unoperated position, may be placed at any convenient point on the diagram, that is, detached from the relay coil, and are indicated by the relay code letter followed by the contact unit number (that is, A1, or A3). A relay having more than one winding should not be shown with the windings separated.

If desired, keys may also be shown with their contacts "detached". In such cases, each contact unit is designated by the letter code, commencing with the letter K, which may also be followed by the contact unit number (that is, KS1 or KS3). Furthermore, where the springsets are detached on the diagram an inset is shown as in Fig. 6, the denominator of the designation being the number of springset units. For single throw keys the first portion of the inset only is shown and the plus sign omitted. Mechanically operated springsets, such as Off Normal, 11th Step, etc., associated with bimotional switches, are also shown with their contacts "detached" and an inset shown on the diagram as in Figs. 2 and 4.

Routed Schematic Diagrams: Routed schematic diagrams are schematic diagrams prepared as above with information added to indicate the route taken by any connection wire. The theoretical or schematic diagram is reasonably satisfactory as a means of depicting the general circuit arrangements and the method of operation of a piece of equipment. It does not, however, serve as a wiring diagram and is not very useful for the tracing and rectification of faults.

Until recent years a separate wiring diagram was provided for each piece of apparatus in addition to the theoretical or schematic drawing.

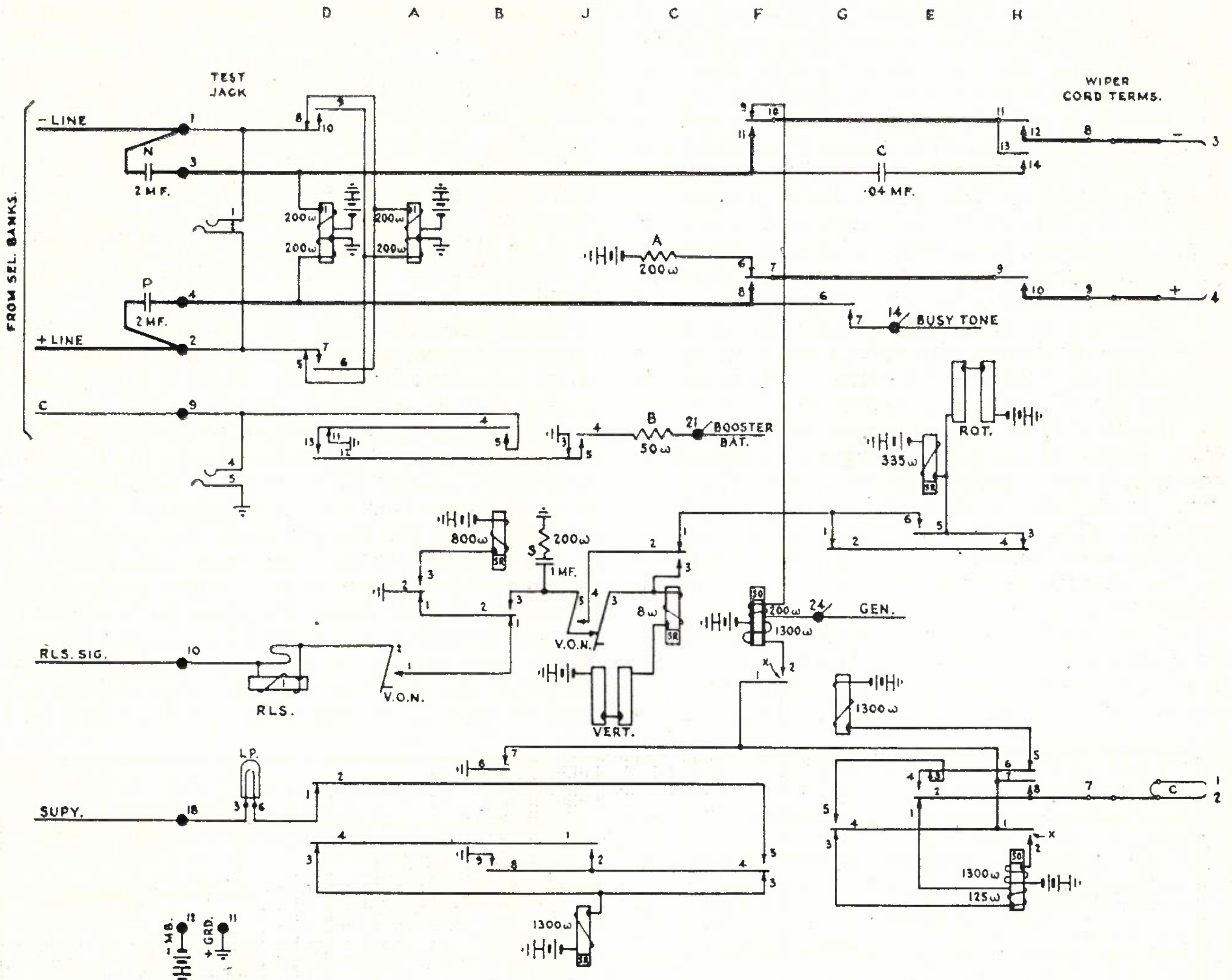


Fig. 3.—Final Selector Circuit drawn with the "attached contact" method (alternative to Fig. 1.)

These wiring diagrams, in general, followed the normal practice of producing a rear view of the equipment and showing the actual route of the wires between the components. Such diagrams were reasonably satisfactory for the less complicated circuits, but owing to the ever increasing complexity of automatic switching, become too complicated to follow. Generally, pictorial wiring diagrams are now superseded by routed schematic diagrams which retain the simplicity of the schematic diagram, but, in addition, include all necessary wiring information.

The conventions and principles governing the wiring information supplied for the routed schematic diagrams are as follows:—

(a) All apparatus connection tags are numbered or lettered and all spare tags, relay and key contacts, etc., are shown on the diagram.

(b) Where a wire merely links together two connection tags, the simple line of the ordinary schematic diagram fully describes the run of the wire and no additional information is necessary.

(c) When a wire connects together three points it must be "looped" in and out of one of the points. The looping point is indicated on the diagram by the letter "L" drawn across the "wire line" as near possible to the connection concerned, see Figs. 4, 5 and 6 for typical routed schematic diagrams.

(d) When a wire connects together four or more points, the route is described by placing at a convenient point on the wire a legend, in the form of a group of code letters, etc. This indicates, in sequence, the route taken by the particular connection, see Figs. 4, 5 and 6 for typical routed schematic diagrams.

(e) When a "common" such as earth or battery is not shown as a connecting line on the schematic diagram, the routing is indicated by a separate group of tag designations placed at any convenient point on the diagram, see Figs. 4, 5 and 6 for examples.

It should be noted that schematic diagrams show the apparatus in the unoperated position, unless specifically stated otherwise.

Procedure

From the standard telephone equipment drawings issued by the Department, each manufacturer prepares, for production purposes, wiring diagrams in a routed schematic form to suit his own factory methods. The standard symbols and wiring rules governing the preparation of these diagrams are taken from the established practices observed by all telephone equipment manufacturers supplying equipment to the Department. The Departmental practice of issuing standard drawings as routed schematic diagrams obviates the necessity of providing a pictorial or some other type of wiring diagram in addition to the theoretical or schematic diagram. However, in the absence of a physical layout or pictorial wiring diagram, it is Departmental practice to include, on routed schematic diagrams, a legend, in the form of a component layout, as seen from the rear, of the base or plate. See Figs. 5 and 6 for examples. This legend provides a ready key to the component layout and also serves as a guide for the draftsman when preparing the routing information.

The issuing of standard telephone equipment drawings as above tends towards uniformity in all units purchased to the particular diagram, irrespective of place of manufacture. Also, installation and maintenance problems are not complicated unnecessarily. Furthermore, the tracing and rectification of wiring faults are satisfactorily carried out with the aid of these diagrams. It will be seen that the routing information is governed by the layout of the components on the plate and/or condenser box, that is their position must be determined beforehand. Therefore, for all proposals or tentative drawings, or where there is to be (for special purposes) a wiring diagram, a theoretical or schematic diagram only is prepared.

There are two types of mountings for 2000 type equipment, namely, jacked-in equipment and strip mounted equipment. Figs. 5 and 6 show typical routed schematic diagrams for jacked-in and strip mounted equipment respectively. There are drawings for the standard bases for jacked-in equipment, known as 2000 type, including relay sets (drawing C.E.160) and selectors (drawing C.E.227), and for the guide to the arrangement of the components on these bases (drawing C.E. 235). However, there is no similar guide to the allocation of jack points for circuits in excess of one per base, but the practice generally adopted is for each circuit to grow outwards from the centre of the jack, for example, the negative and positive line of an incoming circuit would be 1

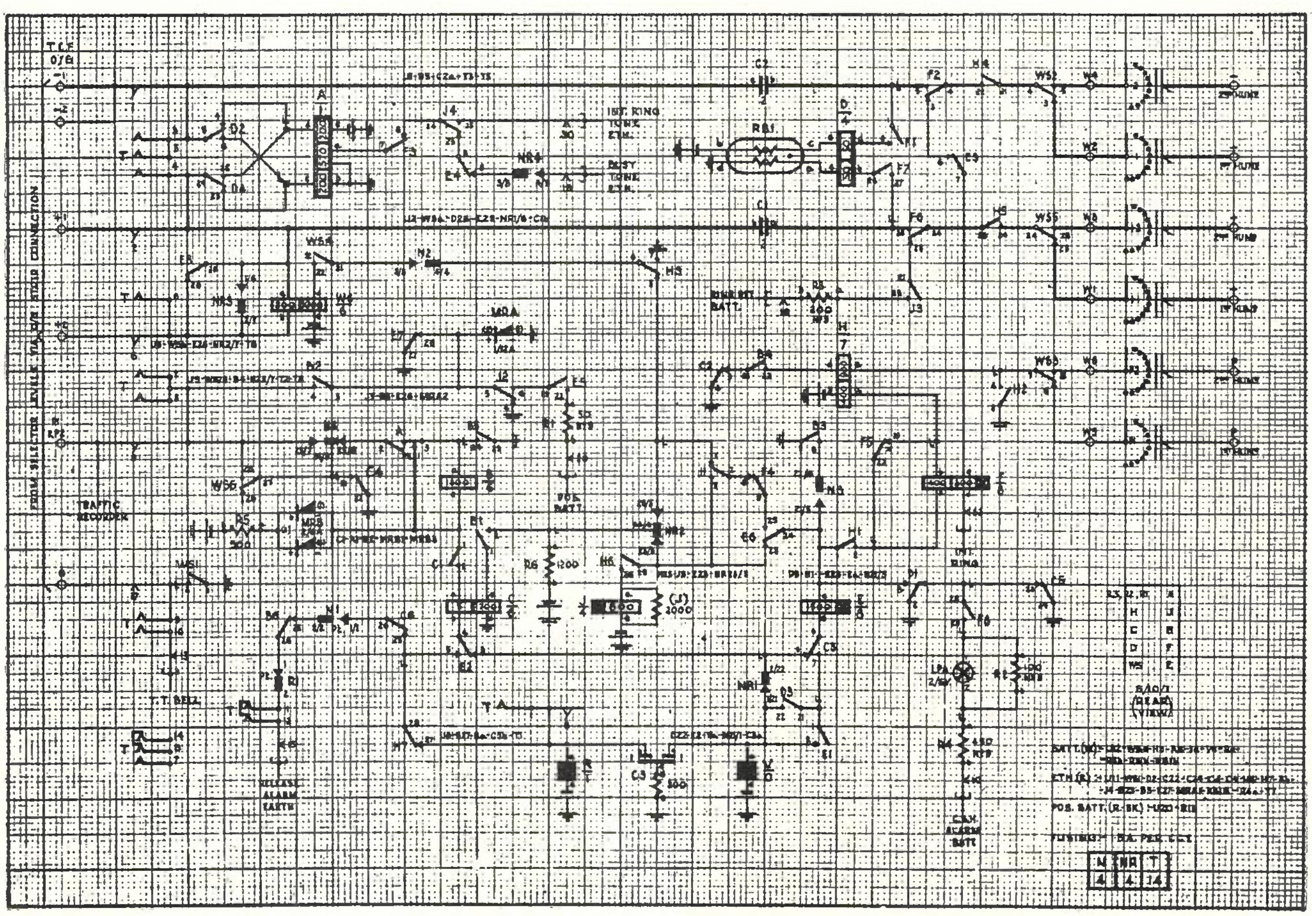


Fig. 4.—Final Selector, 200 line, ordinary, drawn on 1/12" divisions, sectional paper to illustrate its use as a dimensional facility.

