The
Telecommunication Journal of Australia

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

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

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

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Telecommunication Journal of Australia

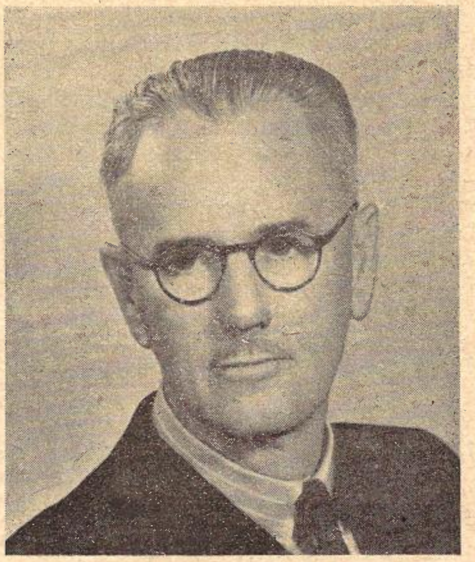
Vol. 6, No. 1 *June, 1946*

DIRECTOR-GENERAL—RESIGNATION—APPOINTMENT

On June 10, Mr. D. McVey, A.M.I.E.(Aust.), resigned as Director-General of the Posts and Telegraphs Department and was succeeded in that office by Mr. L. B. Fanning, I.S.O.

Mr. McVey had occupied the position since December, 1939, and at that time officers who knew him, particularly his former colleagues in the technical services, looked forward with high hopes to the influence his outstanding attributes would have on the progress of this Department. The war almost immediately broke through those hopes. The Government showed such appreciation of his exceptional qualities, that he was appointed successively to many important public positions, where his ability, his capacity for drive and his experience in effective organization were most needed to meet the exigencies of the home-front war activities.

D. McVEY, A.M.I.E.(Aust.)



L. B. FANNING, I.S.O.

He established the Department of War Organization of Industry, became Chief Executive Officer of the Production Executive of Cabinet, also Secretary, Department of Aircraft Production, and Director-General of Civil Aviation. In all these positions he applied his experience and knowledge, to win universal approval and inspire the further confidence of the Government, being acclaimed in the Press as Australia's No. 1 Public Servant. These spectacular moves were a tribute to the man, and also a credit to the Post Office organization, in which he received his training, and which he ultimately controlled.

He represented the Government at various Conferences overseas on matters connected with telecommunications and aircraft production, in all of which he became an outstanding figure. Although we benefited from his leadership for only a brief period, he will be long remembered by the staff for his brilliant achievements, commanding personality and warm friendliness, and particularly by members of this Society for his support of our activities.

Mr. McVey has taken an attractive position with a firm having international associations, and we are confident that he will continue to play a very important part in the development of communications in this country and possibly, overseas. The members of this Society join in extending to him their best wishes for his success and happiness in the future.

Mr. Fanning is welcomed as our Director-General. He already has a monument to his organizing and administrative ability in the establishment of the Telephone Branch, which he was selected to control when a separate organization for dealing with telephone traffic matters was found to be essential. That his wisdom, foresight and energy were successful is evidenced by the great development which has taken place in that branch during the past 20 years, and the high degree of efficiency that has been attained.

From the position of Chief Inspector (Telephones) he received appointment as Assistant Director-General, and was called upon to act for the Director-General and to administer this Department in the uncertain conditions brought about by the war, when quick action and momentous decisions were needed. He achieved notable success in these tasks, and this has culminated in the well-merited promotion as Director-General.

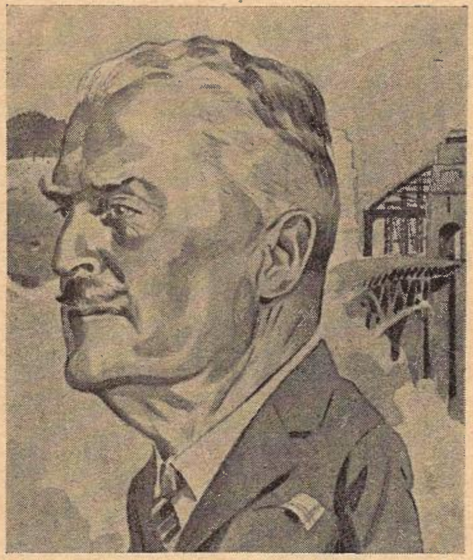
Extensive and involved as were the problems of the war years, there will be even greater ones to face in overtaking the very large arrears of connections and depreciation in quality of the services given to the community, which are the inevitable aftermath of the concentration on war needs. Apart from the normal day-to-day activities of the Department, a special post-war programme of works must be implemented. The new Director-General possesses the necessary experience and personal qualities to ensure an efficient organization, and under his able leadership we can confidently expect that the Post Office will gradually overcome its problems and will effectively meet the public demands.

Mr. Fanning carries with him the loyalty and best wishes of all the members of this Society in the great task ahead of him.

S. W. GLEED, M.I.E.(Aust.)

On 11th May, 1945, Mr. S. W. Gleed, Superintending Engineer, Postmaster-General's Department, N.S.W., retired from the Service. Mr. Gleed came to this country from the British Post Office in 1915 to take an appointment on the staff of the Chief Engineer. He occupied the position of Supervising Engineer, Telegraphs and General Works, from 1924 to 1932. His chief function was to direct policy on the Engineering side of the Telegraph Service, and during his règime very great strides were made in the mechanization of the system and the modernization of the larger telegraph offices throughout the Commonwealth. The first major change was the introduction of the Murray Multiplex System on the heavily loaded interstate circuits. He was responsible for the direction of, and took an active part personally in the early experimental work and pioneering of this system in Australia.

About 1926, under his direction, the capitals of the two major States, Victoria and New South Wales, were provided with completely new and up-to-date Chief Telegraph Offices, which for the first time possessed such facilities as belt conveyors and other devices for the speedy circulation of traffic within these large offices. Picture transmission and carrier telegraph systems were also introduced during this period; and it may well be said that during Mr. Gleed's period as Chief Telegraph Engineer for the Commonwealth, a new era of telegraph communication within the country was entered upon. He had the satisfaction, before moving on to South Australia as Superintending Engineer in 1934, of seeing it established on a highly efficient basis, and having almost entirely displaced the old Wheatstone Creed system.



S. W. GLEED, M.I.E.(Aust.)

While in Central Office he took a very active interest in the Professional Officers' Association, and it was while he was General President that the system of annual increments was first introduced into the Commonwealth Public Service. The whole of the Service must be thankful for Mr. Gleed's efforts in this direction, as it was mainly on evidence he produced from England that the system was introduced. As Superintending Engineer, South Australia, he was associated with the Centenary of South Australia, when the P.M.G.'s Department presented an outstanding display at the Centenary Exhibition and also in the Pageant of Progress procession. He also developed co-operation between the Traffic and Engineering Branches on matters concerning the grade of service to the public.

In 1938 he assumed control of New South Wales as Superintending Engineer, and to him fell the onerous task of maintaining communications over the difficult war years. While in Sydney he took an active interest in the Institution of Engineers, Australia, and was Vice-Chairman and then Chairman of the Electrical and Communication Engineering Branch Committee, as well as being a member of the Sydney Division Committee. Mr. Gleed is a full member of this Institution.

Mr. and Mrs. Gleed have returned to England to enjoy the peaceful conditions of the countryside. We wish them good health and a long enjoyment of their new surroundings.

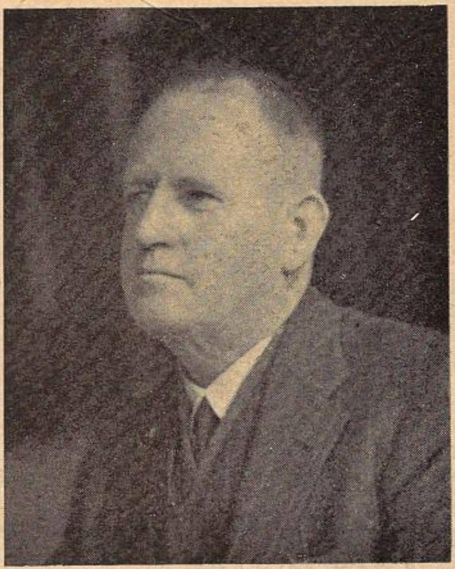
A. S. McGREGOR

With the resignation of Mr. A. S. McGregor the Department has lost an enterprising and vigorous engineer, an original thinker, and a forceful and colourful personality. He joined the Department as telegraph messenger at Condobolin, N.S.W., in 1907 and, graduating through the ranks of telephone attendant, junior instrument fitter, junior mechanic, mechanic and assistant engineer, he was appointed as engineer in 1918. In 1927 he was appointed State Sectional Engineer in Sydney, and in 1929 became Divisional Engineer. From this position he was appointed as Supervising Engineer (Lines), Victoria, in 1934, became Assistant Superintending Engineer, Victoria, in 1937, and in 1940 was promoted to the position of Supervising Engineer, Telegraphs and General Works, Chief Engineer's Branch, which he held at the time of his resignation.

Although most of Mr. McGregor's Departmental experience was in New South Wales and Victoria, he will be remembered by many as one of the three members of the Lines Committee which toured the Commonwealth during 1928-29, and whose recommendations had a marked influence upon Departmental Lines practice in the decade which followed.

He was, and presumably still is, a man of unbounded energy, and possesses the ability to concentrate his energies in one direction, apparently to the exclusion of all other matters, when it seems to him that the importance of the matter warrants it. For this reason, it sometimes appeared that his interests were limited; but this is far from true, and those who know him best recognize his wide knowledge of many things quite extraneous to his Departmental duties.

One of the most pleasant aspects of Mr. McGregor's character was his instinctive sympathy for the underdog; and, notwithstanding the fact that he himself owed his success largely to his own energy and ability, he was always ready to stretch out a helping hand to those who needed it, and there are many members of this Department who will remember him with affection and gratitude.



A. S. McGREGOR

During his Departmental career he gave all he had to the Department; but at the back of his mind remained the ambition to return one day to his station at Condobolin. He has now achieved that ambition, whilst still in the prime of life, and all who knew him will wish him many years of happiness and success in his new sphere of activities.

VISITORS FROM THE BRITISH POST OFFICE

Recently, four members of the British Post Office arrived in Australia to discuss with officers of this Department telephone developments in the Commonwealth, particularly those related to the Melbourne Trunk Exchange.

Mr. G. J. S. Little, the leader of the delegation, and Mr. R. L. Bell, are engineers, while Messrs. A. Murphy and H. C. Andrews are from the Administrative and Traffic Staff. Although the visitors were extremely busy with their official investigations, they graciously gave up an evening to speak at a meeting of the Postal Electrical Society in Melbourne on 13th May, during which they gave very interesting information in a pleasant and informal talk on the long line developments in Great Britain, including a forecast of future trends, the work of the B.P.O. during the war years and the traffic problems related to trunk line operating.

The Director-General, Mr. McVey, expressed the thanks of the Society to the visitors, and emphasized the value to be gained by inter-Departmental visits of this nature. He indicated the satisfaction of the Australian Post Office in attracting the attention of the British Post Office to some of our achievements.

The visitors spent six crowded weeks in special investigations and considerations of the trunk line services in Victoria, particularly in the effect on the installation of the trunk exchange.

They spent a few days in South Australia, where they gave a talk to officers of the Department, and later visited New South Wales for further discussions and inspections of plant. They left Sydney by flying boat on June 22nd, and are now back home.

As a result of the visit, many personal associations have resulted in friendships which are sure to be of mutual value in the future. The visitors readily provided information on various phases of B.P.O. organization and conditions, which we feel confident has been of considerable benefit to this Department. It is hoped that the information gained by the delegation will be of great help to the organization sponsoring the visit.

MAKING THE A.P.O. GENERATOR

A. R. Cameron

Before the war our workshops were concerned mainly with jobbing type of work and, when the demand came for manufacture of items of signal equipment in considerable quantities, it was necessary to change the organisation in many respects to meet the needs for mass production. The changes were made in accordance with the requirements from time to time and, therefore, it was a gradual process which did not interfere with output in the course of its rapid and unforeseeable expansion. The organisation thus built up is still needed in the production of material for the Department.

One of the items now being made under mass production methods in the Sydney workshops is the A.P.O. generator, and it is intended in this article to indicate some of the main features of the organisation which facilitate the production, before describing the making of the generator itself. The term "Mass Production" is frequently used to denote any type of production in quantity; but there are many different methods used, and these can be classified into two main types of manufacturing, i.e., "Unitary Production" and "Job Production." The former term covers the continuous production of a proprietary line embodying a special works layout and organisation individual to the unit or line being produced. Although many of the items of material required by the Department readily lend themselves to this class of manufacture, the Departmental system does not conveniently permit of the establishment of "Unitary Production" in its own workshops. There is no guarantee of continuity of orders, and there is a great variety of equipment ordered, the priority for which may alter from time to time. At most times there is a large number of contracts or jobs, each requiring different treatment, passing through or waiting to be done in any particular section of the workshops. The work is, therefore, of the "Job Production" type; that is, the production of orders of limited quantity. The numbers may range up to 50,000 or more of one type of article, but the plans must assume that the job finishes at this quantity and is not a continuous process. (The term "Job Production" has no association with individual jobbing work, which is carried out in a different section of the workshops).

The production of signal equipment for defence purposes required "Job Production" methods. It had not been necessary to organise for such methods prior to the war, for no manufacturing of such extent or diversity had ever been undertaken before the war demands were made. Simultaneously, there were orders for specific items for increased quantities of Departmental equipment for service purposes, and the demands for equipment for this Department have now completely replaced the defence work. The main special sections of the organisation peculiar to the "Job Production" undertaken in the Sydney Workshops, and which have been applied in the production of the generator are the "Design and Estimating Section" and the "Production Planning Section," and some aspects of these sections will now be given.

Design and Estimating: For any project it is first necessary to determine if it is practicable to make the article satisfactorily with the facilities available in the workshops. This requires practical knowledge of the accommodation, plant and capacity of the shops, and the practicability of carrying out the various processes involved. The preliminary consideration and planning involve, mainly:—

(1) Feasibility of manufacture;
(2) Availability of raw material;
(3) Plant availability and capacity;
(4) Workshops accommodation;
(5) Availability of technical staff;
(6) Tool and jig design;
(7) Preparation of the estimate.

In making the estimate it is necessary to consider fully all factors outlined, and prepare information sufficiently detailed to serve as a guide to the production department when the order is received.

Although in many cases and for various

reasons the prepared information incidental to estimating is not accurate enough for production control purposes, it does save considerable time when the order is received.

The preparation of every estimate in detail would require an executive and design staff out of all proportion to the benefits to be derived. A large amount of work is involved in thoroughly pre-planning a job, and it is not economical to carefully design tools and jigs and establish machine hours and other factors unless there is a reasonable prospect of getting the job. As a usual practice, so far as tools and jigs are concerned, the estimate is based on rough sketches rather than accurate drawings, and past experience and knowledge are applied to determine that they can be used successfully.

Availability of raw material is a vital factor affecting production. Very often it is necessary to use substitute materials for those specified, necessitating variation in the method of manufacture. In considering substitutes, in the case of metals, it is initially important whether ferrous or non-ferrous metals are to be used; and, in either case, there are innumerable grades of each type, and often selection with a view to economy and ease of manufacture is a difficult matter. For instance, where a ferrous metal is to be used, the first determination is in regard to the function of the metal, i.e., whether used for simple fabrication, such as a housing pillar, or whether for internal or external use. Possibly, requirements in this connection will need special types of mild steel for blanking or deep drawing operations, while other parts may require specially strong steel. Again, magnetic iron or steel may be required, and there is invariably a number of factors which have to be given consideration in order to determine the exact type required to meet the specification. In the non-ferrous group, there is an enormous field to be explored in order to ensure selection of the most appropriate material.

The designing engineer must know the details of each machine, and its capability and capacity, to be in a position to design appropriate tools. In this field, the engineer is required to exercise his utmost ingenuity, so that when the tools are produced they will be within the capacity of the machine and capable of producing a worthwhile and useful article. Press work plays a very important part in mass production. It enables blanking, piercing, forming, drawing and bending operations to be carried out rapidly and economically. It provides the most effective means of producing interchangeable parts within confined tolerances. Plastic moulding of parts also occupies a big field in the production sphere. Again in this case the engineer is confronted with the problem of selecting the type and grade of moulded product to meet the specifications of the job, or to provide a satisfactory substitute.

In many cases, the shop has expensive dies and tools, some of which may, with slight modifications, be adapted to the needs of the job in hand. This often involves additional processes as against the properly designed tool for the job, but it often saves considerable time and cost in the manufacture of tools. The engineer is required to know or assess the relative merits of using adapted tools, with extra processes, probably, as against manufacture of a new tool. Within limits, it is often possible to save much time and money by the adaptation of existing tools.

Estimating and tendering are major factors in sustaining the life of a workshops; and, no matter what production facilities exist, if the planning for the order is not technically and economically sound, no amount of doctoring will keep the "patient" alive.

Production Planning: When the order is received, the job then concerns both the design and production sections. The main considerations are briefly discussed below:—

(a) **Tools, Jigs and Fixtures:** A very important aspect of each job is the design and production of the tools and jigs. Tool design is under the control of a Divisional Engineer, assisted by tool design draughtsmen. It is essential, in the interests of efficiency, that the design staff co-operates fully with the production staff. In the preliminary discussions several general methods of attacking a job might be examined and, after determining the most suitable, the design staff is let loose on the work of preparing the detailed tooling plans.

(b) **Material Ordering:** This is controlled by the Production Engineer who, firstly, re-examines the estimate and determines as closely as practicable the grades, classes and quantities of material required.

These lists are charted by the procurement section, and a continuous follow-up is maintained so that the procurement officer is in a position to advise the Engineer daily in respect of material supplies.

(c) **Production Charts** (Piece parts, components and assemblies): These cover full manufacturing details and process operations. Jobs are divided into group quantities, and progressive costing of each group is available to the Engineer. Material quantities are listed for each group quantity to be produced. This information furnishes a ready check of the material ordered and used on the job.

(d) **Master Production Charts:** These charts record the progressive manufacture of piece parts, sub-components, components and final assemblies. By reference to this chart, the production Engineer is able to ascertain readily the exact overall position of the job at any stage.

The above will give some idea of the major processes for planning the production of an item such as the generator. While it does not give a complete picture of the detailed work required, it forms a background to the following section.

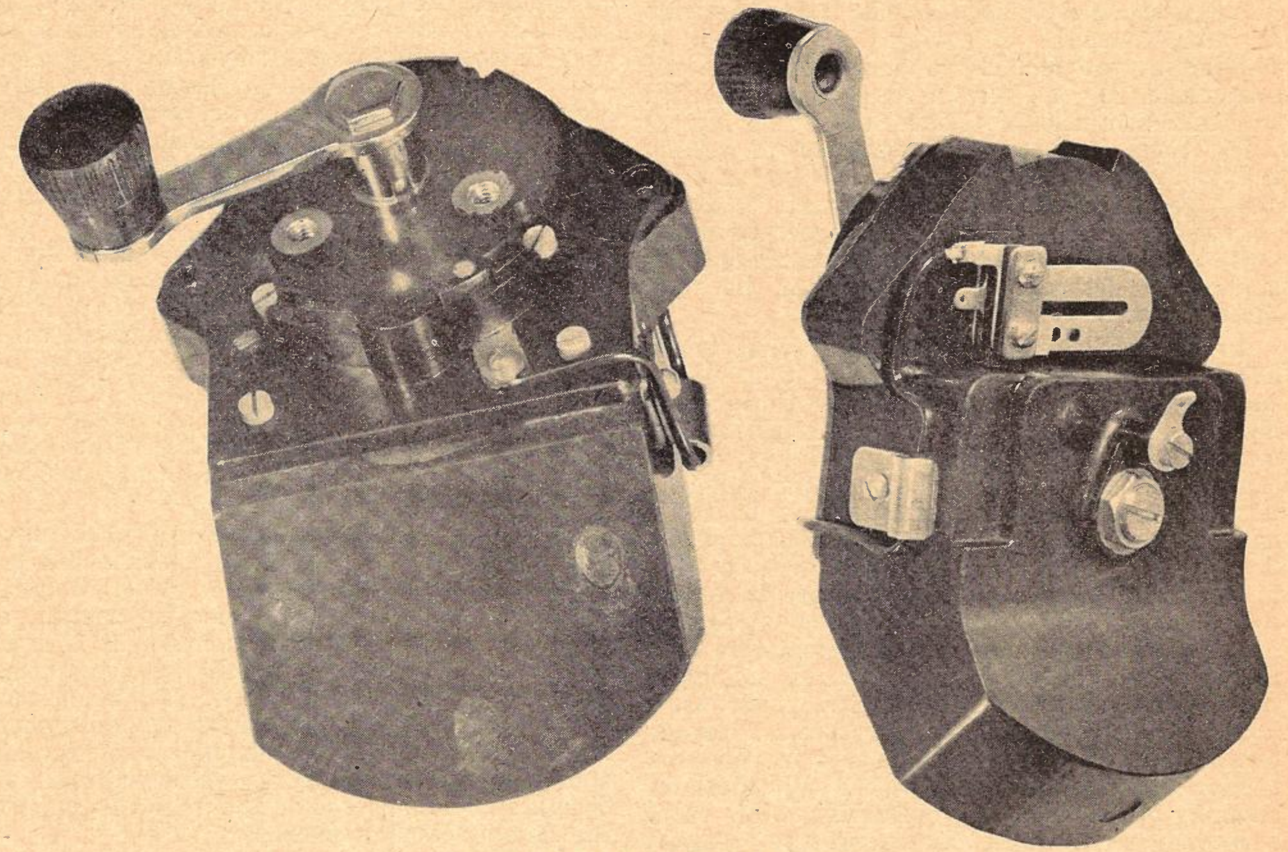


Fig. 1.—The A.P.O. Moulded Generator.

MANUFACTURE OF THE A.P.O. GENERATOR

The design and production of the plastic bonded A.P.O. Generator is an indication of the progress being made in Australia towards establishing our own standards for equipment to meet the communication requirements of the Commonwealth. Reference was made in previous articles to the fact that it originated in the circuit laboratory of the Chief Engineer's Office, and was developed for manufacture by the Sydney Workshops staff.

A general view of the completed generator is given in Fig. 1. The special shape enables it to be fitted in the minimum space in a 300 type telephone as an alternative to the dial in the design of the universal telephone (see Vol. 5, No. 6, p. 368). A special feature—detailed later —is the bonding in plastic of the armature laminations and the magnet with pole pieces. This method was developed in the Sydney Workshops and, as far as is known, it is a novel process.

For assembly purposes the moulded generator consists of five sub-assemblies, namely, Crank, Front Plate, Armature, Moulded Body and Springset, shown in an exploded arrangement in Fig. 2. Dealing in turn with the various sub-assemblies in the order shown in the exploded view, the first is:—

The Crank Assembly: The crank assembly offers no major problems of manufacture, a multiple-cavity moulding die for the plastic knob and a milling fixture being used in order to keep manufacturing cost to a minimum. Cleveland auto lathes are used in the production of the spindle socket, spigot, knob insert and knob mounting screw. A left-hand thread is used to prevent loosening of this screw during operation of the generator.

The crank arm is made from brass strip in a normal type pierce and blank follow die. The driving slot is milled in the spindle socket. The assembly of the crank arm, spindle socket and spigot is effected in riveting tools. This assembly is then inspected and finished by plating in bright chromium. The knobs are moulded seven at a time. The insertion of the knob mounting screw completes this unit, which is then inspected and is ready for use in the final assembly.

Front Plate Assembly (see Fig. 3): Manufacture of this assembly forms quite a large portion of the total work in the generator, because it contains the driving spindle unit, one of the armature bearings, brush-holder and locating flanges.

The spindle unit consists of a silver steel rod selected to the limits of ±.0005″ tolerance on the nominal size of .250″, fitted with driving pins. This simple looking piece of ¼″ steel rod with two holes drilled across it requires care in manufacture. The size particularly and position of the holes is vital, because .104″ diameter pins have to be pressed into them. After trials, it was decided to knurl the centre section of the driving pin. This permitted the hole to have limits of .103″ to .105″, and the .104″ pin is knurled to .106″ to .109″. Assembly of these parts then became simple and efficient. The driving gear blank is turned from extruded brass rod in a turret lathe. A bush, turned from phosphor bronze and having a driving slot milled across it, is pressed into the gear blank. This driving slot is not merely a keyway, it is actually a cam track, along which the driving pin travels when the crank is turned, to close the ringing circuit of the springset, which is mounted on the rear of the body moulding. The finish on this slot had to be free from any irregularity which would cause sticking and incorrect operation of the springset.

Three rivet holes are then drilled through the gear blank and the driving bush shoulder and copper rivets inserted. The bearing hole is then bored true to the outside periphery of the blank and reamed to size. The unit is then ready for gear cutting to British standard specifications on a Fellow's gear shaper. The hobbs used for this purpose are subjected to inspection by the C.S.I.R. for size and shape.

A collar which takes the thrust of this spring is produced in a Cleveland automatic lathe, and the grub screw hole drilled and tapped. The spacing sleeve which serves to keep the driving gear in position is machined from ½″ x 20 gauge brass tubing, an oil hole being drilled in its wall. The components are then ready for the insertion of the driving pin and fitting of the collar.

The front plate moulding contains inserts for the spindle bearing, generator mounting screws and brush-holder; all turning work for these inserts is performed in Cleveland auto. lathes. The terminal link which forms part of the brush-holder is blanked from 14 gauge H.H. brass sheet. The punch and die used on this blank were given excessive clearance, and this gave a heavy break on the side of the blank, thus forming a taper on the blank edge. One face of this insert faces on the moulding, and the tapered edge enables it to lock in the moulding. The terminal link and the brush insert are staked together.