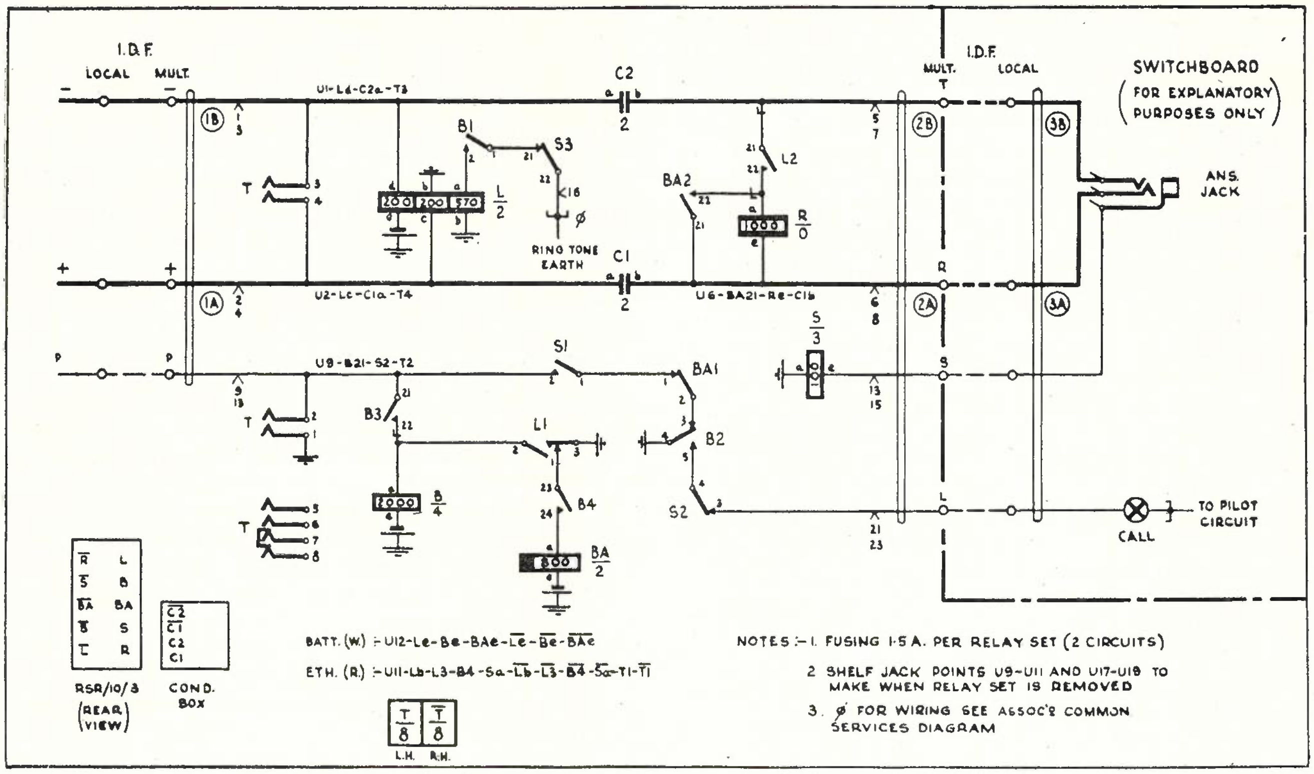


Fig. 5.—Typical routed schematic diagram for Jacked-in Equipment (2000 type).

and 3 and 2 and 4 for the 1st and 2nd circuits respectively. See Fig. 5 for typical example.

In addition, although drawings are available for the mountings for 2000 type equipment which are to be strip mounted and not jacked-in (drawing C.E.122), there are no instructions covering the arrangement of the components on these strips, but the main points to be watched are economy in wiring and placement to avoid interference and interaction between them. Drawings for the standard general purpose relays, known as 600 type and 3000 type (drawings C.E.110 and C.E.129 respectively), include the types of coils and springset assemblies. The 600 type is restricted in its use owing to electrical and springset limitations. It should be noted that the 600 and 3000 type relays are provided with insulated mountings to minimise electrolytic corrosion of the winding wire, which might otherwise occur, due to small leakage currents between the core and the winding.

Generally, the routed schematic method of preparing circuit diagrams is used to cover existing and future designs of 2000 type equipment, but by suitable modification it can be applied to the various types of obsolescent mountings still in service and which are frequently installed to augment existing equipment.

In many cases standardisation entails the use of keys, relays, etc., in circuit designs with spring units in excess of those actually required. In these cases the spare units appear on the routed schematic diagrams as part of the circuit. This is necessary for maintenance purposes. As a matter of interest, the general and detailed wiring rules summarising current practice are set out hereunder.

General Rules

The following general rules apply to the preparation of telephone equipment diagrams:

Symbols: Only standard symbols of correct size and terminology shall be used for circuit diagrams. Full details are contained in the Department's Drafting Engineering Instructions.

Notes: All notes shall be numbered and grouped together. They shall be so placed that room is left for additions. Fusing particulars shall be included in the notes and the letter "A" shall be used as the abbreviation for amperes, for example, "Fusing 1.5A. per circuit."

Lettering: All designations and lettering shall be drawn to be right way up when viewing the main body of the drawing except for vertical lines which will read correctly when the drawing is turned clockwise through 90°.

Character sizes: All designations, contact letters and unit numbers shall be formed of $\frac{1}{8}''$ characters. Point-to-point wiring, spring numbers, notes, etc., shall be formed of 3/32″ characters. The characters used in the title plate for the drawing shall conform to the current instructions for these items (Drafting Engineering Instructions, Standard Drawing Practice LO100).

Lines representing connections: All connections shall be represented by continuous lines and the use of an arrow head with a cross reference to another part of the circuit shall be avoided where possible. Such cross reference shall not be used on diagrams covering jacked-in equipment.

Detailed Wiring Rules

The following detailed wiring rules cover the established practices observed by all telephone equipment manufacturers supplying equipment to the Australian Post Office.

Jacked-in Apparatus: The order of wiring components shall follow the priority list below. Routing information shall be given in the correct order, that is, in ascending order of alphabetical sequence (a, b, c, etc.) when the plate is viewed from the rear. In the case of selectors the following applies:

a. "U" points lower or upper.
b. Bottom L.H. relay.
c. Up and round plate (clockwise) to bottom R.H. relay.
d. Vertical magnet coil (VM)
e. Vertical magnet springs (V).
f. NR springs (normal rotary).
g. N springs (off normal).
h. S springs (11th step).
j. NPA } springs (normal post).
k. NPB }
l. Rotary magnet springs (R).
m. Rotary magnet coil (RM).
n. Wiper cord block.
p. Lower rear cover or condenser box.
q. Upper rear cover or condenser box.
r. Spark quench condenser in rear clip.
s. Test jack.
t. Lamp.

For relay sets the order of wiring is:

a. "U" points upper plug to top R.H. relay.
b. "U" points lower plug to bottom L.H. relay.
c. Top R.H. or bottom L.H. relay round plate (clockwise) to top L.H. or bottom R.H. relay respectively.
d. Lower rear cover or condenser box.
e. Upper rear cover or condenser box.
f. Condenser in rear clip.
g. Test jack other than that for uniselector mounted on base.
h. Lamp.

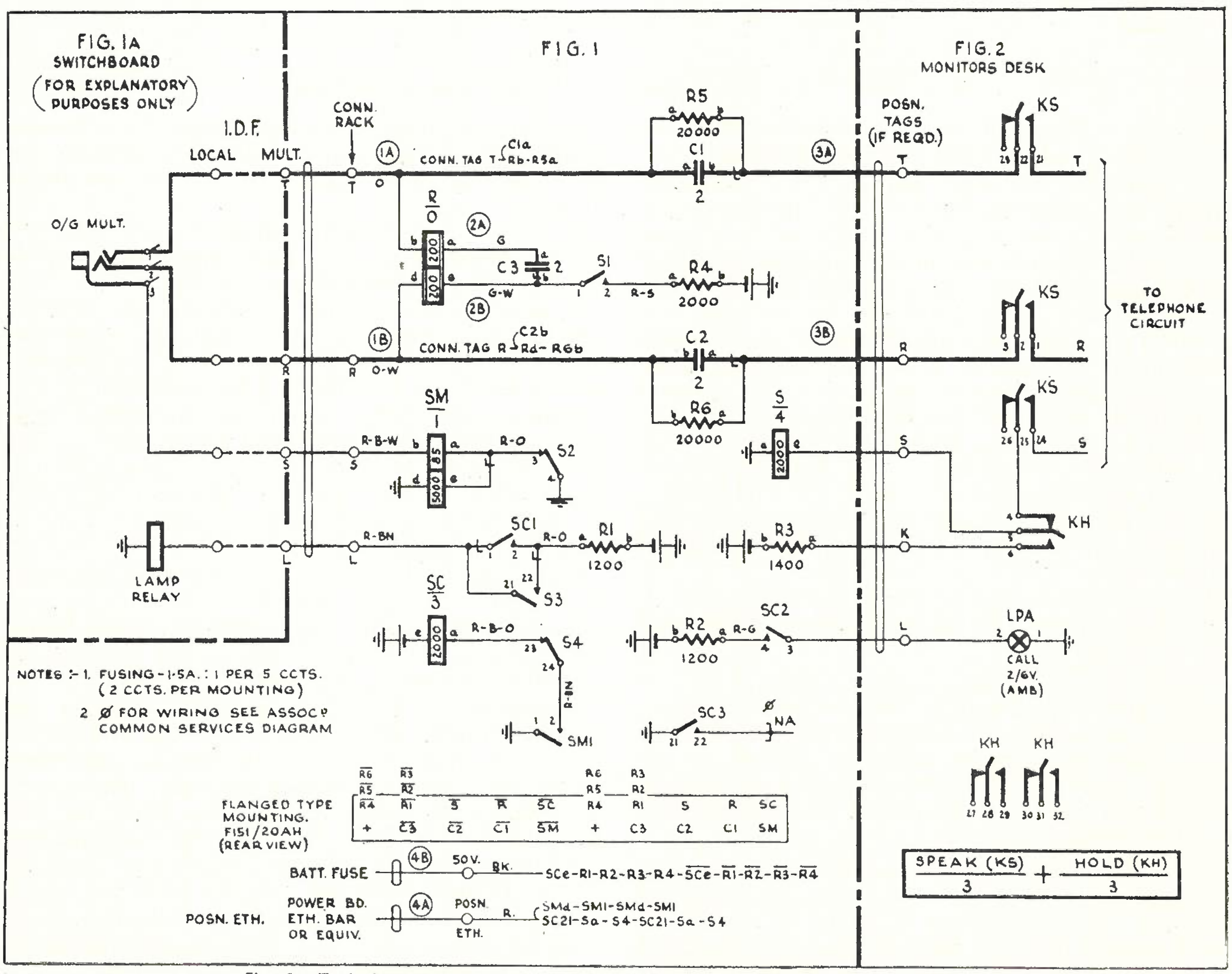


Fig. 6.—Typical routed schematic diagram for Strip Mounted Equipment (2000 type).

All jack points which make contact when the selector or relay set is removed shall be indicated on the diagram and also on the associated shelf jack wiring if prepared.

Strip Mounted Apparatus: The routing of wires shall follow the shortest possible routes as determined by the covering specifications or equipment drawings.

Wires—All Mountings

The main requirements for wires are:

Type: The type of wire to be used shall be that indicated in the covering specification.

Colours: The colours of wires shall be indicated where necessary and the standard abbreviations shall be used.

Commons: Battery and earth commons shall be wired with conductors to the following colours:

Negative battery—White.
Positive battery—Blue.
Earth—Red.