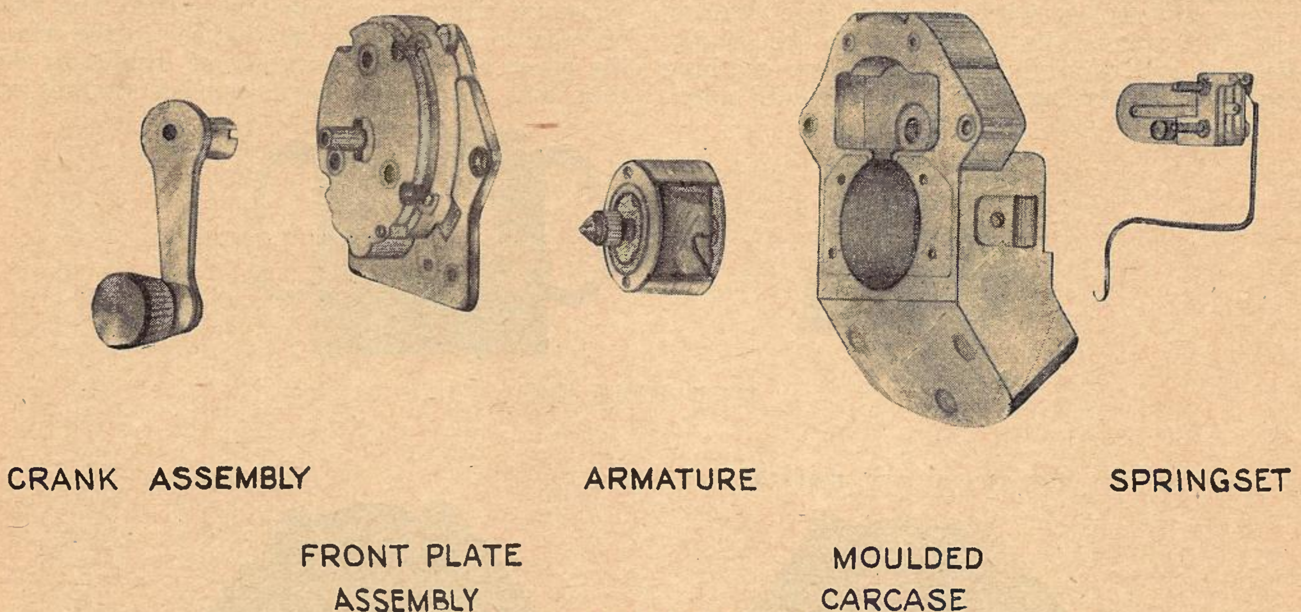


Fig. 2.—Sub Assemblies—Exploded Form.

Moulding of Front Plate: It was expected that the moulded front plate would warp badly if precautions were not taken, so cooling fixtures were provided. The only unexpected trouble was breaking of the brush-holder insert location pin. When the pin was tempered sufficiently to prevent breakage, it bent, thus allowing the insert to be out of square in the moulding. This was overcome by using "vibrac 65" pins and taking a little care to have sufficient powder in the near vicinity of this insert to prevent very much "flow" occurring around the brush-holder during moulding.

Slight warpage made it necessary to duplicate the flattening effect of screwing the front plate on to the body, when machining it. To gain this effect, cam-operated pins, duplicating as closely as possible the clamping action of the screws, were used in the fixtures for all machining and gauging operations on the front plate.

The location lugs are machined. The location for this operation is taken from the rough machined spindle bearing, a hollow mill type of cutter being used to size the lugs. Ordinary high-speed cutters wore badly, and only sufficed to machine about 100 components before becoming oversize. It was found that "nitriding" the cutters increased their life to about 1000 components.

A jig is used to finish machining the spindle bearing and form the pivot bearing. The centre dimensions between this cone bearing and the spindle bearing have to be closely watched and carefully gauged, as gear meshing tolerances, according to British standard specifications, permitted only .001" variance from the nominal mounting centres. These specifications have to be adhered to to ensure quiet running of gears and the least possible loss of efficiency in drive. This last point is important, as it is necessary to keep the torque needed to operate the generator below certain specified figures. Very slight tightness in the meshing of the gears increases this torque immensely. The cone bearing is burnished to ensure long life and free running.

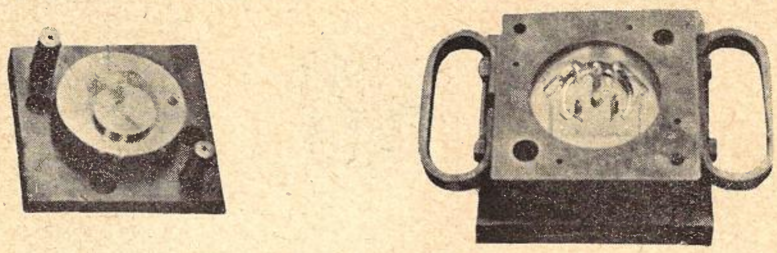
The moulding is then inspected and is ready for the assembly of the driving gear and spindle unit, to form the completed front plate assembly.

Armature Assembly (see Fig. 4): This unit contains a component which, as far as is known, is the first of its type ever made. That is the moulded armature core. In this moulding, $1^1/_3$ oz. of magnetic iron laminations are suspended in only $^1/_3$ oz. of Phenol Formaldehyde moulding powder.

These laminations are of two sizes, large and small. There are six large and twelve small laminations to a core. The only material holding this pile-up of laminations together is a light skin of bakelite over the section of the core which forms the winding space, and whatever flows into the four $^1/_{16}$" diameter holes provided for the purpose in the laminations. These, in effect, form bakelite rivets. The skin of bakelite covering the laminations in the winding space avoids the necessity of insulating the core, and so the winding is applied straight on to the moulding. Destruction tests have proved that the armature has considerable strength, and that the moulding powder flows well in between the laminations and into the "rivet holes."

The blanked laminations of magnetic iron are annealed and assembled on a loading fixture, shown in Fig. 4. The moulding die is a four-cavity "sprue" type die.

High-speed winding machines with special chucks are used to apply the 6500 turns of 37 B and S enamelled wire which forms the winding of the armature. Lead-out wires —4/.0060 D.S.C. are attached, and the outer surface of the winding is protected with two layers of oiled silk.



MOULDING DIE

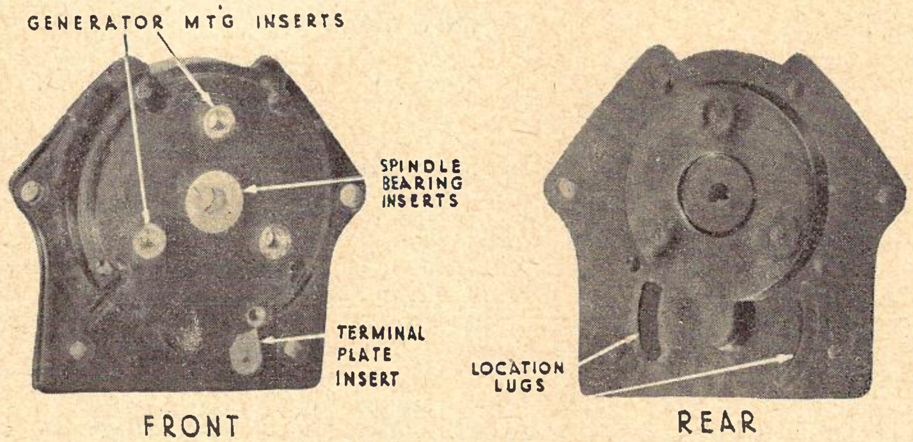


Fig. 3.—Front Plate Assembly.

The end plate which mounts the pinion is made from die-cast brass. Due to warpage in casting, they are put through a flattening operation. When flattened, the holes for mounting screws and brush ring mounting are pierced. The pivot hole is drilled, the spigot of the end plate being held in a collet and the face of the job trued up to an indicator. When the mounting holes are countersunk, the end plate is ready for fitting of pivot, pinion and the brush ring.

Machining of the driving tongue on the pivot offered a little problem if it was to be milled. It was decided to swage the turned blank. This was done, and the displaced metal cropped off in another press operation. The finished article has an excellently formed tongue of the correct dimensions, and there is no burr to be removed in milling.

The pinion blanks are turned and the driving slots milled in them. They are gear cut in a "Fellow's," and subjected to the same rigid inspection as to the driving gears. The pinion is pressed on to the end plate spigot and the pivot inserted and staked. The bush for brush ring insulation is injection moulded from polystyrene. The brush ring and insulation are assembled to the end plate in a fixture which clamps the assembly together and at the same time secures the brush ring by means of three lugs. This serves to keep the brush ring flat and so eliminates excess torque in operations of the generator due to excess brush friction. The finished end plate is inspected, and then is ready for attaching to the wound armature.

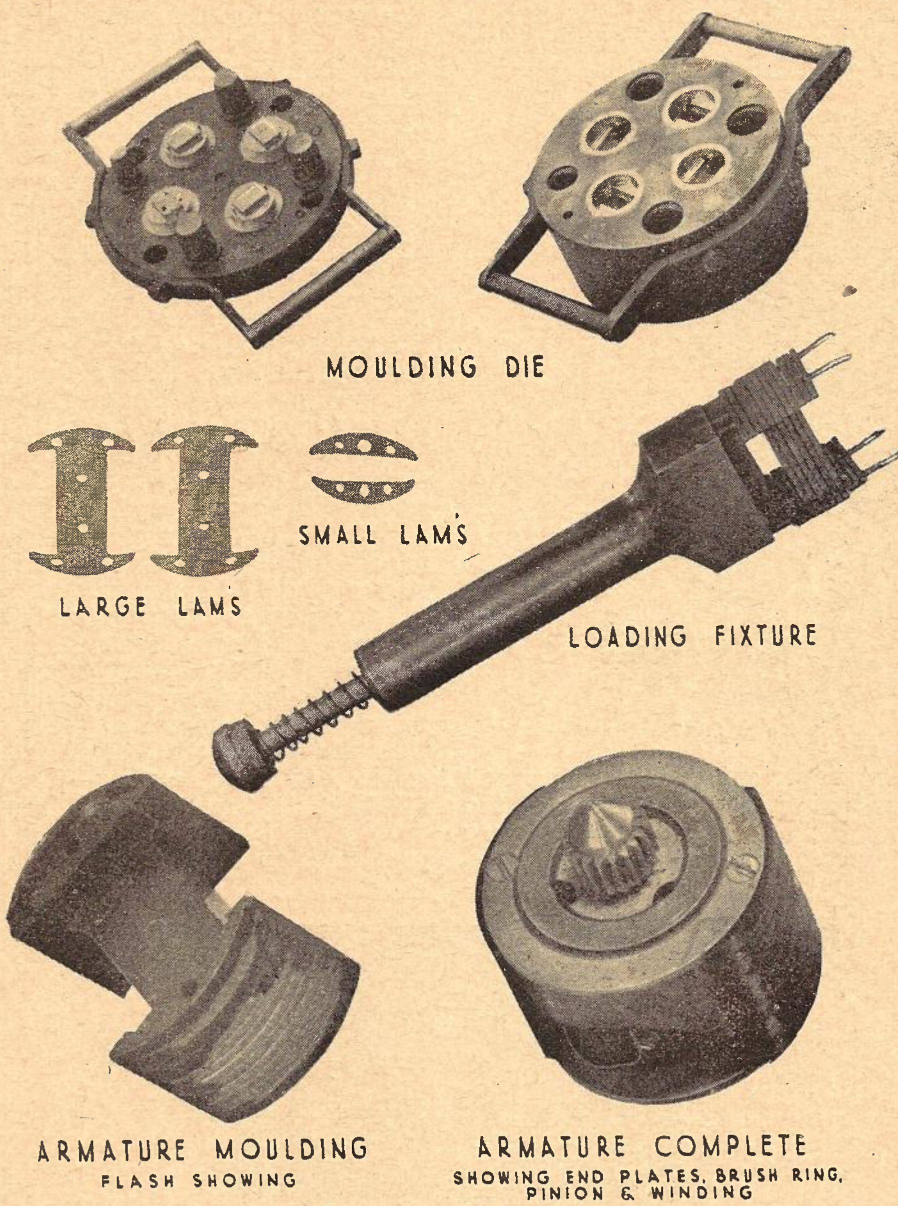


Fig. 4.—Armature Assembly.

Pivots are rough machined in a "Rivett" capstan lathe and staked into the blanked end plate in a press tool. This unit is then inspected. These components are now assembled and the leads soldered to the brush ring lugs. The operation consists simply of connecting the leads, soldering and inserting four screws. Location of end plates is taken care of by lips on the moulding which remain remarkably constant in size and afford good location.

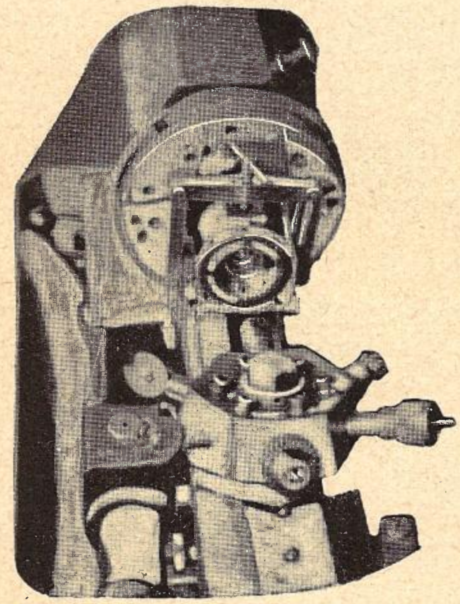


Fig. 5.—Armature Set-up in Lathe for Machining of Pivots.

One of the most important operations has yet to be performed, that is, the machining of the pivots and fitting the ball into the adjustment end of the armature. This operation is necessary for the purpose of trueing-up the pivot axis with the working face of the pinion. The necessity for this feature will be realised if one considers that, when the armature is mounted between centres, the pinion must run true to within .001". Otherwise, tight meshing of gear and pinion occurs. To acquire this result, a fixture was designed for use on a "Rivett" capstan lathe. The fact that the outside face of the pinion is hobbed to size during gear cutting ensures that it is true to the working face of it. So the armature was located from the face and clamped between a face square with the axis of the pinion location and a universally moving face at the other end. This allowed the armature to find its own location and so throw any out-of-truth in the moulding and end plates to the end opposite the pinion. The fixture is clamped on a V block mounted on the face plate. Tools for the machining of the pivots are mounted in the capstan head. The set-up is shown in Fig. 5. The gear end pivot is faced, formed, and then burnished. The fixture is reversed in the V block and the other end-pivot faced and formed, the ball hole drilled and the ball inserted and spun over. Thus, both the pivots are machined in the one location. In this way it is possible to obtain the required degree of accuracy on this component.

Armatures are then given final inspection and are ready for assembly.

Moulded Body Carcase (see Fig. 6): There are many inserts in this mould, the main ones being the pole pieces and the magnet casting. The pole pieces are formed from a single malleable cast iron casting—these are bored to 1.500" ±.002" and the end faced in an auto-fed drilling machine. This machine was chosen in preference to a lathe, because of the heavy de-

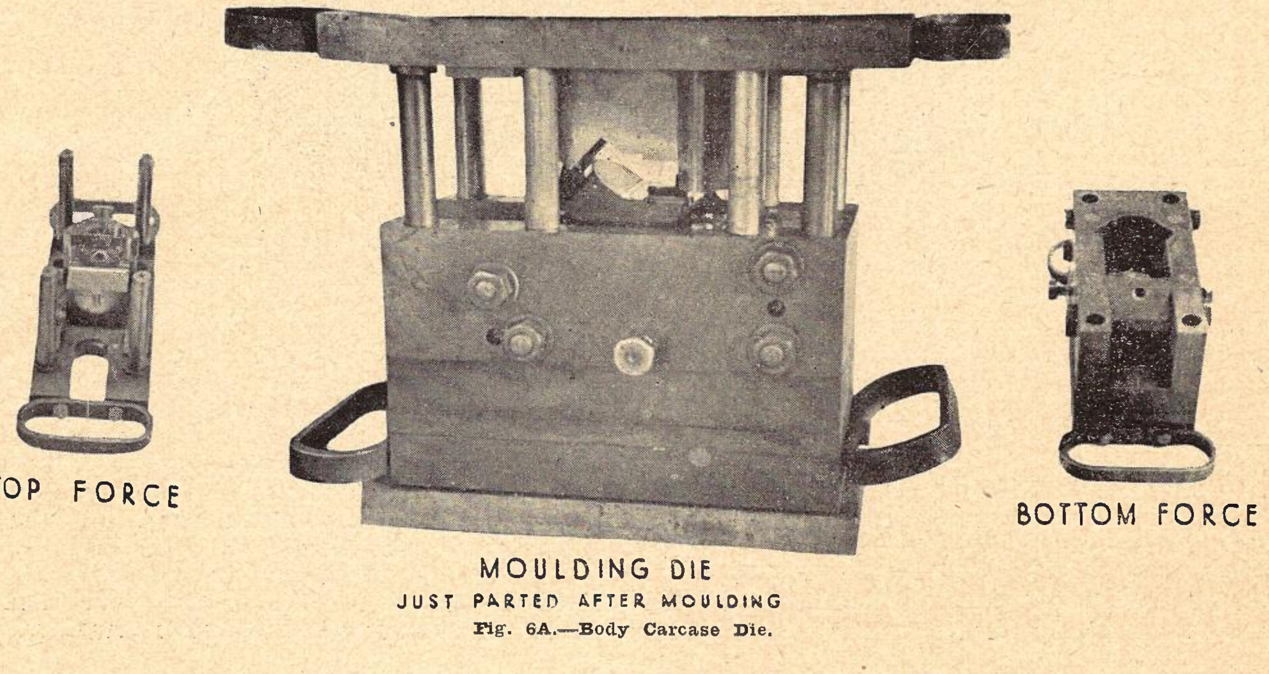


Fig. 6A.—Body Carcase Die.

mand which was already placed on our turning shop and the inability to secure a further lathe of suitable dimensions.

The next operation is to slab mill the top side (as illustrated). This faces and breaks through one side of the casting, into the bore. A single cut approximately $2^5/_{16}''$ x $\frac{5}{8}''$ in a heavy-duty "Herbert" milling machine performs this operation. The fixture used holds 10 castings. The final milling operation is to gang mill the lower side. This faces and parts off the two pole pieces, which now require only deburring. The pole pieces are cadmium plated to prevent rust.

tractions. Clamps had to be set at critical angles and "draw" on all inserts varied to give a satisfactory product. All these factors were determined in the initial trial die, and it is a tribute to the design staff that it is still in production. A second die is now in service, in order that production can be maintained at a satisfactory rate.

Finishing: Several "fins" unavoidable in moulding have to be removed, and grinding operations are used for this purpose. All drilling and tapping operations are located from the armature cavity and from the plate mounting face. Insert clamping holes in the moulding

Fig. 6B.—Pole Piece Inserts.

The other major insert, the magnet, is cast Alnico 2, and the only finishing operation is to grind the two end faces where the magnet abuts the pole pieces. The brush insert, pivot bearing, front plate fixing and case mounting inserts used in the carcase are turned from bar stock in Cleveland auto. lathes.

The springset mounting plate insert is produced in a pierce and blank die. This tool is given excess clearance between punch and die as was the terminal link die used in the front plate moulding. The reason was, again, to have the blank sufficiently tapered to lock it in the moulding.

Moulding of Body Carcase (see Fig. 6): The original sample to which tenders were called provided for an all-metal assembly of pole pieces to magnet, with separate metal back and front plates affixed. In conceiving the idea of fabrication by moulding, it was considered that, apart from assembling pole pieces to magnet, the back plate could be incorporated in one moulding. The job was not, however, as easy as it looked. Two spindle centres had to be accurately located and retain their location after moulding. Shrinkage variations both in metals and powder had to be taken care of, and, in view of the large percentage of metal to powder content, some experimentation was necessary before a suitable mica-filled powder with satisfactory shrinkage characteristics was obtained. Many of the location pins were small, and would not stand the pressures of moulding or con-

are filled with hard pitch and lightly buffed over. Carcases are inspected and magnetised. They are then ready for assembly.

The Springset: This is the remaining sub-assembly of the generator. It is simply a twin-buffer, changeover spring assembly. Buffer springs are pierced and blanked from spring hard nickel silver strip.

Contacting of springs has always been a problem. The number of springs to be contacted for generators necessitated an improved method to those existing for jobbing in the Workshops. Contacting tools which headed both contacts in one blow, whether single or twin contacts, were designed. These were the forerunners to an automatic contacting device which has been designed; but, owing to limited tooling capacity, is not yet in use. It has a hopper feed, and is so completely automatic that springs simply drop out when contacted. The springs are insulated by separators between the springs and tubes around the mounting screws. These components, together with the lifting stud, are injection moulded with polystyrene.

Other Accessories: These include brushes, pivot bearing and locknut, screws, solder lug and cord clip. The brushes are supplied complete with springs from the manufacturer. Pivot bearings are turned and threaded in a capstan lathe from phosphor bronze alloy. Originally, these were made from mild steel and case hardened, but did not wear very well, so the phosphor bronze was substituted.

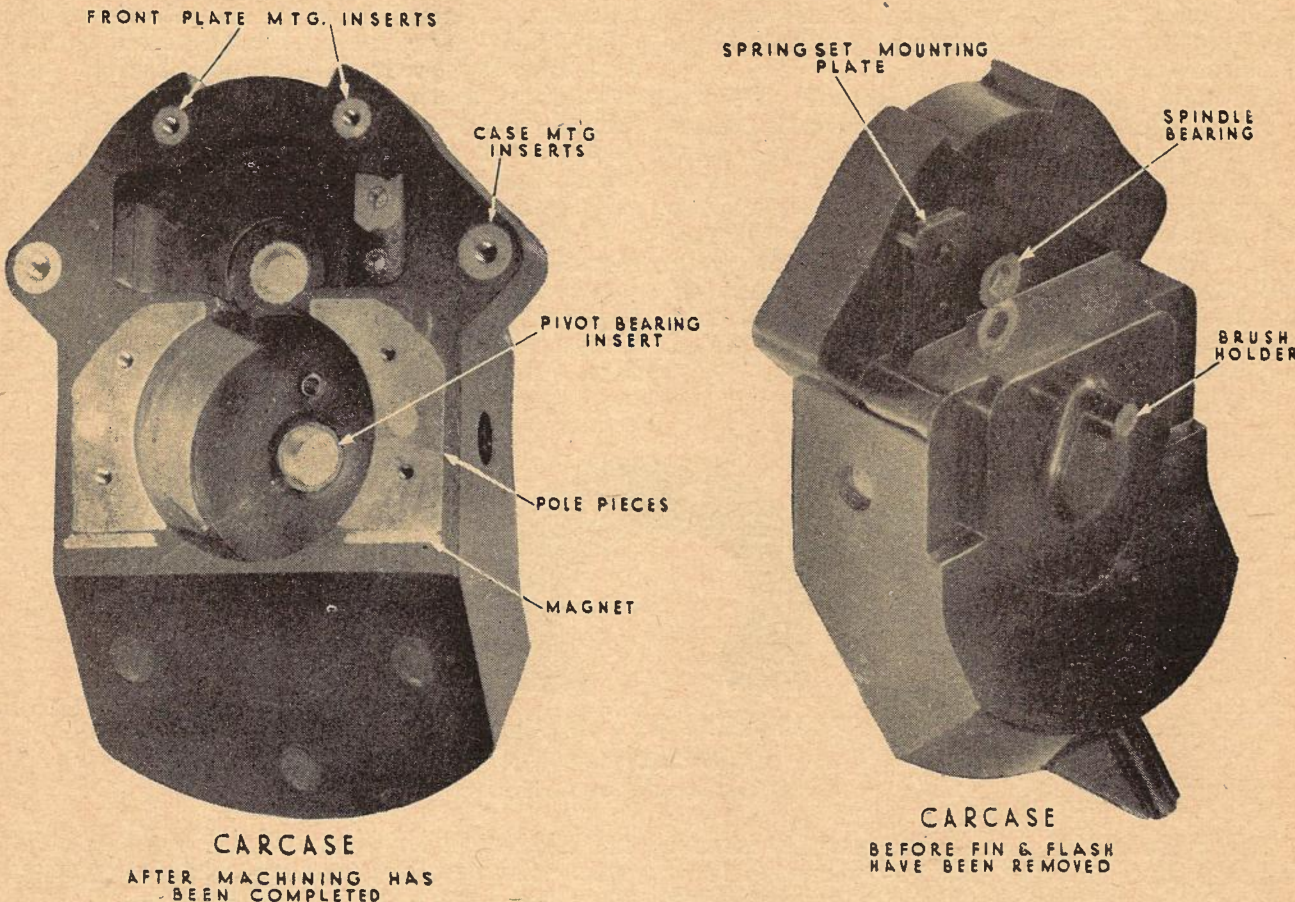


Fig. 6C.—Moulded Carcase.

Cutter marks on the pivot bearing face could not be completely removed, so a turning operation was changed to a simple indenting operation, which produced a polished, work-hardened bearing core. This gives good wearing properties.

The Final Assembly: Final assembly is straightforward, due to the amount of thought given to the design of the generators. The moulding in one piece of the pole pieces, magnet and what is normally the back plate assembly, eliminates the separate assembly of these several components. In short, the assembly of the five sub-assemblies involves merely the insertion of a few screws.

First operation is to attach the springset assembly in proper alignment to the body with two screws. The armature is then inserted and the front plate assembly fitted. The alignment is effected by machined lugs on the front plate moulding by six screws.

A pivot bearing is screwed into the insert in the carcase moulding and the locknut loosely fitted. The crank is fitted in place and the fixing screw inserted. The brushes are inserted and the springset is wired. The cord clip is screwed in place and the generator is ready for adjusting and testing.

The watchword in all these operations is cleanliness. All moving parts, gears and bearings have to be scrupulously clean, and the lubricant which is used carefully protected from grit.