Pairs: Twisted pairs shall always be indicated on diagrams. The colours used shall continue throughout the run of a pair notwithstanding that it may loop in on components or contain series resistors, capacitors, relays, etc.

Rack Common Service Diagrams: The wiring of common service leads is not shown on routed schematic diagrams, but is to be covered by a separate drawing. These leads are indicated by the use of the symbol "ϕ" against the lead concerned, and is covered by a note which reads "for wiring see ....."

Looping of Wires: As far as possible, wires should not be looped on tags on the following components:

a. "U" points.
b. Test jacks (other than those on uniselectors)
c. Apparatus in a condenser box.
d. Wiper cord block.

The priority shown is indicative of the relative importance of single wire connections and, therefore, if looping must be done on these items, choose tags of the lower order. For example, it is preferable to loop on apparatus in a condenser box than on a "U" point. When a large selector or relay set base requires a large number of outlets two shelf jacks are necessary, and very often wires connect between the two jacks with lateral connections to apparatus on the bases. To avoid looping on jack points these wires should be routed via the intermediate equipment. When looping may be done either on a resistor or a capacitor, it is preferable to arrange it on the capacitor tags.

Wiring of Relays: Where wiring interconnects contact units or contacts and coil tags of an individual relay the following order shall be followed:

a. Springs 21 to 29 (R.H. side when viewed from the front).
b. Coil tags a to e.
c. Springs 1 to 9 (L.H. side when viewed from the front).

Wiring of Resistors: The "a" tag of fixed resistors shall be wired to the earth side of the circuit and this tag will be the one nearest the mounting plate. Where several resistors are mounted on a post they will normally be coded away from the base, i.e., R1, R2, R3, etc. An exception occurs when they are of mixed types with fibre and ceramic spools, in which case the ceramic will be nearest the base.

Modern circuitry demands the use of smaller components and, providing the current carrying capacities are satisfactory, it is customary to specify the radio type of resistor for certain equipment. However, indiscriminate use of this type of resistor can cause complexities in wiring and mounting, therefore they must not be specified unless they can be fitted across relay coil and spring tags or condenser terminals within the limits of their pigtail ends. When circumstances permit they can be grouped on resistor strips and mounted in relay mountings or condenser boxes.

Wiring of Uniselectors: When the uniselector is intermediate or finishes the point-to-point wiring, the sequence is USt - US contacts 25 to 1 - US wipers - USdm - dm, and vice versa when it is a starting point. When uniselector bank wiring is included in wiring runs, only the points where the plate wiring reaches or leaves the bank are quoted. The connections shown on the schematic diagram need not indicate the physical connections. Where wiring runs are not necessary the physical connections to uniselector arcs must be indicated on the diagram.

Circuit Drafting.

The present state of the telephone art is such that telephone design is becoming increasingly complex to meet the requirements of the modern telephone systems. The inherent reliability of the components, particularly the relays, enables the more complicated circuits to function reliably and to provide a greater range of facilities than could be offered by earlier types of components. Consequently, the difficulties encountered on the part of the maintenance and installation staffs in interpreting the circuits concerned, have increased to a degree where the maximum assistance must be given by the draftsman in the initial laying out of the diagram in as simple and readable manner as possible. It is essential, therefore, that the circuit draftsman must fully understand the function of the entire circuit and arrange his layout in a simple and logical manner.

However, before the draftsman can become efficient in the art of preparing schematic and routed schematic circuit diagrams he must acquire a thorough grounding in telephony. This will be realised when consideration is given to what is actually involved when, for instance, the draftsman is required to prepare circuit diagrams for some new design of major proportions. The usual practice is for the engineer responsible for the design or otherwise of the circuits concerned, to provide rough sketches and instructions for his guidance. Also, in many cases, reference only is made to parts of existing circuits to be embodied into the new scheme. It is the draftsman's task to gather all this information in order to piece the circuits together. After satisfying himself that he has a general outline of the scheme and understands the operation of the circuits, he must then proceed to set out the diagram in order to show a clear picture of the general arrangement and, at the same time, must pay particular attention to the separation of the circuit functions. The isolation of the functions is most important, not only for the general arrangement and understanding of the circuit, but a circuit is more often examined to ascertain how some particular function is performed than to cover details of the whole circuit.

If jacked-in relay sets are to be prepared, and the number of relays in the circuit design exceeds the mounting points on the bases available, it may be necessary to divide the circuit into two or more relay sets. If such is the case, care must be taken to arrange the layout of the diagram to show the relay sets without unduly upsetting the general arrangement and functional sense of the circuit. Also, the relays and other components selected for each base should, within limits, be those that will have the least number of interconnecting wires between the relay sets. Furthermore, it may be necessary to divide the circuit into various figures depicting jacked-in, strip mounted or existing equipment for explanatory purposes. It may also be necessary to show modifications to existing equipment which is required to work in conjunction with the new scheme.

When the stage is reached to add the routing information to the diagram, the next consideration is the layout of the components on the mounting plates. This requires care to avoid interaction and interference between components, especially when two or more circuits are to appear on the same mounting plate. Components, such as resistors and electron tubes which dissipate heat should be mounted at the top of the plate. Due regard must be paid to economy in wiring and mounting space.

If rack layouts are involved, economy in wiring and cabling must be considered also. Circuits with most incoming and outgoing wires should be situated at the top of the rack to conserve cabling, but consideration must be given to accessibility for maintenance. Generally, such factors will be considered by the engineer, but the draftsman should be fully acquainted with these aspects to save too frequent consultations. The foregoing considerations cover briefly some of the functions of the circuit draftsman in the preparation of telephone equipment schematic and routed schematic diagrams.

In order to assist those required to prepare telephone equipment diagrams the following principles to be observed and the procedure necessary for the initial setting out of circuit diagrams may be found useful.

(a) Use sectional paper, 1/12″ divisions, as a dimensional facility in the setting out of the diagram (see below under "Use of Sectional Paper").

(b) Before an attempt is made to set the diagram out the operation of the circuit should be understood. This enables the draftsman to separate the functions and orient the components so that the sense of the circuit follows a definite sequence. See Fig. 7 for a typical example of the functional grouping of relays in a circuit. Each relay group is designed for convenience only.

(c) Normally, the circuit should be prepared to read from left to right and from top to bottom.

(d) The circuit should be of minimum size consistent with even distribution, that is cramping and large open spaces should be avoided.

(e) The lines representing connections should be drawn so that the number of angles are at a minimum and unnecessary crossings avoided.

(f) All lines must cross at right angles, the only variation being cases similar to those shown on Figs. 2 and 4, that is, the reversal connections to the "A" (battery feed) relay.

(g) Speech transmission paths should be shown in heavier lines than the rest of the circuit, see Figs. 1 to 6 for examples.

(h) Earth or positive battery connection, whether direct or indirect, should be connected to the moving spring of all simple make or simple break contacts.

(j) Wires in contact should never be shown as a simple crossing, but should be indicated as separate tappings. Failure to observe this rule can result in confusion and cause wiring complications if the connection "dot" is indistinct.

(k) To avoid confusion with the symbol for the relay make contact, break contacts should never be drawn with the contacting leads in the same straight line. Break contacts should be drawn with the two leads at right angles and shall not be turned at an angle until at least $\frac{1}{8}$″ from the contact, see Fig. 8.

(l) The symbol for the "slow-to-operate" and "slow-to-release" relays should be memorised. In the earlier type of diagrams the meaning of these symbols was the opposite to present practice.

(m) Attention should be paid to the difference between the following symbols:—
Alternative connections and boundary lines.

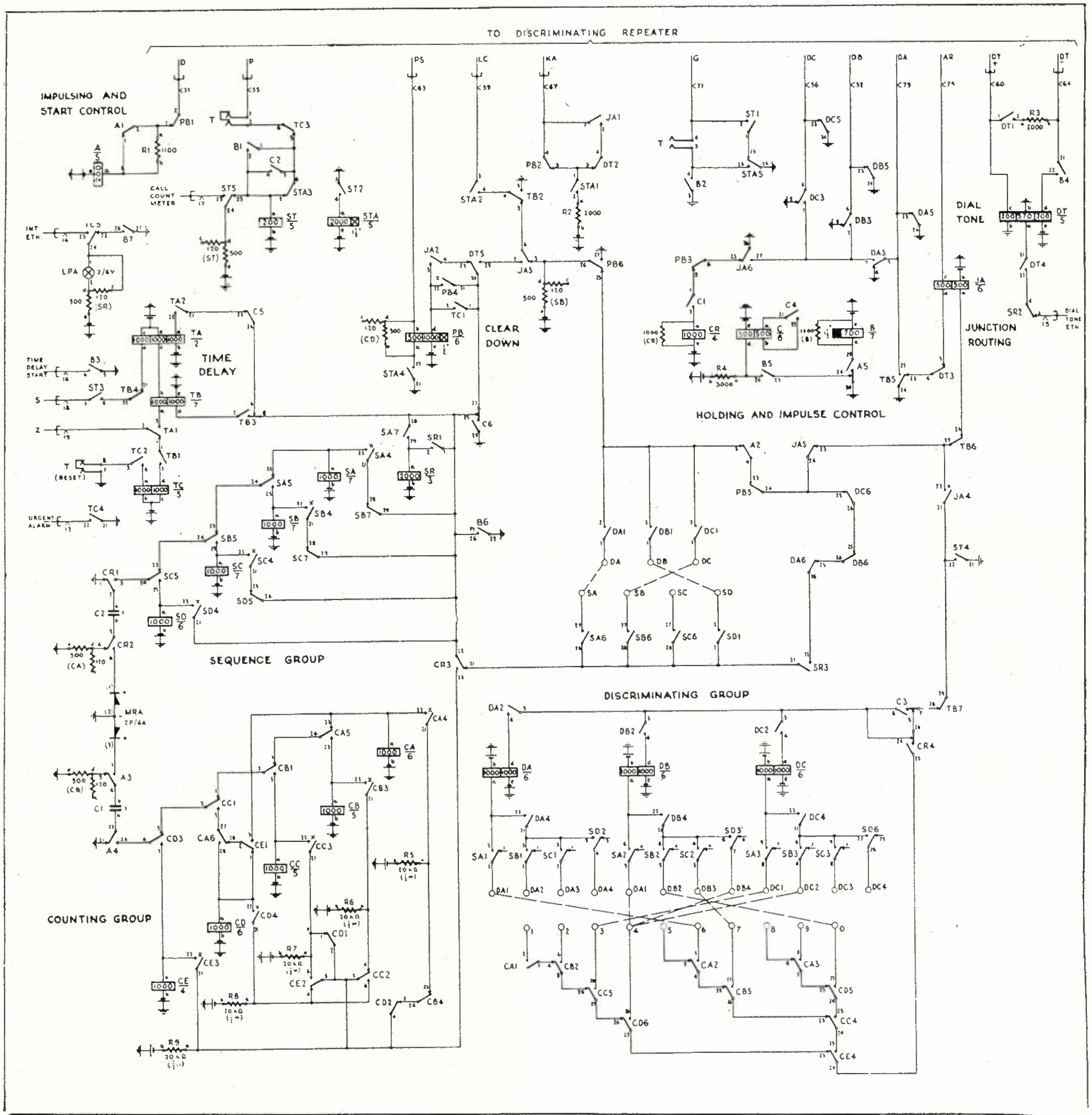


Fig. 7.—Circuit layout showing the functional grouping of relays.

"U" points for routiner access and for jacking-in.

Locking and non-locking keys.

Bells and buzzers.

Bridging and non-bridging wipers.

Uniselector and bimotional switch wipers.

Make-before-break contacts and the similar earlier types of mechanically operated contacts.

General symbol for condenser and electrolytic condenser.