Adjustment and Testing: Adjustment of the generator is reasonably straightforward. The cone bearing has simply to be adjusted and the locknut tightened. The tension and set of the lever spring are checked, and contact points are adjusted for alignment. During test, generators are inspected for any flaws in appearance, as well as for torque of operation and output. Output is considerably higher for the specified torque than called for, which indicates that both electrical and mechanical design are efficient. Throughout the production regular gauging and inspections are made of each part and of all sub-assemblies.

OUTLINE OF VF DIALLING SYSTEM, QUEENSLAND

J. M. Loth and G. N. Smith, B.Sc.

A review of V.F. dialling systems at present in use on world telephone networks, including Australian systems, was given by Mr. F. P. O'Grady in the "Journal" for February, 1944 (Vol. 4, No. 6). As a supplement to the information given therein, the present article outlines a comparatively simple and inexpensive system developed in Queensland during recent months, which has performed very satisfactorily in field trials. It does not give the range of signals covered by the two V.F. systems described in the article referred to, but it supplies signals similar to those at present used on battery dialling circuits, and these satisfactorily meet existing traffic requirements.

Features of Equipment

(1) V.F. dialling from distant station to automatic networks, with visual supervision on metered calls, but without supervision on non-metered calls.

(2) Manual working in both directions with supervision, in the event of a heavy through traffic demand or the failure of the automatic equipment.

(3) As the primary purpose of the system is to provide dialling facilities for the country station, the country operator exercises control of the circuit.

(4) Dial tone and supervisory tones, if present between impulsing trains, are heard by the country operator.

(5) The operation of the equipment relies on a definite order for seizing, impulsing and release; therefore provision is made at the country end, by means of a sequence key, for the country operator to restore the correct sequence of signals should this order be put out of step by a line fault or momentary interruptions to the circuit. This sequence arrangement is also utilised by the operator for ease in operating when a succession of automatic numbers is required, in that, instead of having to release the circuit by removal of the plug from the line jack and re-insertion of the plug to again seize the switch for the next call, the operator operates the sequence key twice, the first operation releasing the switch and the next operation seizing the switch for the next call.

(6) The signal frequency used is 1000 c/s., with a working margin of ± 30 c/s. The margin takes care of the frequency drift experienced on a carrier channel, and also covers the allowable frequency drift of two carrier systems working in tandem.

(7) The system will operate on circuits having equivalents +2 to —19 db., with reference 1 m.w. The receiver can be adjusted by a potentiometer to work on any line equivalent in this range and, having been adjusted, it will continue to operate satisfactorily if the equivalent changes by ± 5 db. The sending level is 1 db., below 1 m.w.

(8) The receiver is permanently connected across the circuit and, whilst working manual to manual calls, a guard facility is in circuit and prevents the false operation of the V.F. dialling equipment.

(9) The receiver is not immune to operation by speech, but the succeeding circuit arrangement is such that, on establishment of the connection, any false operation of the receiver by speech frequencies does not interrupt the call. The seizing and dialling signals occur at a stage when speech is not present on the line. The release signal also normally occurs at a stage when speech is not present on the line; but, at times, this signal must be transmitted when automatic tones are present. To effect release in this case, a time delay relay is incorporated.

After a connection is set up and speech is present on the line, disturbances of the receiver may last as long as 400 ms. The circuit arrangement of the receiver is such that its operation at this stage does not interrupt the connection, and guard facilities come into operation to prevent breakdown of the connection. Under these conditions, it is not essential that the receiver be immune to operation by speech. Therefore, any frequency within the range 200-2500 c/s. could be used.

(10) The present circuit arrangement of the system at the country end is for operation from existing magneto switchboards. With slight modifications, the country end circuit can be arranged to work from the new C.1202 type switchboards, using either key senders or dials.

(11) The country station equipment consists of a modified W.E. ringer oscillator, as well as send equipment, mounted on a 19 in. x $3\frac{1}{4}$ in. panel. This apparatus supplies the 1000 c/s. signal frequency, and provides the operator with facilities for seizing, impulsing, releasing, control of the circuit and supervisory signals, both for V.F. dialling and manual working.

(12) The receiving station equipment consists of a modified S.T.C. 122 L.U./5D ringer, and additional relays, mounted on a 19 in. x 7 in. panel. This equipment converts pulses of V.F. to direct current for seizing, impulsing, releasing of switches and supervisory signal, both for V.F. dialling and manual working.

(13) Twelve receivers, or eleven receivers plus a transmission measuring set and test panel, can be mounted on a 10 ft. 6 in. x $20\frac{1}{4}$ in. rack. The test panel contains a timing device constructed from a uniselector, which measures

relay times in seconds and milli seconds. The circuit arrangement is such that all timing and functions of the circuit may be readily checked for both the country station and the receiving station.

(14) The maintenance of the equipment presents no difficulty, as it is similar to that required for V.F. ringers, the most important point being relay timing. This is not critical, and allows a good working margin. It is accomplished by electrical means, therefore departure from the standard mechanical adjustment of any relay is not necessary.

Control of Circuit: As mentioned in para. (3), the country operator controls the circuit. In the early experiments this was found to be very important, as partial control of the circuit by the trunk telephonist could interfere with the V.F. dialling circuit, with the result that it is hard to maintain sequence of signalling, and P.G. conditions at the automatic end are set up. Whilst it is possible for a P.G. condition to occur with the existing circuit, no trouble from this cause has been experienced so far. However, when a number of these circuits have been installed, there will be an increase in the possibilities of false operation by the country telephonists, and the P.G. condition may possibly give trouble, necessitating counter measures. The use of a short seize and long release burst is being considered, so that the sequence can be maintained automatically, thus dispensing with the sequence key at the country end. Also, the circuit would be more readily adaptable for use with the new C.1202 type switchboard. If P.G. conditions are experienced with this method of operation, the trouble can be overcome by the use of a release circuit which has been specially developed for this purpose. The arrangement automatically restores the circuit to normal when a P.G. condition is established. The additional equipment for this feature would be three relays, plus wiring (one pair) from the PL alarm cam of the automatic exchange ringing machine.

Choice of Frequency

The frequency of 1000 c/s. was adopted for the following reasons:—

(i) A saving was effected, due to the use of ringer equipment which was already available for carrier and long-distance V.F. channels. It also provided the 1000 c/s. tuned operating and guard circuit and, with the addition of a valve and ten relays, provided the required dialling receiver. The cost of this additional equipment is approximately £25.

(ii) The use of the W.E. ringer-oscillator at the country end, because of its self-oscillating facility, reduced the size of the installation. The addition of five relays to this circuit provided the necessary facilities for the country end. The cost of this additional equipment is approximately £13.

(iii) Provides manual to manual operating in both directions, if required.

(iv) It was found that the guard circuit of the existing 122 LU/5D ringer, which is a wide band circuit, could be adjusted so that it normally performed the function of guarding against false operation by speech; but with this adjustment it is not so sensitive that it causes trouble by responding to slight line noises or introduces distortion from short pulses of signal frequency.

(v) The visual supervisory signal equipment at the country end is operated by means of pulses of 1000/20 c/s. frequency.

Call to Automatic, Country End—City End

(See Figs. 1, 2 and 3)

Country End: Operator plugs into line and operates dial key. This operation short-circuits the output of the modified W.E. ringer oscillator to prevent premature transmission, extinguishes the supervisory lamp and opens the operator's transmitter circuit. R relay operates for the charging time of the 500 mfds. condenser (approximately 1.5 seconds). R contacts remove the short circuit from the output of the oscillator, light the guard lamp and operate relays T and C. The ringer oscillator is switched to the send position, and a burst of 1000 c/s. current is sent to line—duration approximately 1.5 seconds.

City End: The long, seizing burst enters the modified 122 LU/5D ringer and, after amplification by the first two stages, passes to the output transformer, across the secondary of which is a series tuned circuit for 1000 c/s. This circuit is tapped, and feeds the grid of a 6V6 valve, which is biassed so that, normally, there is no anode current, and rectified reaction applied. With a signal input, the alternating current energy in the plate circuit of the valve produces, by means of the feedback condenser and rectifier, a positive potential on the grid of the tube and, consequently, a large plate current flows. Therefore A relay operates during the seizing burst of tone. A1 contact changes over, and operates relay B. B3 contact changes over and completes the circuit for relay E which, however, takes approximately 1 second to operate. At the end of the seizing burst, A and B relays release. B3 contact falls back to

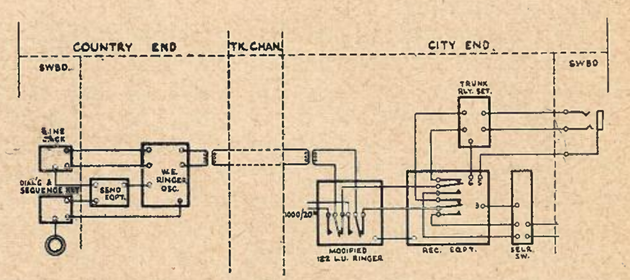


Fig. 1.—Block schematic diagram of V.F. dialling channel.

normal and completes a holding earth through G1 contact for relay E, and also operates relay X. CO relay releases, contacts of which extend the line to the automatic switch. Dial tone is fed out to line on the A and B wires, and an additional contact on the dial tone relay of the automatic switch operates relay V. V contacts operate relay W and terminate the rectifier of the 1000 c/s. band suppression circuit in 200 ohms, preventing the operation of the guard relays by dial tone. Contact W1 completes a locking circuit for relay W through contact GG2. Contact W2 prepares a circuit for the operation of CO relay by B1 contact on each train of impulses, therefore terminating the line with the L relay of the trunk relay set and preventing backlash from the impulsing of the automatic switch from interfering with the received impulsing signal of 1000 c/s. frequency.

Country End: Dial tone should now be heard at the country end, and the guard lamp should be extinguished. The operator commences to dial, and moves the dial off normal. Earth through the off-normal springs of the dial, via the dial

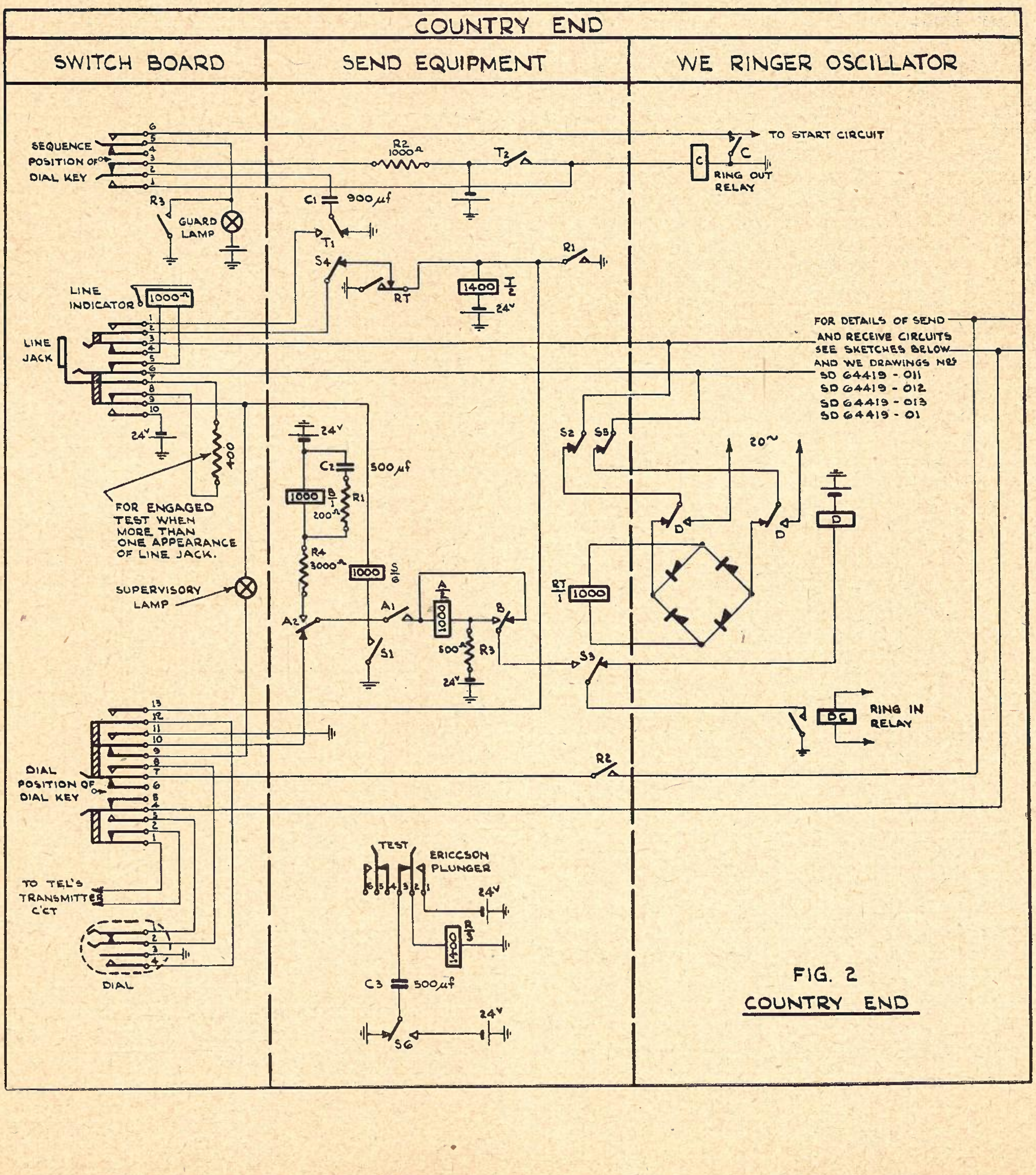


FIG. 2
COUNTRY END

key, operates relay T. T2 contacts operate relay C, which switches the W.E. ringer oscillator to the 1000 c/s. send position. This occurs at the commencing of each impulse train. As the dial returns to normal, the impulsing contacts make and break to feed out spurts of a 1000 c/s. tone to line. After each train of impulses, the off-normal contacts in the dial open and the relays in the ringer restore. This permits the operator to hear supervisory signals, if present, between impulsing trains. At the conclusion of dialling, the operator restores the dialling key. Ringing signal or the appropriate supervisory signal should now be heard.

City End: The 1000 c/s. impulses from the country end are converted to D.C. impulses by the receiver. Relay A operates and supplies impulses to the automatic switch. With 25 m.-amps. flowing through relay A, the impulse weight is normal with the standard adjustments of relay A. On completion of the dialling, supervisory tones are sent to country end from the automatic switch. Should Busy, N.U. or ring tone (with sub. D.N.A.) be received, these tones or their harmonics are in the speech range and will operate the guard relays. The country operator sends the release signal (duration 1.5 seconds) and, after the A relay has operated at the city end for approximately 0.5 of a second, relay C releases, completes the circuit for CO relay. CO contacts change over and cut out the tone, and hence G relay does not operate and interfere with the release. Relay GG is provided to control the operation of relay W and to arrange for the release of this relay when the required subscribers' trains of impulses have been completed—i.e., the GG relay operates on busy tone, N.U. tone or ring tone, and GG2 contact releases W, and W2 contact, which opens, prevents interruption of the circuit by the CO relay should the A and B relays be operated due to speech currents. When the called sub. answers, in the case of a metering call, the Y relay contact of the automatic switch operates relay P. P1 contact operates J relay for the charging time of the 130mfds. condenser (approximately two seconds). J contact completes the circuit of SR relay, the contacts of which change over and feed 1000/20 c/s. to the country end. P2 contact opens and prevents interference to the connection should A relay operate, due to speech current. On non-metering calls, Y and P relays do not operate, and the circuit in this case is guarded by relays G, GG and C. On interferences to the receiver of, say, 400 mS duration, GG1 contact continually masks the impulsing contact A2. If, however, the interference due to speech is greater than 400 mS, which is very improbable, the C relay releases, and contact C2 masks the impulsing contact A2, preventing release of the connection, and C3 contact changes over to G relay, which operates. Contacts G1 and G2 prevent breakdown of the connection by establishing a holding earth for the E, X and D relays.

Country End: The 1000/20 c/s. signal enters the modified W.E. ringer oscillator, which is in the receive position, and the DC relay provides an earth which operates relay A. Contacts of A extinguish the supervisory lamp and operate relay B (operating and release time of approximately 2.5 seconds). B contact changes over and prepares a circuit for the release of relay A when called sub. clear signal is received from the city end.

City End: When called sub. clears, Y relay of the automatic switch releases and P relay returns to normal. J relay operates for the time of discharge of the condenser, and J contact operates relay SR, contacts of which supply 1000/20 c/s. to country end.

Country End: The 1000/20 c/s. clear signal enters the W.E. ringer oscillator, which is in the receive position, and operates the DC relay. A relay releases, and the supervisory lamp glows. The operator removes the plug from jack and S relay releases. S6 contact, in falling back, applies an earth to the 500 mfds. charged condenser in circuit with relay R, which operates for the time of discharge of this condenser. R1 contact operates relay T; R3 contact lights the guard lamp. Contact T2 operates C relay and switches the W.E. ringer oscillator to the 1000 c/s. send position, and a release burst is sent to line during the time that relay is operated, which is approximately 1.5 seconds.

City End: The release burst operates relay A; A1 contact changes over and operates relay B. B3 contact changes over and holds X relay through its holding winding for the time of the release burst via X4 contact. E relay circuit is then opened at B3 and X4 contacts, and E relay releases after approximately 1 second. At the end of the burst, B relay releases and B3 contact falls back to normal, thus releasing X relay, the contacts of which return the chain of relays to normal, and the circuit is released.

Manual Calls

Manual calls from the city to the country are accomplished in the normal manner. Manual calls from the country to the city are made by the country operator plugging into the jack and operating the ring key, as for a normal call. The 20 c/s. operates a ring relay, which completes the circuit of a timing relay, and at least 3 seconds' burst of 1000 c/s. is sent to line. At the city end, the relay timing is such that, after 2 seconds, the D relay releases and operates R relay, R3 contact opens and prevents the seizure of the automatic equipment. R1 and R2 contacts supply 20 cycles ringing current to the trunk relay set.

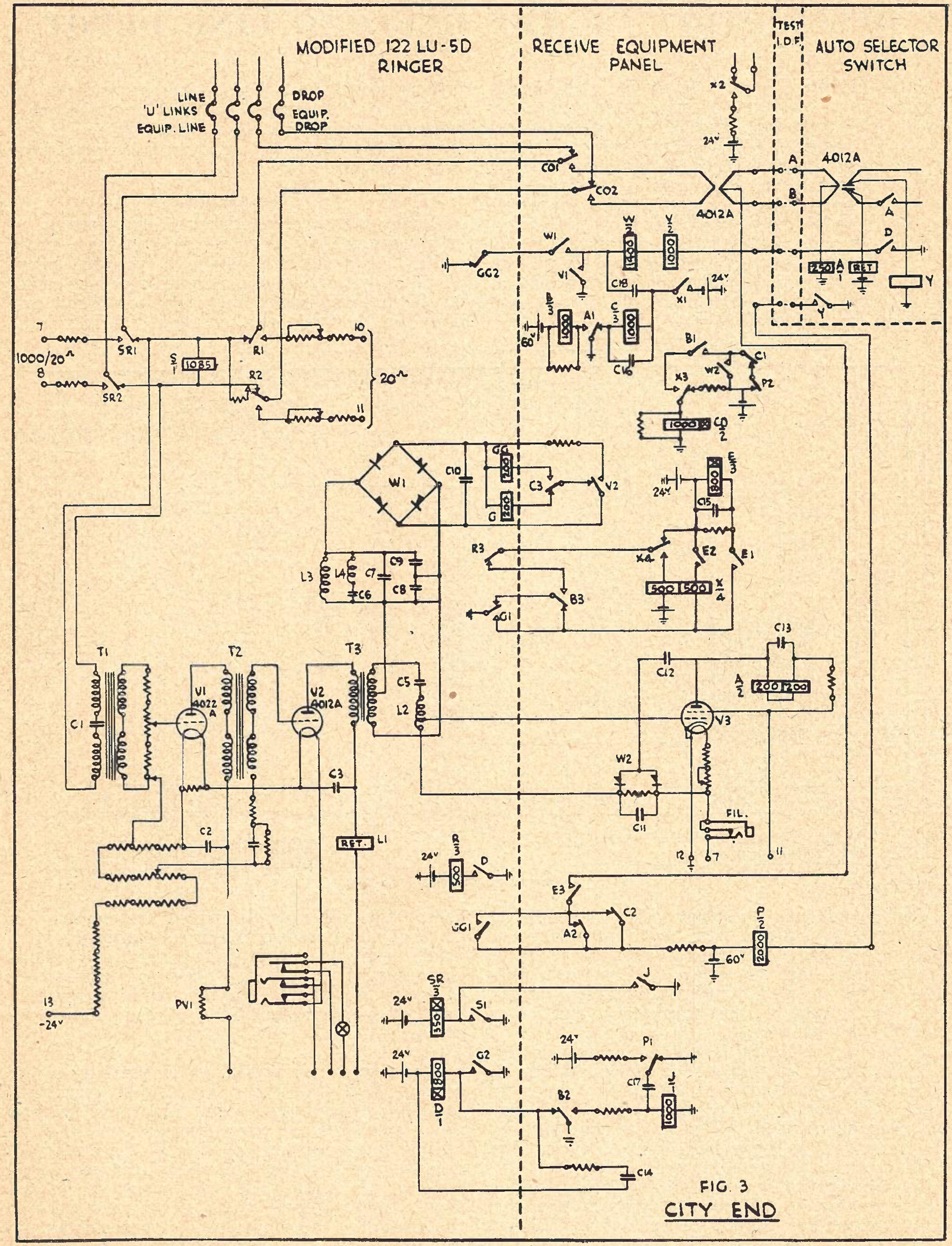


FIG. 3

CITY END

A DESCRIPTION OF THE GEELONG LINE DEPOT

J. Sloss, B.Sc.

Introduction: Post-war expansion will necessitate the acquisition of new sites for many depots, the present sites being either inadequate or required for other purposes, such as Exchange or Post Office building projects. Such instances will afford opportunities for the provision of improved facilities, the need for which is being increasingly appreciated by Lines personnel. In this regard it is realised that many of the features of the Geelong Line Depot can be improved upon, but their description may at least serve as a contribution to the general problem of line depots.

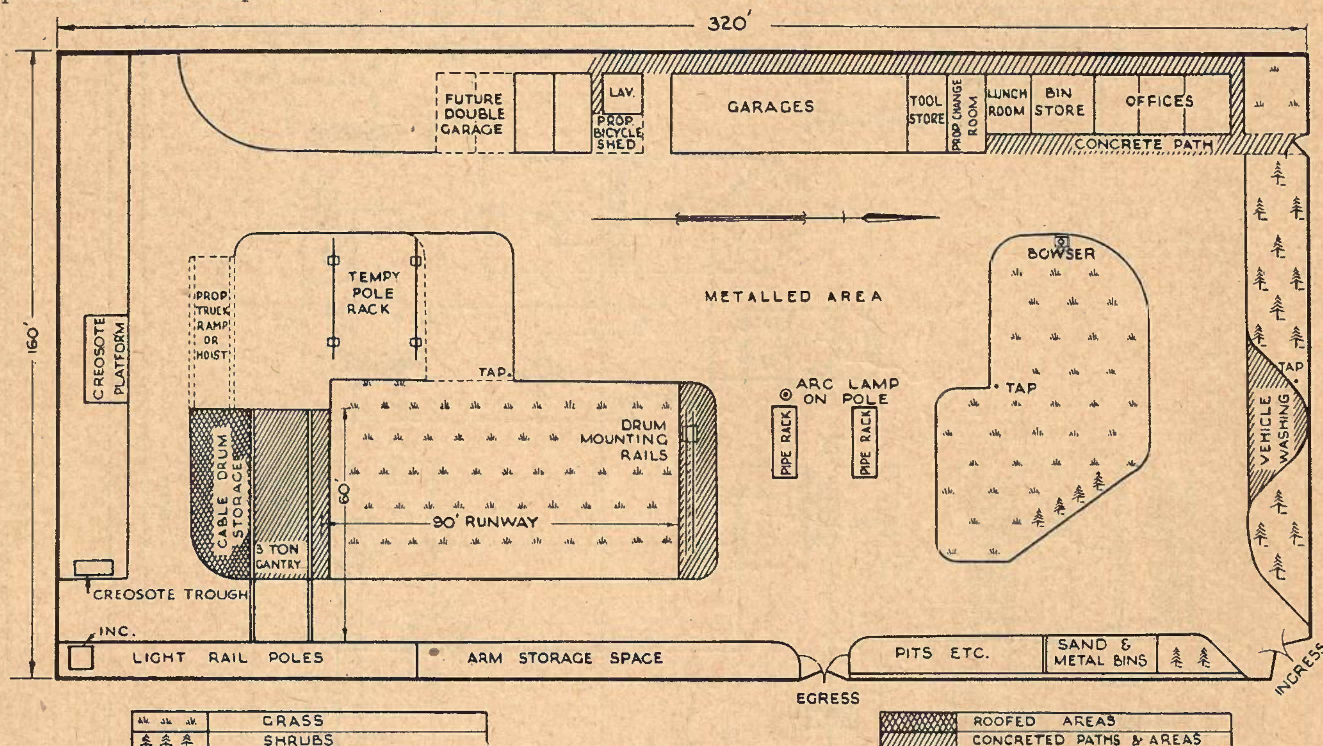


Fig. 1.—Layout of Geelong Line Depot.

The layout of the depot: The choice of a comparatively liberal site was necessary at Geelong, which is the centre of a large cable network and heavy arterial trunk routes. Geelong Depot is also a natural divisional centre for the storage of movable plant and other special equipment.

A flat corner block, 160' x 320', was selected, and the layout of this site is shown in Fig. 1, whilst views from various aspects are shown in Figs. 2, 3 and 4. To a large degree, this layout was determined by the initial building requirement of a continuous line of offices and garages along the west fence-line.