Use of Sectional Paper: For speedy and efficient circuit layouts the employment of 1/12" divi-

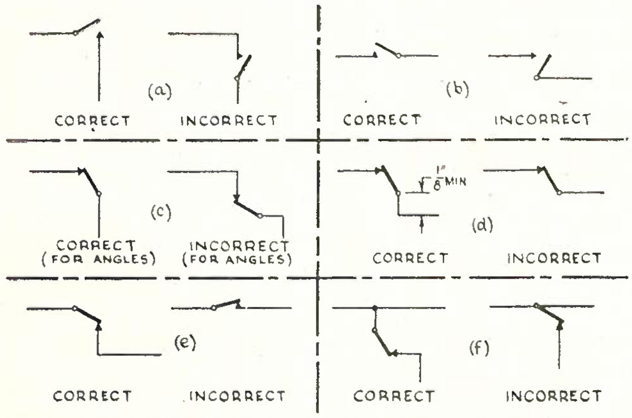


Fig. 8.—Correct and incorrect methods of drawing simple make and simple break relay contacts.

sions, sectional paper, as a dimensional facility, is an essential to the circuit draftsman. Without such paper, which also serves as a backing for the diagram, it would be a slow and laborious proces to prepare a large circuit diagram, as all symbols must be drawn to correct size, equidistant lines scaled off and general measurements made for even distribution of the circuit. The use of sectional paper enables this to be accomplished without the aid of a rule or scale as would be the case if plain paper were used as a backing.

The choice of 1/12" divisions sectional paper in preference to other sectional paper will be understood if reference is made to Fig. 4, when it will be seen that the symbols sizes coincide with the divisions and the 1/12", $\frac{1}{4}$", $\frac{1}{2}$" and 1" rulings differ slightly in thickness, thus enabling the draftsman to readily plot the dimensions not only in inches but, also, in the fractions mentioned above. Furthermore, the rulings closely approximate the standard lettering sizes and may therefore be utilised as lettering guides to save time and labour.

LOWERING OF A FOUR-WAY DUCT ROUTE

K. M. Dober, B.Sc.

At Mentone, Melbourne, extensive alterations to the layout of a major road intersection necessitated rearrangement of Departmental plant in the vicinity. The main problem was presented by a section of a duct route composed of earthenware, self-aligning four-way conduits, which would be left above ground level by the proposed alteration. The ducts were occupied by a trunk cable, a junction cable and two subscribers' cables.

As the amount of labour involved in laying new conduits and cables at the correct depth would have been heavy, it was decided to lower the existing route to the new level. The section affected was between two manholes 130 yards apart, the minimum depth to be lowered varying from 27" at one manhole to zero at the other. The operation was to be effected by lashing a "splint" to the conduits and lowering the semi-rigid system bodily by means of block and tackle.

First a means of bracing the conduits was required so that they could be transformed into a semi-rigid beam. Preliminary experiments with a 3" diameter G.I. pipe normally used to house cables, indicated that if the conduits were secured to the pipe and the pipe suspended at intervals of 18 feet, the sag in the conduits would be approximately $\frac{3}{4}$", midway between suspension points. This was accepted as a sufficient degree of rigidity to prevent damage to the conduits. This was a convenient interval from the suspension aspect also, as blocks and tackle which could be secured for the job would support an 18 feet section of conduits and cables with a reasonable safety margin.

Initially, alterations were made to the manhole where the conduits were to be lowered 27". The floor of the manhole was rebuilt at the lower level and the end of the manhole broken away to allow the conduits to drop. Earth was cleared from around the conduits and the 3" pipes laid on top of them and threaded together. Each conduit was then lashed securely to the iron pipe, see Fig. 1.

At 18 feet intervals along the route supports were placed on both sides of the trench. Empty cable drums made ideal supports and as many as were available were used for this purpose. 7" x 4" H-section steel girders were placed across each

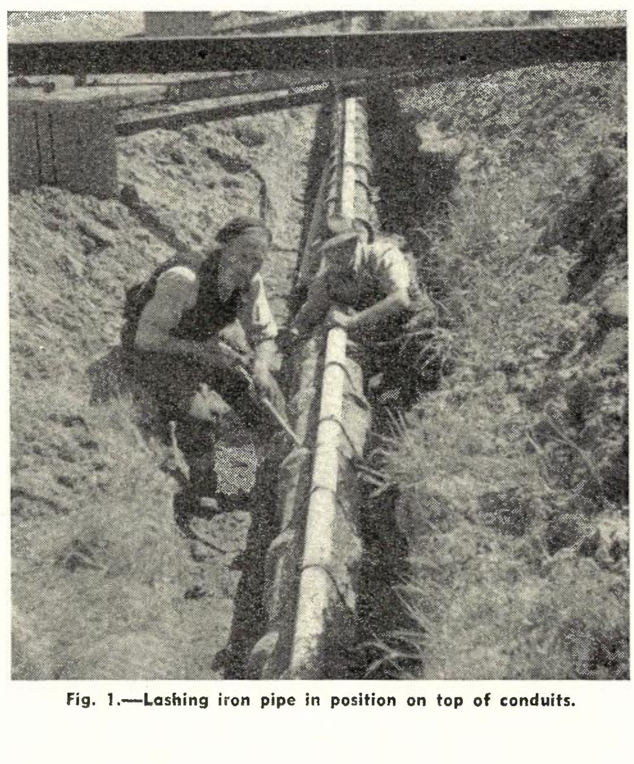


Fig. 1.—Lashing iron pipe in position on top of conduits.

pair of supports. It was necessary to maintain a clearance of at least 3 feet between the girder and the 3" pipe to permit the fitting of the block and tackle. Midway between these bridges other girders were laid directly on top of the trench. Strong wire lashings comprising several turns of 200 lb. G.I. wire were then made between pipe and girders and twitched up until they were taking the full weight of the ducts. Although it was considered that suspension points 18 feet apart would be satisfactory when lowering the ducts, the second set of girders was necessary to give extra support to the system during excavation of the trench. Without the extra girders the breaking of one suspension would have placed dangerous stresses on the adjacent suspension, with a possibility of partial collapse of the system. It was possible to lay the extra girders across the trench with very little clearance over the conduits as no block and tackle was to be fitted to them.

One side of the trench was now excavated to the depth required to provide adequate coverage for the conduits, the earth under the conduits being removed also, and the floor of the trench boned. Fig. 2 shows the conduits at this stage. In the meantime sufficient sets of tackle, composed of double sheave and triple sheave blocks with 2" rope, had been prepared and these were fastened between the girders placed on the cable drums and the iron pipe.

It was essential in lowering the conduits that they maintained a straight line, so indicators were provided alongside each tackle to record the distance the conduits had been lowered. These consisted simply of wooden stakes marked at the top, standing in the trench, the intervals between marks corresponding to the distance the ducts were to be lowered, and being divided into ten equal parts. A piece of rigid wire fastened to the pipe and rising vertically from it was bent horizontally so that the horizontal portion coincided with the top mark on the stake. As the conduits dropped into the trench their progress could be followed by the men on the tackles, who would be standing clear of the trench.

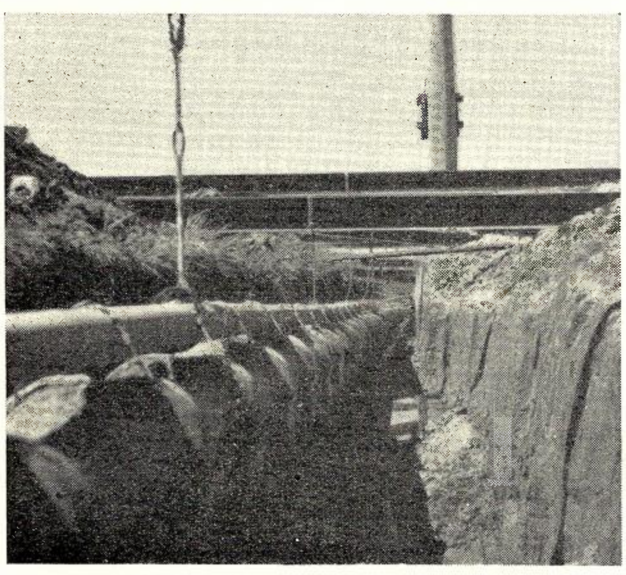


Fig. 2.—Conduits suspended from girders.

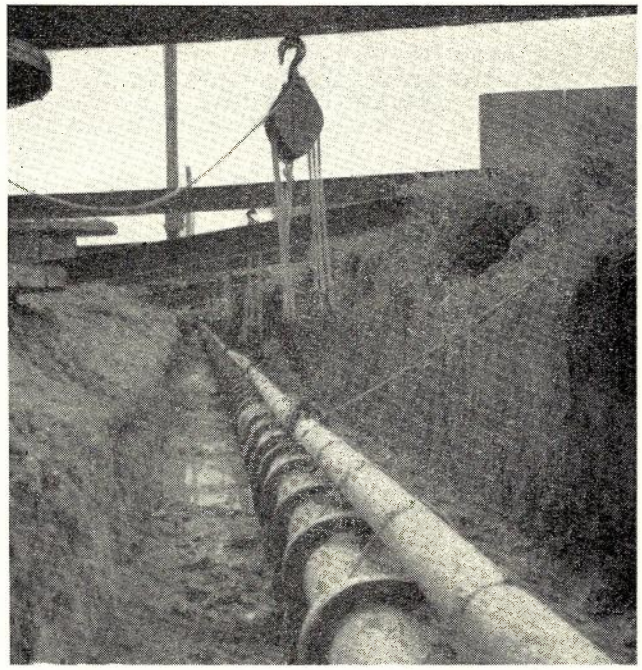


Fig. 3.—Lowering completed. Conduits laying on floor of trench.

When all preparations had been made, line parties involving a total of 60 men, were brought to the job to man the tackles, three or four men being assigned to each rope. The suspensions midway between the tackles were cut with bolt-cutters, leaving the system suspended by the wire at each lowering point. The strain was then taken on each tackle in turn and the wire suspension cut.

At a given signal all parties lowered through a distance corresponding to one division on their indicator. This was repeated until the conduits lay on the floor of the trench as shown in Fig. 3. A close inspection of the route after lowering failed to disclose any cracks in the conduits. Be fore removing the iron pipe, earth was rammed around the conduits to ensure that they were firmly bedded and could not move when released from the relatively rigid pipe. Sufficient slack cable was available in the manhole to permit rehousing of the joints to suit the lower level of conduits on one side of the manhole.

In comparison with the cost of laying a new section of conduits and cables, cutting over to them and recovering the old plant, it is estimated that a saving in costs of approximately 60% was effected. There was also the important advantage that no interruptions were necessary to working circuits.

The method described is based on an article, "Conduits—Alterations to the Alignment of a Butt-Jointed Duct Route," by W. B. Ridgeway, in the Telecommunication Journal, Vol. 4, No. 2, October, 1942.

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. 2906—ENGINEER NATURAL SCIENCE

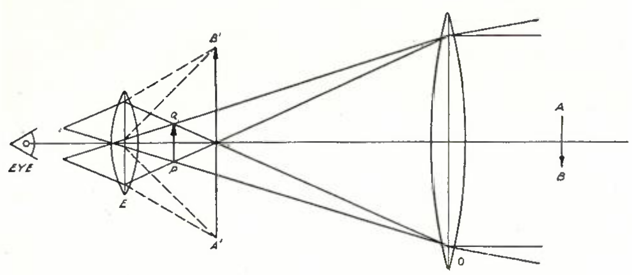
K. W. Macdonald, B.Sc., Dip.Pub. Admin.

Part 2.

Q. 11.—Describe with the aid of a diagram a simple refracting astronomical telescope.

Explain clearly what is meant by the magnification of such a telescope and obtain an expression for the magnification.

A.—A simple astronomical telescope of the refracting type consists essentially of two convex lenses, called respectively the objective and eye-piece. Since the object to be observed is very distant, the rays coming from any point on it are parallel, and so the real inverted image (PQ) formed by the objective is situated in the focal plane of this lens, i.e. OP = F where F is the focal length of the objective lens. This image is magnified further by the eye-piece lens. The path of the rays is shown in Fig. 1.



Q.11, Fig. 1.

As shown below, the magnifying power of a telescope depends upon an objective lens with a large focal length. The objective lens also needs to be achromatic to compensate for the dispersion which would otherwise occur due to the angle of refraction varying for light rays of different wavelength. This lens should also have a large diameter in order to throw a considerable amount of light into the image PQ and increase its intensity. Some astronomical telescopes have objectives whose diameter is 3 ft. or more.