In the light of subsequent expansion, and a desire to provide additional staff amenities, this arrangement has proved unsatisfactory, and additions would have been more economical and suitable if the garages had been arranged as a separate block from the offices, etc. If only from a fire risk point of view, this would have been desirable.

Description

Traffic Ways: The circular arrangement of driveways, which are nowhere less than 14' in width, combined with maximum possible radius of curvature at corners, permits free movement of the largest trucks and trailers without any need for backing and turning. Due to the liberal turning space provided immediately in front of the garages, traffic congestion is practically negligible, even during the early morning assembly of vehicles. For the convenience of tip trucks, the turning and backing space in front of sand and screening pits might also be noted.

A through road passes under one bay of the gantry, and pipe racks are island structures accessible from either side. Separate "in" and "out" gateways are very desirable where a relatively large transport fleet is in use, and were necessary at Geelong for safety reasons alone, due to the nature of the approach to the depot. A hand gate was also provided close to the offices for the convenience of pedestrians and cyclists and to enable the main gates to be locked from within.

Storage and handling of cable: A 3-ton gantry of the overhead trolley type was provided, as large drums of trunk and subscribers' cable are often handled. (See Fig. 5). Both a lateral and a longitudinal movement are possible with this type, which is considered more satisfactory than the single beam or cantilever type, where the hoist itself runs on the web of the main beam and is confined to longitudinal movement. This latter type is slower in operation and covers a restricted storage space. With an area of operation of 60′ x 15′ (including the roadway), the Geelong gantry was constructed from 7″ x $3\frac{1}{2}$″ I-beams for the vertical supports, and two horizontal I-beams 10″ x $4\frac{1}{2}$″. As a result, the design was somewhat complicated by struts and braces necessary to strengthen the structure. Apart from the initial expense, any gantry has the disadvantage that a continuous roof cannot reasonably be provided over the storage space without interference to the working of the hoist. As shown in Fig. 5, a shelter was therefore provided immediately behind the span of the gantry for large and slowly-moving drums necessarily stored at Geelong. These could be rolled directly forward to a point where the gantry could be brought into operation. As some sizes of cable periodically become relatively slowly-moving, it was also considered essential to protect working drums. Individual covers were consequently provided on each pair of cable stanchions.

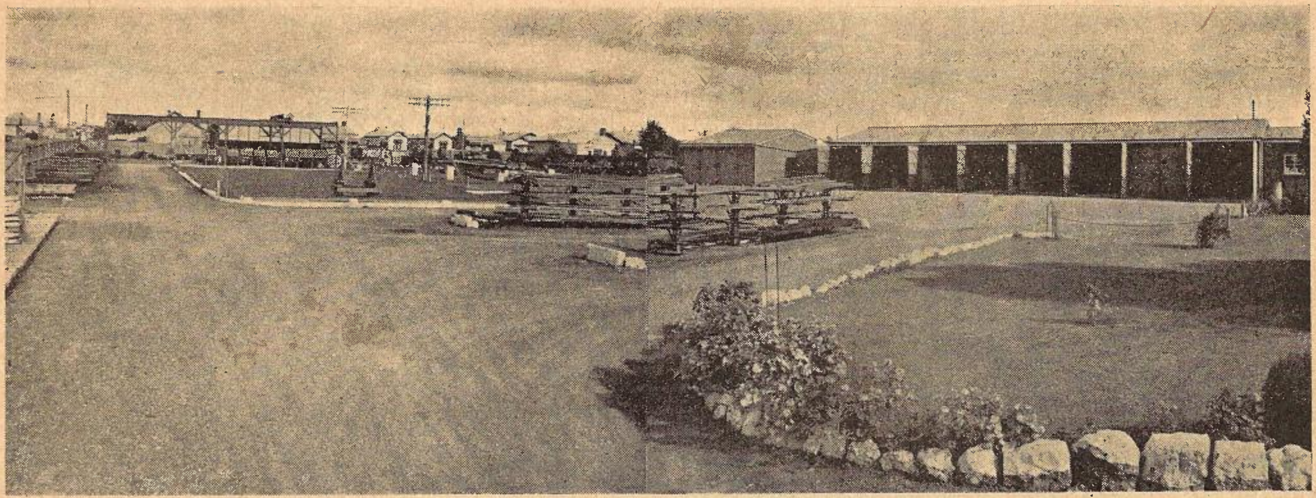


Fig. 2.—General View of Geelong Line Depot, looking South. Note Practice Aerial Route.

The use of girder uprights as stanchions may also be observed in Fig. 5. The axles of working drums rest on slightly bent bolts secured between the inside flanges of each pair of girder uprights. These bolts are kept greased and, as a result, drums revolve very freely compared with those mounted on pole stumps. Rails or concrete posts can also form a pleasing alternative to the use of pole stumps as stanchions.

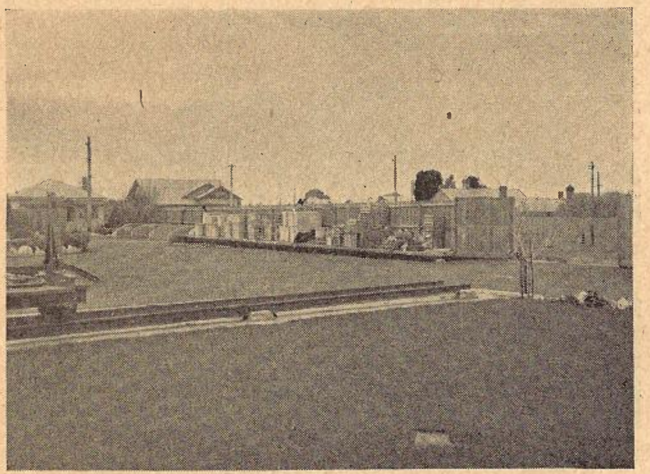


Fig. 3.—East Boundary between Gates. Note Sand and Screening Bins.

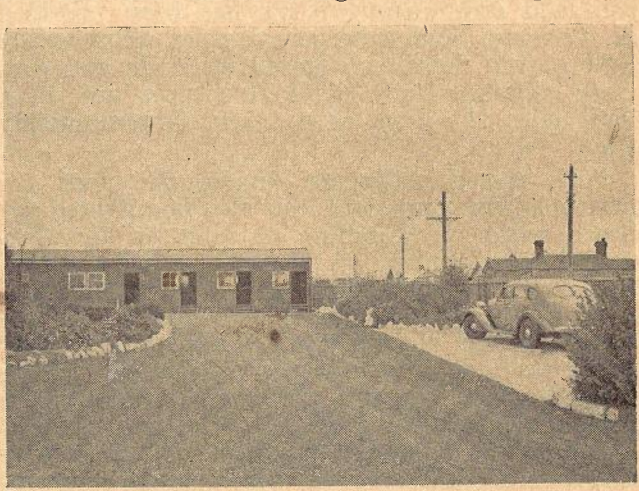


Fig. 4.—North Boundary showing Offices and Car Washing Space.

It may also be of interest to note that a trolley mounting is provided at the end of the cable runway. Measured lengths of cable can be conveniently wound on to a spare drum, which can then be rolled directly, via light runners, on to the tray of a truck for transport to the railhead or smaller jobs where a cable trailer is not needed. A better solution would seem to be the use of a cable barrow as a support at the end of the runway, combined with the convenient location of a ramp or vehicle hoist adapted to raise the drum to the height of the tray of a vehicle.

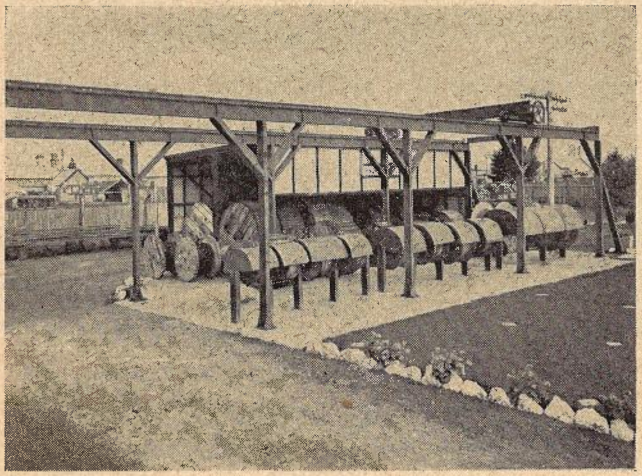


Fig. 5.—Three-Ton Gantry and Cable Protection Arrangements.

Storage and handling of other heavy material: A commodious platform for the storage of creosote and other heavy items has been provided at Geelong, and emergency poles temporarily held at the depot are stored on skids and concrete pillars. Both these structures are on a level with the tray of a truck (approximately 3′6″).

Such raised platforms obviate the need for lifting heavy items, and can also be adapted for the storage and handling of cable as an alternative to a gantry, which is essentially expensive and requires skilled labor for its erection. At smaller stations, in particular, a well-designed, raised platform has the advantage that it can be built as opportunity offers, and timber or, preferably, concreting material is all that is required; also cable and material can be protected from exposure by means of a cheaply constructed skillion roof, which in no way interferes with the mounting of cables on supports set in the platform.

As a point of comparative interest, an isometric sketch of such a platform (which also incorporates a truck ramp) has been shown in Fig. 6. Relevant comments are as follow:—

(a) The retaining wall of reinforced concrete can be buttressed at the top or bottom by simply inverting the boiler plate mould (6′ x 4′) used in its construction.

(b) Cable stanchions in this case should not be at a uniform height, but stepped in careful relationship to the radius of different working drums. With this arrangement, only small wedges are necessary to raise cable drums sufficiently for mounting.

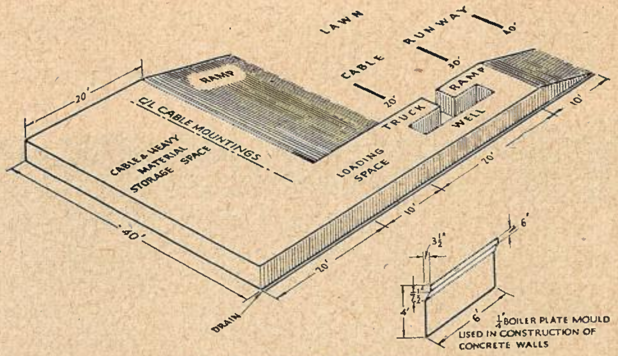


Fig. 6.—Raised Platform.

(c) A ramp is provided between the cable rack on the platform and cable runway at ground level.

(d) Smaller drums of cable can be rolled and turned on the platform without great difficulty, and if larger drums are frequently handled the provision of a simple turntable, at least on the loading space, could be considered.

On a flat site it would be necessary to cart filling for such a raised platform, but on an undulating or sloping site most of the filling may be obtainable in the normal course of grading the yard. In areas where seepage occurs, agricultural pipes can be provided at intervals along the base of the retaining walls.

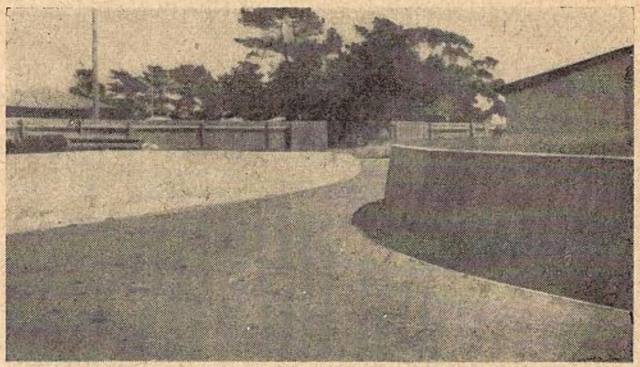


Fig. 7.—Sunken Road, Apollo Bay Line Depot.

An unusual adaptation of the raised platform was employed at Apollo Bay, where an awkward triangular site, waterlogged in winter, was put to good use by the provision of a through sunken road. (See Fig. 7).

Transport maintenance facilities: At present the twelve vehicles at Geelong are not serviced by the Lines staff, and the provision of a hydraulic hoist or ramp has been deferred, although a concreted space drained to the street gutter has been provided for washing the vehicles. (See Fig. 4). Where such a relatively large fleet is maintained, however, consideration should be given to the provision of a chain hoist, especially if this can be adapted to assist in the loading and unloading of other heavy items.

In the concreted garages drip trays preserve cleanliness, and locked cupboards have been provided for the storage of oil and incidentals associated with each vehicle.

The 200-gallon petrol bowser located near the store is such a time-saving device compared with drums and locked taps (or servicing by outside filling stations) that portable, chariot type bowsers are worth considering for much smaller stations.

Appearance of depot: The appearance of the Geelong Depot has caused favorable comment from many visitors, and is due to a careful use of shrubs, combined with well-kept lawns and white stone borders. As a concession to an enthusiastic Line Inspector, a cactus garden has even been allowed to flourish. Whether or not there is any utility in cactus at a Line Depot is left to the reader's imagination, but points in regard to the other features mentioned are as follow:—

(a) Cable should not be measured out across metal roadways or other rough surfaces and, at all but the busiest cable depots, a grass lawn will provide the ideal runway and its appearance will not suffer from normal traffic. At Geelong a neat alternative to jarrah or red-gum measuring strips has been the use of small, 9" square concrete markers, set in the lawn runway and stencilled with figures indicating the measured distance from the base line. This zero or base line at Geelong was drawn out in the concrete approximately 6′ in front of the gantry cable rack.