The apparent size of an object viewed by the eye depends, not only upon its actual dimensions, but also on its distance. Thus an object viewed through the telescope may appear greatly magnified, although it is fairly obvious that the linear dimensions of the image are immeasurably smaller than those of the distant object. When an optical instrument is said to magnify, we mean that it causes the image to subtend at the eye a greater angle than the object does. Hence the magnification or magnifying power of the telescope is defined as the ratio of the angle subtended at the eye by the image to that subtended by the object as seen directly at its actual distance.

In Fig. 1, Angle subtended by object $= \frac{AB}{U}$

Angle subtended by image $= \frac{A^1B^1}{v}$

$$\text{Magnifying Power} = \frac{A^1B^1}{AB} \cdot \frac{U}{v}$$

$$\text{But } \frac{PQ}{AB} = \frac{V}{U} = \frac{F}{U} \text{ (for parallel incident rays)}$$

$$\text{And } \frac{A^1B^1}{PQ} \quad \frac{v}{u}$$

If the image is to be viewed with the naked eye, PQ must be at the focus of the eye-piece, i.e., u = f.

$$\frac{A^1B^1}{PQ} = \frac{v}{f}$$

$$\text{Magnifying power} = \frac{A^1B^1}{AB} \cdot \frac{u}{v}$$

$$= \frac{v}{f} \times \frac{F}{U} \cdot \frac{U}{v}$$

$$= \frac{F}{f}$$

i.e., the magnifying power of the telescope is equal to the ratio of the focal lengths of the 2 lenses. Hence a high-powered telescope implies a massive objective lens of great focal length, and consequently a rather unwieldy mechanical structure.

Q. 12.—The vapour density of the chloride of a metal is 81.5 (Hydrogen = 1). The chloride contains 34.46 per cent of the metal. The specific heat of the metal is 0.115. Find the exact atomic weight of the metal, the formula and the exact molecular weight of the chloride. (The atomic weight of chlorine is 35.46.)

A.—

Specific Heat x Atomic Weight = 6.3.

$$\text{Approx. Atomic Weight of Metal} = \frac{6.3}{.115} = 54.8$$

Approx. Molecular Wt. of Chloride =

$$\frac{\text{Vapour Density of Chloride}}{\text{Vapour Density of Hydrogen}} \times 2$$

$$= \frac{81.5}{1} \times 2 = 163.$$

Assume formula of chloride is $M_x Cl_y$

Then $x \times 54.8 + y \times 35.46 = 163$ approx.

Deduce x = 1 and y = 3

(LH.S = 54.8 + 106.38 = 161.2)

$$\text{But \% of Metal} = \frac{M}{M + 3 \times 35.46} = \frac{34.46}{100}$$

$$\therefore \quad M\,(100 - 34.46) = 34.46 \times 3 \times 35.46$$

$$M = \frac{34.6 \times 3 \times 35.46}{65.54}$$

$$= 55.76 \text{ exactly}$$

and formula is $M\,Cl_3$.

EXAMINATION No. 2906—ENGINEER—TELEPHONE EQUIPMENT.
GROUP 1

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

Q.1—A locality with 1,800 subscribers connected is served by means of an automatic exchange. The automatic equipment, M.D.F., ringers, power board and test desk, &c., are installed on the first floor of the exchange building with the power plant, consisting of two batteries and motor generators, on the ground floor. As the result of the adjacent river overflowing its banks the ground floor of the exchange building is flooded to a depth sufficient to submerge completely all the power plant. As the engineer responsible for the maintenance of the exchange, detail the steps you would take to restore service at the exchange after the flood waters have commenced to subside. Assume that the lead-in cables to the M.D.F. are not faulty and the battery containers are of the open glass type.

A.—In dealing with the situation outlined in the question, several assumptions will be made, viz:—

1. That the busy hour load for the exchange under normal conditions is of the order of 70 amps.

2. That the motor generators have been rendered unfit for use until completely rewired.

3. That the battery cells have a layer of flood water on the top of the electrolyte, but that the greater density of the electrolyte has caused it to remain clearly separate from the foreign liquid.

4. That a suitable 50V 100 amp. rectifier is available, either ex-Store or on loan from another exchange in the same State.

Steps to restore service would then be:—

1. Disconnect the saturated charge and discharge leads from the power board to the batteries and motor generators.

2. Install the 50V rectifier in a temporary position on the first floor, handy to the power board.

3. Run leads from the rectifier to power board to enable the exchange load to be taken directly to the rectifier.

4. Re-establish service in the exchange in groups of, say, 400 subscribers at a time, to provide a gradual build-up of load and avoid overloading of section fuses. Before power was connected to a section, the staff would ensure that all switches were released.

5. Coincident with above, arrange for the reconditioning or replacement of the motor generators and for the rehabilitation of the batteries. Foreign matter would be pumped or siphoned out of the cells—new charge and discharge leads run to the power board, One motor generator would be connected permanently to its correct switch on the board, and it would be used to charge up the batteries while the rectifier was running the exchange in place of the second motor generator.

6. When both batteries were fully charged and satisfactory, the load would be placed on the motor generator floating across the battery.

7. The temporary leads to the rectifier could then be dismantled and the permanent leads to number two motor generator installed.

Q.2—Metal rectifiers used for battery charging at automatic telephone exchanges may be fitted with rectifier elements of either the copper oxide type or the selenium type. Explain the essential differences between the two types and the advantages or disadvantages of the one type compared with the other type. Draw a simple circuit diagram of a metal rectifier suitable for battery charging at a telephone exchange and explain how full wave rectification and voltage adjustment are obtained.

A.—Both selenium and copper oxide rectifiers are classed as "metal rectifiers". However, the materials used are different and their characteristics are not the same.

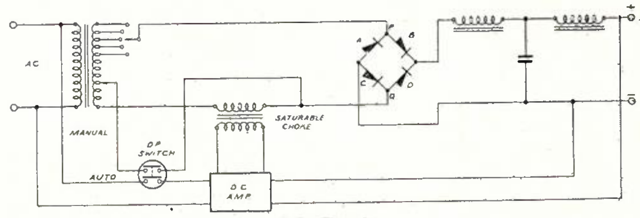
A selenium rectifier consists essentially of a base plate or disc of nickel-plated steel, on one face of which a thin layer of selenium is applied in intimate contact with the disc. The selenium surface is then sprayed with a low melting point alloy to form a counter electrode. After an electrical forming process, it is found that the element shows a much higher resistance in the direction selenium-steel than in the reverse direction.

A copper oxide rectifier comprises essentially a copper plate, one surface of which has been treated to form a layer of cuprous oxide. A lead washer is used to provide intimate contact with the oxide surface, and in this case the high resistance direction is from copper to cuprous oxide and the low resistance direction oxide to copper.

The selenium type of rectifier possesses advantages over the copper oxide type in several features:—

(1) Better temperature coefficient.
(2) Better power factor.
(3) Greater efficiency by about 5-10%.
(4) Working voltage in the reverse direction is approximately 14V per disc, compared with 5V for copper oxide type. Thus fewer discs, and therefore less space, are required for the same kilowatt output.

The circuit of a rectifier suitable for battery charging or floating at a telephone exchange is shown in Q.2, Fig. 1.



Q.2, Fig. 1.

When the rectifier is on load with the battery floating, it would normally be in the automatic control condition. Then, any variation in the output voltage of the rectifier would be amplified in the DC valve amplifier, whose tubes draw their plate current through the saturating winding of the control choke.

Tht resulting change in impedance of the choke is in such a direction as to counter the variation. Consequently the output voltage may be held constant within ± 2%.

For charging purposes, the rectifier can be switched to manual control and by means of varying the secondary tapping in the input transformer, the output voltage of the rectifier can be varied to give the desired charging rate for the battery.

The rectifier provides full wave rectification by means of the 4 sets of discs, A, B, C, and D. Considering one half cycle of the AC input, the point P will be positive and Q negative. In this condition, rectifiers A and D will be high resistance and B and C conducting. Thus current will flow from P via B, the load, and C to Q. In the next half cycle, P will be negative and Q positive. Then D and A will conduct—B and C being high resistance. Thus current flows from Q via D, the load, and A to P.

It is seen that the direction of current through the load is the same for each half cycle, i.e., full wave rectification is given.

Q.3—The lead acid accumulator batteries supplying a 2,000 type automatic exchange are operated on a continuous floating routine. The automatic exchange is a six figure branch located in a metropolitan area and has 3,500 subscribers connected. State in detail the capacity of the batteries and the associated charging equipment which you consider should be provided at this exchange, giving reasons for each statement made. Describe in concise terms a typical operation of the battery and associated charging plant at the exchange from 8 a.m. on a Monday morning until 8 a.m. on the subsequent Monday.

A.—The Busy hour load to be drawn by the exchange is estimated as shown on the table.

Switch Rank	A.H. per T.U.	Local Traffic	Local -Main	Main -Local	
L & K's	.05	√	√		
Line finders	.25	√	√		
D.S.R's	.07	√	√		
2nd Selectors	.03	√		√	
3rd Selectors	.03	√		√	
4th Selectors	.03	√		√	
Finals	.40	√		√	
C.O. Relays (called line)	.04	√		√	
Additions		0.90	0.37	0.53	
Assumed traffic		50A	70	70	
Ampere hours in Busy hour		45	26	37	Total 108 Amps in Busy Hr.

On floating basis, provide 2 batteries with combined capacity = 10 x Busy Hour load, i.e., 2 batteries of 581 A.Hrs. Charging equipment provided would comprise a 100 Amp Rectifier with final automatic voltage control, which would enable the battery to float across it for the major portion of the day. A motor generator of 200 Amps capacity would also be provided to cover the busiest period of the day and provide for traffic increasing in the future.

Since both batteries are to be floated alternately, they should both be available with practically full capacity in the event of a power failure. Since a capacity of 10 Busy hours is normally equivalent to a 24-hour load, the battery installation would provide an emergency power supply for a power interruption of that duration.

The day by day operation of batteries and charging equipment would be:—

Monday:—

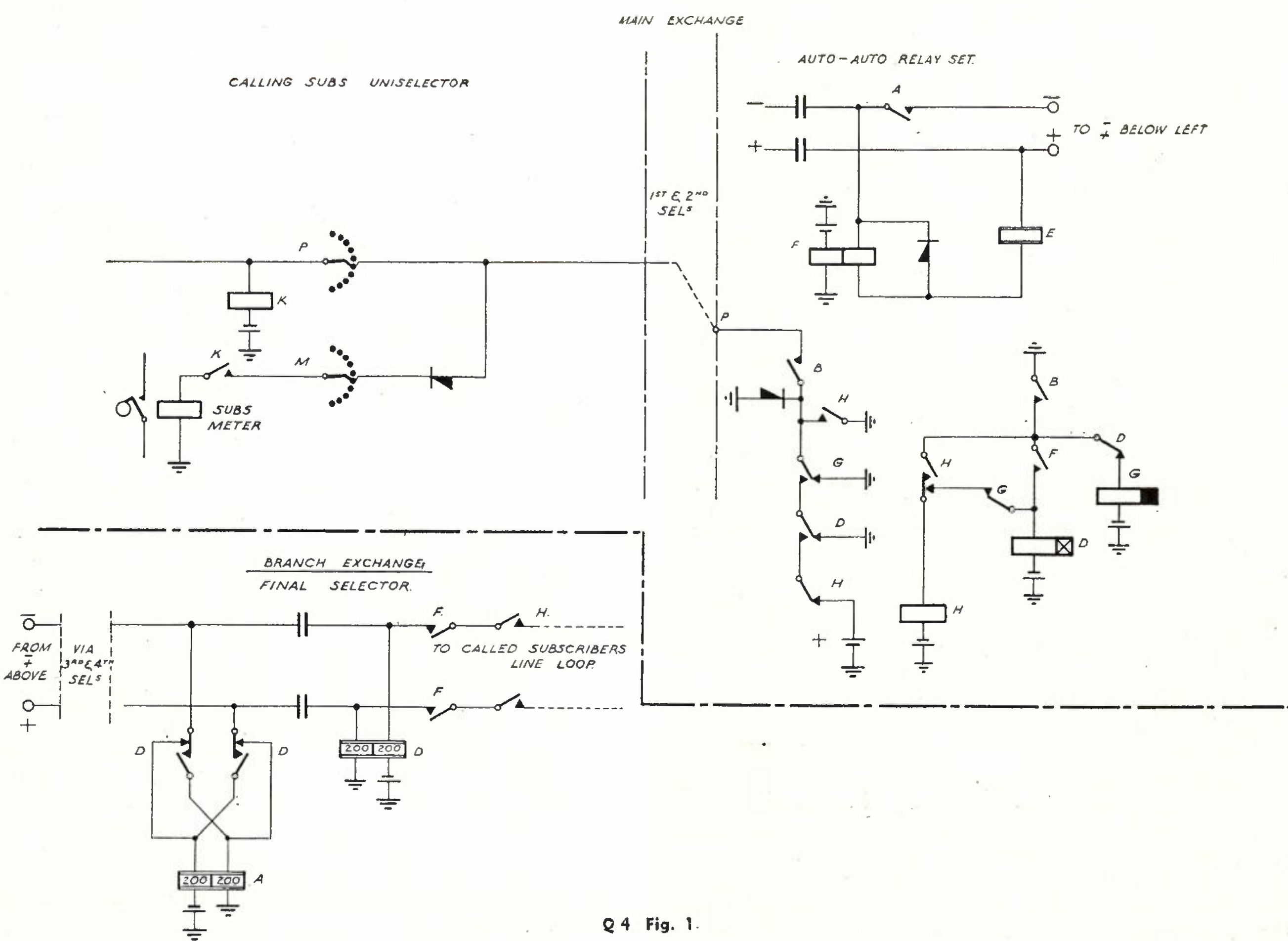
8 a.m. (say): No. 1 battery floating across Rectifier on load. No. 2 battery and MG set idle.

9 a.m.: Start up motor generator, and connect No. 2 battery across it and then put on load.

Leave No. 1 battery cross rectifier for sufficient period to fully charge the battery at a very low rate (trickle charge condition). When battery is fully charged, disconnect rectifier and shut down.

4 p.m.: Connect AC to rectifier and connect rectifier across battery on load in lieu of motor generator, which is closed down.

Leave battery floating across rectifier load overnight.



Q 4 Fig. 1

A similar procedure would be followed on other week days except, of course, that the battery charging would be performed on Mondays only.

Assuming that the exchange were staffed on Saturdays, the same procedure would obtain on Saturdays, i.e., Motor generator on load from 9 a.m. to 4 p.m. and the rectifier for the balance of the 24 hours. Since the exchange is a branch, it is assumed to be unstaffed on Sundays, so that the rectifier would be on load from 4 p.m. on Saturday until 9 a.m. on Monday, with the battery floated across it.

GROUP 2

Q.4.—A subscriber connected to a main exchange of the 2000 type employing subscribers' uniselectors originates a call to a subscriber connected to a pre-2000 type branch of this main exchange. Explain by means of a schematic diagram of the relative circuit elements how the call is metered when the called subscriber answers. Portions of automatic switch circuits not actually concerned in the metering of the call must be omitted from the circuit diagram.

A.—The relative circuit elements are shown in Q.4, Fig. 1:

Referring to the diagram, during the progressive set up of the call the K relay of the calling subscriber is held to the P. wire earth supplied by the first two rank selectors and then by the Auto-Auto repeater located at the Main Exchange. Prior to the called subscriber answering, relays B and G are held in the repeater, so earth from back contact of D is applied to the P wire.

When the called subscriber answers, his loop causes the final selector relay F to operate and trip the ring, and then D operates to the loop. D reverses the potentials applied to the negative and positive wires of the junction from the Main Exchange. At the Main Exchange this reversal operates the polarized relay F, which then operates D (slowly). D changeover contact then replaces earth on the P. wire by positive battery via a break contact of H.

D also opens the circuit of G, which releases slowly and then permits the operation and locking up of H.

H then opens the positive battery, which has previously been removed from the P wire by the release of G.

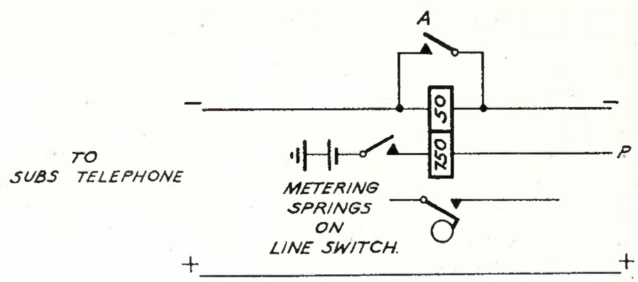
Thus the condition on the P wire to the Relay Set is that a pulse of positive battery—of length equal to the release time of G—is applied. This pulse is sufficient to operate the calling subscriber's meter via the M bank of the uniselector, the metal rectifier being in the conducting direction for positive battery.

Q.5—(a) The first automatic exchange in Australia was opened at Geelong, Victoria, in 1912. Review in chronological order the call metering schemes which have been used in public automatic exchanges in Australia. Each type of metering should be described by reference to a schematic circuit diagram of the essential circuit elements.

(b) What do you understand by the term "multi-metering" and where do you consider this method of metering might be applied with advantage in Australia?

A.—(a) Reverse Battery Metering using two-coil meter. See Q.5, Fig. 1.

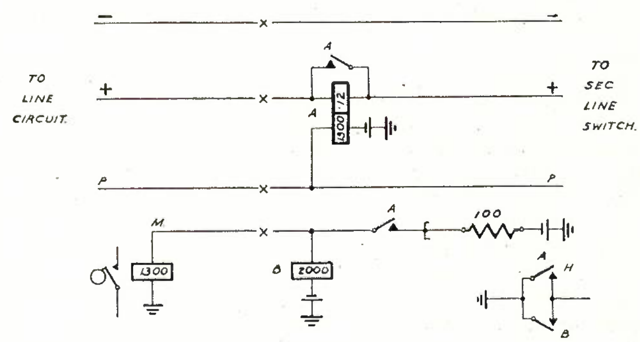
In this circuit, used with Keith Line Switches, the 750 ohm meter winding is for polarizing purposes, and the other is the line winding. When the called party answers, the battery is reversed in the line, the meter operates, and retains on its polarizing winding.



Q.5, Fig. 1.

These meters were difficult to adjust due to the line currents, and the insertion of an impedance in the line during dialling was a disadvantage.

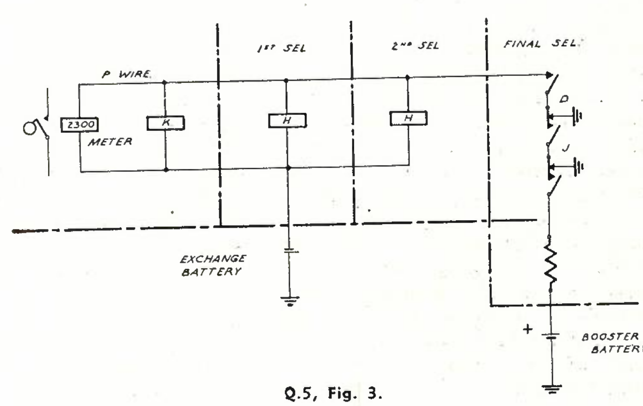
2. Single Coil Meter with polarized relay. See Q.5, Fig. 2.



Q.5, Fig. 2.

In this method a polarized relay is interposed between the line circuit and the meter, which has only a single coil operated in a local circuit from a relay contact. The polarized relay was easier to manufacture and adjust than was a polarized meter but the impedance condition during dialling remained.

3. Booster Battery Metering (Used with Non-homing 4-level Uniselectors). See Q.5, Fig. 3.

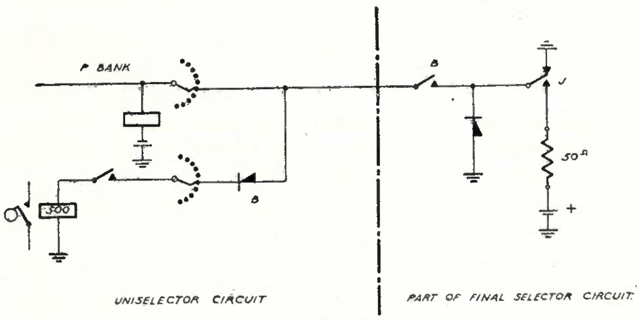


Q.5, Fig. 3.

In this method the meter was connected to the private wire, but operated only when the booster battery voltage was added to the exchange battery voltage across the meter.

This system had disadvantages in that the meter had to be adjusted to a non-operate current, and also that a disconnection in the booster battery path could lead to connections being released when the called party answered. Since, like the two previous methods, the meter was operated for the duration of the call multi-metering was still not possible.

4. Positive Battery Metering with 100A Meter. (Used with homing uniselectors.)



Q.5, Fig. 4.

In this method, the metering battery is arranged as a positive source of potential, and this positive battery is applied to the meter via a metal rectifier when the called party has answered. The operating battery is only connected for a short pulse, and therefore multi-operation of the meter becomes possible.

The 100A type meter used in this system is smaller and more economical than former types.

(b) "Multi-metering means the operation of a subscriber's meter more than once on a particular call, according to either the time of duration or the distance of the connection involved. Application of this system implies that subscribers are dialling the call without assistance from a manual operator. It is considered that this method could be applied with great advantage to automatic exchanges which are established in the outer metropolitan area—just beyond the unit fee area. Established practices would require the provision of a manual trunk suite to handle all calls from such a centre to the metropolitan area with which there would be a great community of interest. In most cases, the comparatively small trunk call fee for short distance trunk calls would make the trunk traffic unprofitable. By relating the trunk charge to be a multiple of the unit fee charge, subscribers could be permitted to dial their own metropolitan calls—preceding the wanted number by a code call which would cause the appropriate number of pulses to be directed to the calling subscriber's meter. It would also probably be of great advantage to permit metropolitan subscribers to directly dial into the outer metro. area but in this case the variety of equipment involved, the lack of a uniform standard of positive battery metering and the problem of allotting suitable discriminating calling codes would require such extensive rearrangements to existing automatic exchanges that the economies in trunk line call operation would be outweighed by the costs of modifications. A further fruitful field for multi-metering would be the case of two country automatic exchanges at near-by country towns with a high community of interest, as well as R.A.X's which were not far outside the unit fee areas of one or both exchanges.

In the ultimate it is considered that multi-metering could be applied to a very large percentage of all short haul trunk calls originated by automatic subscribers. In the case of long-distance calls where the call charges would represent an excessive number of times the unit fees automatic call ticketing appears to be a more logical solution than multi-metering.

Q.6.—State the function and operating characteristics of each of the relays required—

(a) In a 2000-type group selector with 200 outlets.

(b) In an Auto-Auto Relay Set used between two 2000-type automatic exchanges.

A.—(a) "A" Relay. Seizing and Impulsing. Operates when subscriber's loop is extended to the selector in the particular switch rank. Responds to a train of impulses, and operates the vertical magnet to make the appropriate number of steps. Third winding (570) acts as transformer to feed dial tone (if a first selector), or busy tones if all outlets from the required level are engaged.

"B" Relay.—Holding and Guarding relay. Operated by A, but arranged to be held over impulsing by virtue of the delayed release due to a short-circuited winding. Earths the incoming P wire and holds the connection up to the stage of a guarding earth being returned from the next rank switch.

"C" Relay.—Inter. train pause discrimination. Preoperated by B, but retained during impulsing by series action of a low resistance winding in the Vertical Magnet circuit. C releases during interdigital pause, and so completes Rotary Drive circuit. If a free outlet is found C re-operates to a contact of the test relay and disconnects A relay from the line wires. C is held for duration of call.

HA and HB Relays.—Outlet testing and switching relays concerned with the odd and even outlets respectively. Each relay has 3 windings, 1500, 550 and 400 ohm. Both operate in parallel on 550 winding when first vertical step is made. During rotary drive either relay is held by an earth in the P. wire contact. If one relay encounters a contact, it will be released. If both simultaneously encounter free contacts, both release, but HA reoperates first and so switches on to the odd outlet. Relevant relay HA or HB is held to the P. wire earth from next rank for the duration of the call. The release of either HA or HB must occur within the time of the break in the Rotary Interrupter springs.

(b)—"A" Relay. Seizing, Impulsing Repetition and Battery Feed. Operates when calling subscriber's loop is extended to relay set via preceeding ranks of selectors—responds to subsequent trains of impulses, and repeats them over the junction. Associated with the relay set. Acts as transmitter battery feed for calling subscriber. Coils have nickel-iron sleeves to make them high impedance and reduce the transmission loss caused by their being bridged across the circuit.

"B" Relay. Holding and Guarding. Operated by A, but holds during impulsing, by virtue of heel end slug. Earths the P. wire and holds the junction busy to any other searching selectors while the calling subscriber's loop is retained.

"C" Relay. Dialling Repetition Control. C relay is operated via A relay contact during the breaks of impulsing, but by virtue of a heel end slug remains operated throughout a dialling train. A contact of C short circuits the high impedance holding relay E, and polarized relay F, thereby providing a dead short circuit across the junction, and the best conditions for dialling repetition to the distant exchange. C releases during the inter-digital pause.

"D" Relay. Meter Pulse Control. D relay is operated by an F contact when the called party has answered and a D contact presents the positive metering battery to the P wire to operate the calling subscriber's meter. D also opens the circuit of relay G, whose slow release times the length of the meter pulse.

"E" Relay. Loop Holding. E relay has a 400 ohm coil with nickel iron sleeves, making it high impedance. This relay provides a holding loop on the junction between impulse trains, and at the conclusion of impulsing.

"F" Relay. Called Party Answer Supervision. F is a polarized relay, one winding is shunted by a metal rectifier and connected in series with E across the junction. When a called party answers at the distant exchange the potentials applied to the negative and positive wires of the junction are reversed. This operates F, and initiates the train of operations to provide for metering the call.

"G" Relay. Meter Pulse Timing. G is originally operated by B, but is released by the operation of D subsequent to the called party answering. The positive metering battery is connected to the P. wire to operate the subscriber's meter for the duration of the release of G. G has a heel end slug to ensure that this period is adequate to operate the meter.

"H" Relay. Meter Re-operation. H operates only after D has operated and G has released AH contact, then opens the positive battery from the P. wire, and H locks to a B contact. Consequently any subsequent release and re-operation of D and G (e.g., caused by a called subscriber hanging up or pressing the switch hook) cannot cause a second operation of the calling party's meter. H also ensures that the junction remains guarded, during any such re-operations of D and G.

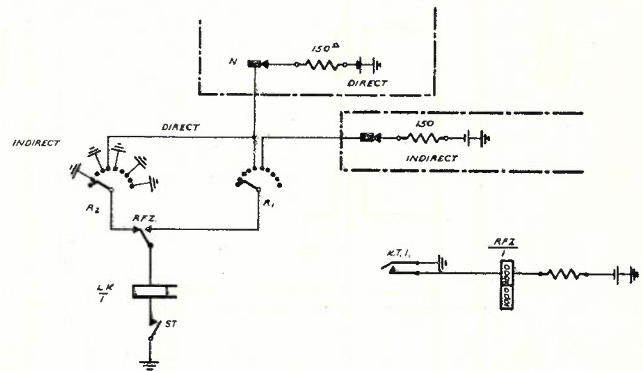
GROUP 3

Q.7.—Explain by means of a schematic diagram of the relative circuit elements the facilities provided at an automatic exchange of the 2,000 type for the comprehensive routine testing on a group basis of both direct and indirectly connected line finders. For the sake of simplicity the circuit need deal only with levels 1, 2, 7, 9 and 0.

A.—In a 2000 type line finder exchange, a set of Routining Keys is provided, which can enable every line finder either Direct or Indirect, to be tested for response to a calling signal on any level. These keys generate a start signal by operating one of the five Primary Start Relays SA to SE. This causes ST in the appropriate Primary Control Set to operate, and the finder proceeds to find the level marked by the key. On cutting in to the level the finder steps to the eleventh contact which is wired to the auxiliary bank contact. The finder therefore tests in to the eleventh contact as for a normal call, and HA or HB operates, to be held by earth from the associated first selector.

HB or HA operate G relay in the control set, and G contacts short circuit the ST relay so that the control set relays release in turn. G relay is the last to release, and upon this happening the allotter switch is stepped on to the next outlet corresponding to the next Finder. If the finder is free G remains un-operated, and since the Routine Key is maintaining the Start Condition. ST re-operates and the new Finder proceeds to the level marked by the key. It also steps to the eleventh contact, tests in and then releases as before. Thus each Finder in the group may be tested in turn for cut in to the nominated level.

Under normal traffic conditions the Direct finders are always taken first, and only when all Direct Finders are engaged does RFZ relay operate, and cause the allotter to test for Indirect Finders. Under routine conditions it is usual to throw the KTI key, thereby operating RFZ, and changing the allotter test from arc R2 (where indirect finders are busied out by an earth) to arc R_1 where indirect finders are represented alternately with the direct. Thus will KTI throw, all finders in the group are tested for cut in to the level designated by the KRT key thrown. The elements of the allotter circuit are shown in Q.7, Fig. 1.

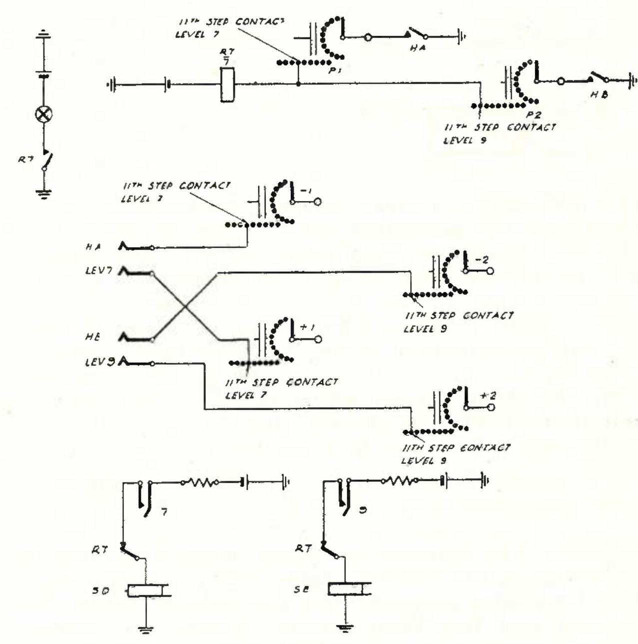


Q. 7, Fig. 1.

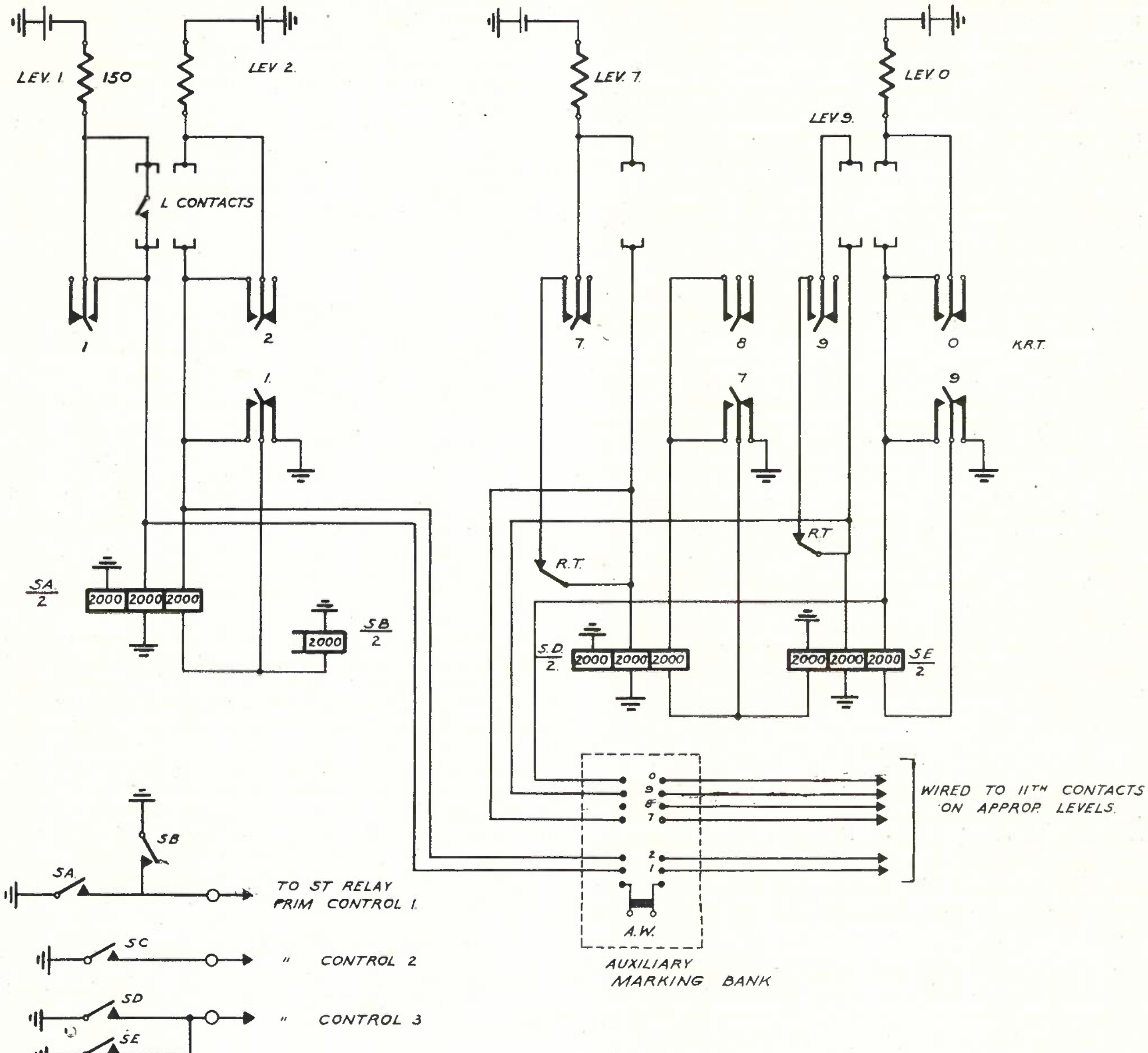
The elements of the KRT keys and Start relays are shown in figure (2)fl It is seen that KRT2 operates SA and therefore seizes Control No. 1. KRT7 operates SD, KRT9 and KRT0 operate SE and seize Control No. 3. (KRT5 or KRT6 would operate SC and take control No. 8.)

In practice, it is desirable to provide for the systematic routining of all finders on all calling levels, so a schedule of tests is drawn up, and the levels are tested in such an order that all control sets are checked each week and all levels are covered every 2 weeks.

Either level 7 or level 9 is done each week, and by plugging a buttinski into the test jacks provided—one



Q. 7, Fig. 3.



Q.7, Fig. 2.

pair per group of finders—a check can be made for dial tone from the associated first selector or D.S.R., and also for response to a loop across the line. During a level 7 or level 9 test, the finder, upon cutting into the 11th contact, causes RT to operate. RT contacts open the starting earth from the KRT key to the SD or SE relay, so that the automatic sequence of one finder after another is prevented, unless the testing officer momentarily breaks the loop, which releases the finder and selector and RT. The allotter then steps on to the next finder, and the test can be repeated.

The circuit elements of this part of the testing equipment are shown in Q.7, Fig. 3.

Q.8.—At an automatic exchange of the 2,000 type the technician at the test desk gains access to a subscriber's line for testing purposes via a Test Selector Trunk, Test Selector and Test Final Selector. Explain by reference to a schematic diagram of the relative circuit elements how the test desk by use of the above-mentioned equipment is connected through to a subscriber's line for testing purposes. Assume the line to be tested is not engaged and do not include in your descriptions the methods used to release the testing switches after completion of a test sequence.

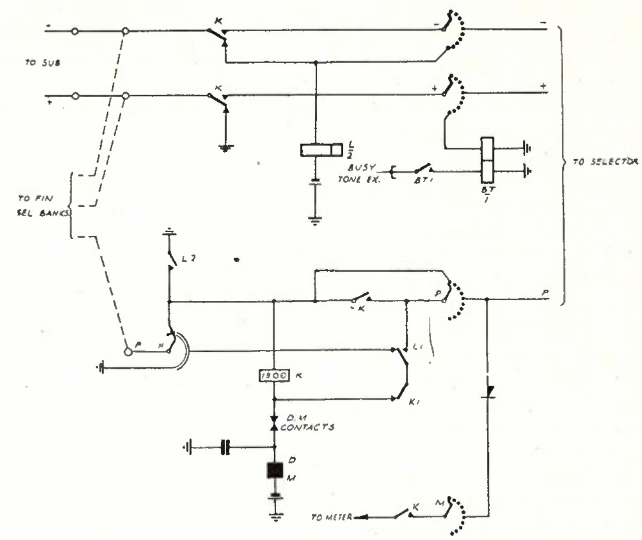
A.—The connection made from the test desk to a subscriber's line is shown in the figure. The testing officer takes an idle test trunk which terminates on a test selector. He proceeds to dial the subscriber's number less the local exchange prefix. The first impulse train from his dial is passed by the selector A relay to the vertical magnet of the test selector, which steps to the appropriate level. During the inter-train pause, C relay releases and operates E, which transfers the impulsing contacts on to the rotary magnet. Thus the second train determines to which rotary contact the test selector will drive. The banks of the test selector are connected to the wipers of a group of test final selectors, each rotary contact corresponding with a group of 100 subscribers. At the end of the second train, the release of C causes EA to operate, and E releases. H then operates, so that the third impulse train is forwarded to the vertical magnet of a test final selector. In the pause preceding this train, the test selector checks that the test final is free, by means of the G relay. A final which is off normal will operate G to 200 ohm battery on the Z bank. G connects busy tone to inform the testing officer.

If a test final is free, the 3rd train which stepped the switch vertically is followed by the 4th train which, with E re-operated, controls the rotary magnet of the test final, which steps the switch on to the required subscriber's line circuit. If the subscriber is disengaged, the K relay will be operated, disconnecting L relay and earth and leaving a clear line for any tests of the external plant.

If a test of the subscriber's exchange equipment is required, the testing officer may throw a B.C.O. key, which causes the release of K relay, and the tester can connect his operator's circuit across the testing leads and make test calls via the subscriber's uniselector or line-finder.

Q.9—Explain by reference to a schematic diagram of the relative circuit elements the operation of a subscriber's uniselector of the homing type at a 2000 type exchange arranged to transmit the busy signal to the calling subscriber when all outlets to which the switch has access are engaged.

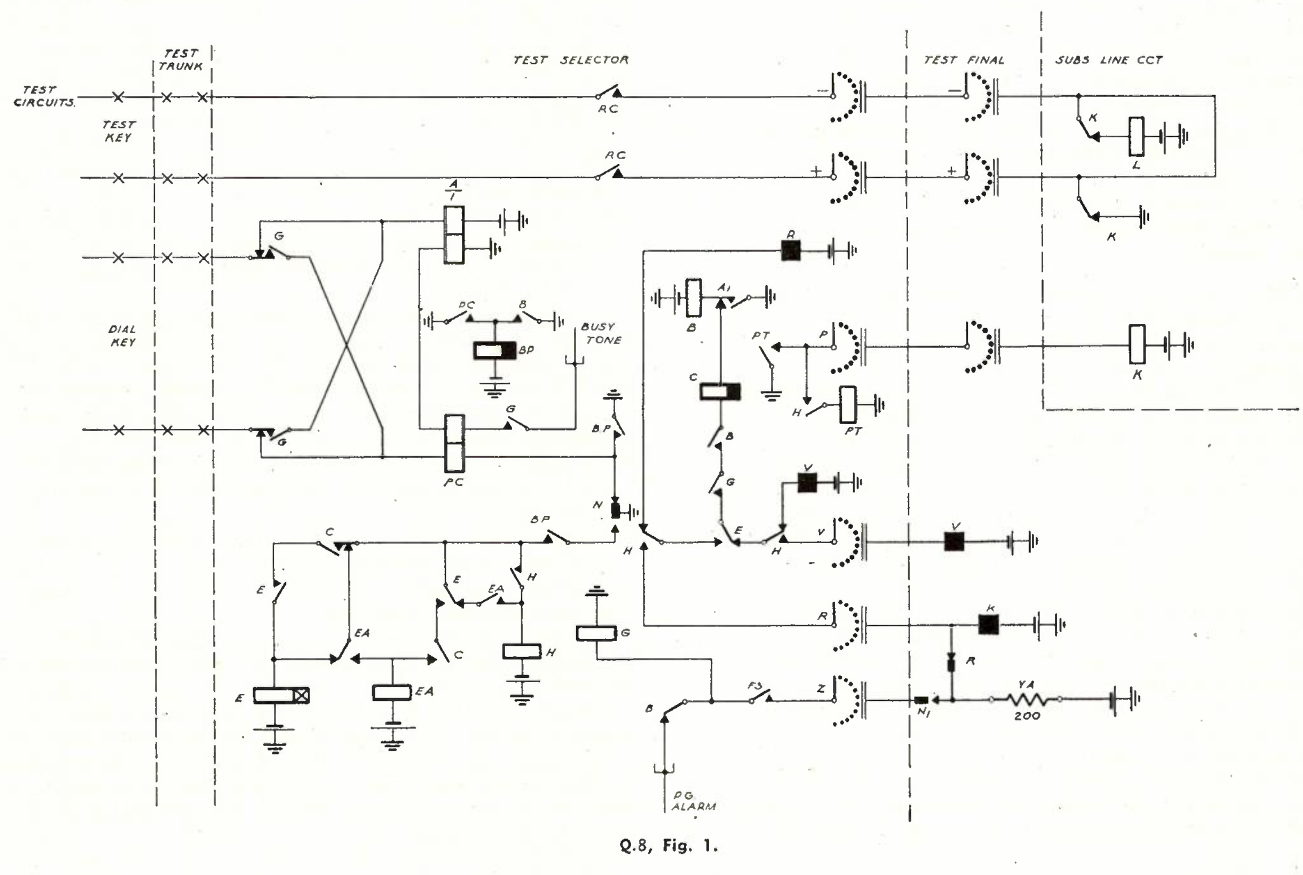
A.—Operation. Outgoing Call. A subscriber lifting his receiver loops his line, which operates L relay. L_1 short circuits K, and when L_2 closes, a drive circuit for the Driving Magnet is completed via K_1, L_1, P wiper, home contact of P arc to L_2 earth. The switch is therefore step-



Q. 9, Fig. 1.

ped off the home contact and the wipers rest on the first outlet to a first selector. If this outlet is engaged, earth will be connected on the P wire, which therefore maintains the short circuit on K relay, so the Driving Magnet re-operates and the switch again steps on.

If all outlets are engaged, the switch will drive on to contact 25, where no P wire earth is encountered. K therefore operates in series with DM, and opens the driving circuit. Operation of K changeover contacts in the line connections completes a circuit from L relay via



Q.8, Fig. 1.

the subscriber's loop to BT winding and earth. BT operates and connects busy tone to one of its windings, and the tone is induced into the subscriber's line. L holds to BT earth.

The caller, hearing busy tone, will hang up, which releases L and BT and then K. The homing drive is then completed via the homing arc L_3 and K_1 back. The switch drives to the home position where the earth is lost, and the switch stops.

On a call incoming to the subscriber, a final selector will test in via the connections from its bank shown in the figure. If the subscriber is free, the P wire will be connected, via the home contact, to the K relay. An earth from the final selector circuit therefore operates K, which opens the magnet drive circuit, and disconnects relay L. The switching through of the lines to the wipers via K contacts is harmless, as the wipers are resting on the home contacts which are open.

If a free outlet to a first selector is encountered at any stage of the search, the corresponding P wire will be clear of earth, and so K will operate. L is therefore disconnected from the subscriber's loop and will release slowly.

However, before L has released, the extension of the loop to the first selector will have operated its A and B relay, so that a holding earth is forwarded on the P wire to hold K after L_2 has released.

EXAMINATION No. 3407—ENGINEER, LINE CONSTRUCTION

Q. 1.—(a) Briefly discuss the principles upon which economic comparisons of alternative methods of plant provision are based.

(b) An economic study is to be made to determine the method to be adopted to provide trunk channels between two towns located about 60 miles apart. In addition to terminating traffic there is extensive predicted "through traffic". Consideration is being given to the following alternative schemes:—

A.—Erect initially an aerial pole route and wires and provide additional wires as required at later stages.

B.—Provide underground trunk cables.

What data would you require to enable you to make the study?

A.—(a) An economic comparison of alternative methods of plant provision is made to determine the **relative** economics of the alternatives. The results do not necessarily indicate the total costs of the alternatives; generally charges which are common to all alternatives are eliminated (these are frequently difficult to assess) with resulting simplification of the work.

With engineering works for providing services, instalments of plant may be provided at different times, i.e., the capital costs are incurred at different times, resulting in annual expenditure commencing at different times and in many instances continuing for different periods. It is essential that all these varying charges be brought to a common basis to effect a true comparison. The common basis used is the **present value** which is the amount of money which must be invested immediately, at the prevailing interest rate, to meet the charges due at a given time. The charges are said to be "capitalised" as at a common date, and the comparison of cost is then based on the "capitalised" value.

All charges must be assessed over a period which is the same for all alternative methods under comparison. If an arbitrary period is selected, allowance must be made for one of the following alternatives at the end of the period:—

(i) the plant will not continue in service after the period;

(ii) the plant will continue in service after the period.

Usually all economic comparisons are based on the assumption that the service will continue forever, i.e. "in perpetuity." For this purpose the annual charges paid must be adequate to keep the plant at its highest state of efficiency at all times, and must provide for all major renewals and replacements which may be required.

Where it is known that plant will be abandoned at the end of a certain time it is necessary, to bring all proposals to a common basis, to credit each with the residual value of the plant concerned.

In carrying out engineering work comparisons it is usual to assume that costs of material and labour and interest rates will remain constant over the period concerned, or that any changes which may occur will not influence the **relative** results.

(b) Data required to make the study is as follows:—

(1) **For each scheme**, the estimated traffic development must be known. This comprises the telephone, telegraph and broadcasting channel requirements during the period over which the comparison is to be made. Usually an arbitrary period of 20 years is selected and development is estimated for intermediate years throughout the period.

(2) For the **aerial route scheme,** the methods by which the channels are to be provided must be determined, for example, telephone channels—VF physical, 3 channel and 12 channel carrier systems. The number of circuits to be provided initially to cater for immediate needs with a margin to meet development must be determined, as well as the plant necessary at intermediate stages to meet continuing growth.

For the cost comparison the data required include:—

(i) Capital costs of the initial work required, including open wire route and lead-in arrangements, and the subsequent instalments of plant necessary.

(ii) Maintenance costs of (i). Usually average conditions are assumed, but variation should be made to cover abnormal conditions.

(iii) Sinking fund provision necessary to permit replacement of the plant at the end of its useful life. Provision is usually based on the average life of the class of plant.

(3) For the **trunk cable scheme** it would be necessary to know the method of circuit provision and the cost of trunk cable required to cater for the types of channels to be operated. Usually the class of cable or cables employed for any given scheme would have been determined as a result of a separate study taking into account lines plant, equipment, buildings and staffing costs.

For the cost comparison the data required include:—

(i) Capital costs of the cable scheme together with any subsequent capital expenditure necessary such as provision of additional loading coils.

(ii) Maintenance costs of the plant, and

(iii) Sinking fund provision.

All costs would be converted to present values, the conversion factors used depending upon the prevailing interest rate.

Usually studies are based on unit costs only, and would be made in advance of any detailed route surveys.

In conjunction with any line plant study, comparisons of alternative equipment proposals would be made so that the most economical scheme for the entire project could be determined.

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