(b) Suitable evergreen trees or hedges can be used to good effect in providing wind-breaks, or even natural shade for exposed cable drums.

(c) Small shrubs planted appropriately can be used to conceal unsightly features and generally improve appearance.

Like many other depots, however, the Geelong site is completely enclosed with a 6′ paling fence, which probably detracts from the value of neighboring properties.

Amenities, storage and workroom facilities: The quantity and variety of work undertaken in the Geelong District, combined with the central nature of the depot to other stations in the South-Western Division, necessitated the storage of larger quantities of tools and equipment than were anticipated. The need for a workroom where cable distribution pillars could be assembled and reconditioning carried out in comfort was soon apparent also. The initial buildings were inadequate for this work, and there was no alternative but to use temporarily two garages for a workroom and tool store respectively. Shortly, it is hoped to provide additional structures for use as a workroom and for the storage of miscellaneous movable plant, tool boxes, ladders, pikes, etc., under cover. These latter items are at present exposed, or housed inconveniently in garages, which are extremely congested as a result.

With the transfer of the workroom it is hoped to suitably modify the garage next to the lunchroom for use as a cloak- and washroom, with three hand-basins and good lighting and ventilation as main features. The cool climate of Geelong does not warrant the provision of showers.

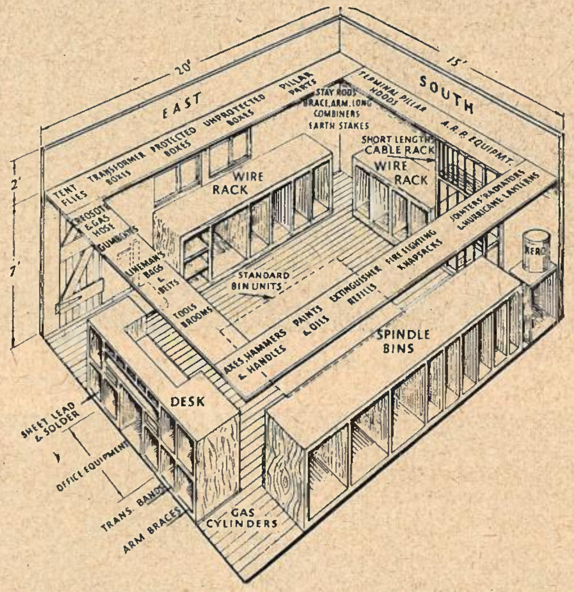


Fig. 8.—Layout of Bin Store. (Roof and North and West Walls removed.)

Separate tool- and workrooms are considered essential at all but the smallest depots. In the case of the workroom, adequate natural lighting and bench space should be aimed at, and the tool store should be conveniently located next to the main store.

At Geelong the best possible use had to be made of the bin store room (20′ x 15′), and the isometric sketch shown in Fig. 8 may be of interest. The overhead shelf provides excellent storage space for slowly-moving and miscellaneous items, while the careful layout of spindle bins, wire racks and cable rack may also form a useful guide. The continuous bench above the spindle bins and wire racks is convenient for assembling material drawn from bin units, which form an island structure in the centre of the room. Actual views of the store are shown in Fig. 9.

Other items of interest in particular rooms are as follow:—

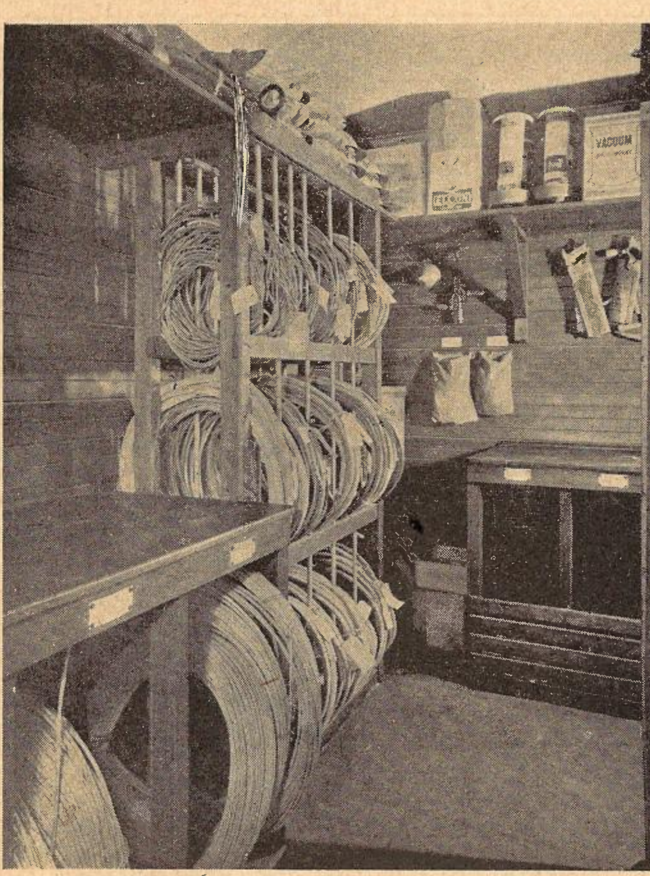


Fig. 9(a).—South and West Walls.

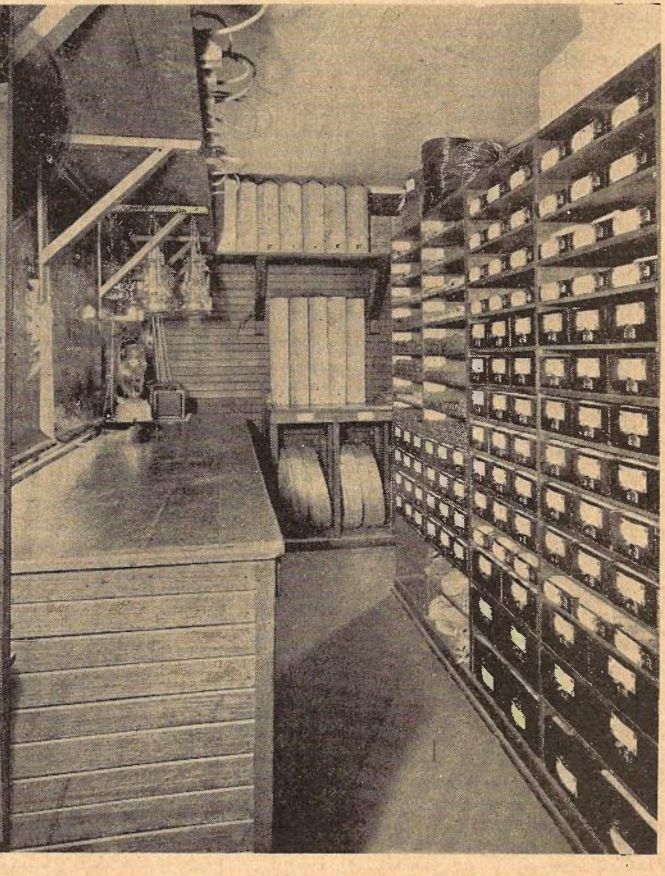


Fig. 9(b).—East and South Walls.

Fig. 9.—Three Views of Interior of Store.

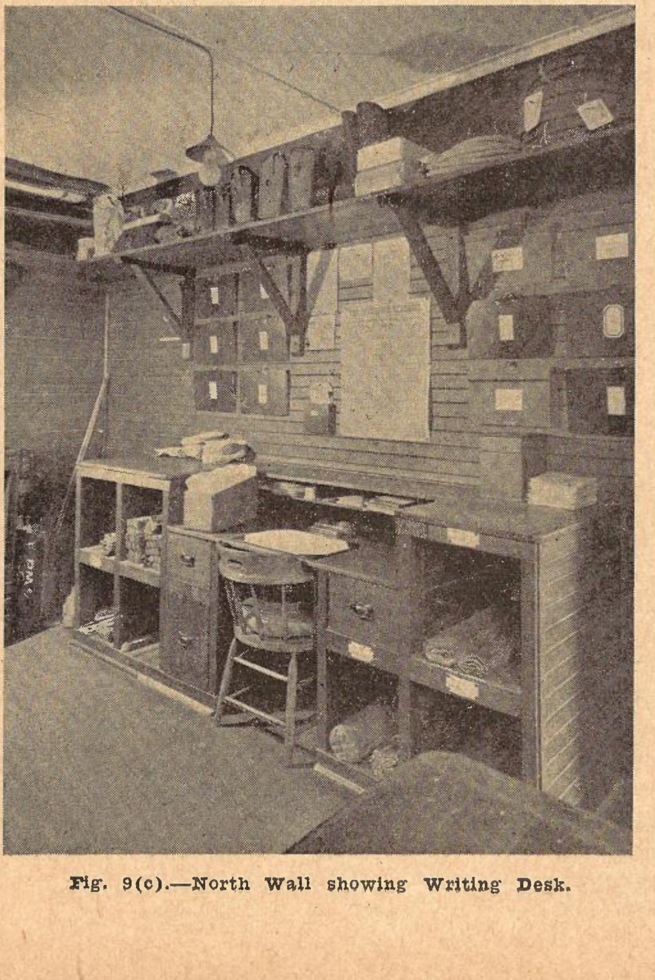


Fig. 9(c).—North Wall showing Writing Desk.

(a) All offices are lined and floors covered with linoleum. Power points, radiators and fans have also been provided.

(b) The lunchroom is equipped with a sink, hot water urn, small gas ring and gas oven. Small luncheon tables and chairs have been obtained recently, and it is intended to suitably line the room.

(c) In the Line Foreman's office, field books are held in pigeonholes, a collapsible plan table has been devised to save space, and correspondence, plans, etc., are filed neatly in manilla folders under a comprehensive subject-heading index.

Miscellaneous: (a) To facilitate the treatment of crossarms and spindles with hot creosote, a half-round trough of boiler plate 10′ long has been provided on a bricked-in firebox and flue. A suitable trolley is being designed for the carriage of arms to and from the stacks.

(b) Sand and screening pits, each 10′ x 10′ x 3′ high, are constructed of concrete 6″ thick, buttressed and reinforced at the back corners to prevent the side walls spreading. Short lengths of rail across the mouth of each bin act as bumpers for tip trucks and also assist in retaining the contents of each bin.

(c) The sealing of road surfaces is being completed as opportunity permits.

(d) Miscellaneous provisions include: Small forge and anvil, drilling machine, grindstone, scrap bins, incinerator and waste bins.

(e) Projected facilities include: Rectifier for battery charging, additional outside lighting for use at night, sump oil container and draining rack for reconditioning old bolts, etc., and accommodation for private bicycles.

(f) Accommodation for camp equipment or cement is not required.

Conclusion: In submitting the above outline, it is realised that many readers will have other views or improved ideas on many of the aspects considered; and, in any case, past experience and local factors largely determine whether any one feature is suitable or can be justified for a particular depot. There can be little doubt that efforts to achieve a satisfactory line depot design are rewarded by increased staff efficiency and neater and more orderly workmanship in the field.

Editor's Note

Recently the question of amenities and working conditions at Line depots has been the subject of investigations by a committee consisting of representatives of the Department and the Australian Postal Workers' Union. It is hoped in a subsequent issue of the "Journal" to publish details of the Line depot plans evolved as a result of this committee's investigations.

REVIEW OF LEAD ACID ACCUMULATOR CELLS

E. J. Bulte, B.Sc.

The number of lead acid accumulator cells used in telephone exchanges, long-line equipment and carrier stations, etc., has increased very considerably in recent years. The following gives a description of the types of cells in use by the Department, and current practice in the provision of such types in their relative locations.

The essential components of a cell are a container, positive and negative plates and electrolyte. The active materials of a fully charged cell consist principally of lead peroxide on the positive plates, spongy lead on the negative plates and sulphuric acid in the electrolyte. The action of the cell is the result of chemical reactions of these materials.

CONTAINERS

(a) **Lead lined wood boxes:** The standard practice is to use lead lined wood boxes for cells of 600 ampere hour capacity or greater. The wood is selected from best quality, good, sound, well-seasoned timber, free from large or dead knots, shakes or other defects. The interior of the wood boxes is protected from the action of sulphuric acid by impregnating with wax or similar means. Metal liable to be affected by sulphuric acid is not used in the construction of the boxes. The lining consists of chemically pure rolled sheet lead, weighing not less than 4 lbs. per square foot. Before insertion in the wood boxes, the linings are tested for pinholes, local action and other defects. The whole of the exterior of the box is protected against the action of sulphuric acid by treatment with acid-resisting paint. The plates are supported in the box by glass slabs, which are kept in position by means of lead shoes on the bottom of the box. A sketch of a typical cell appears in Answers to Examination Papers in this Journal, Examination No. 2586, Senior Technician, Telephone (General), Section B, Q. 1, Fig. 1. Fig. 1 shows a photograph of a typical exchange battery room, containing two batteries using this type of cell.

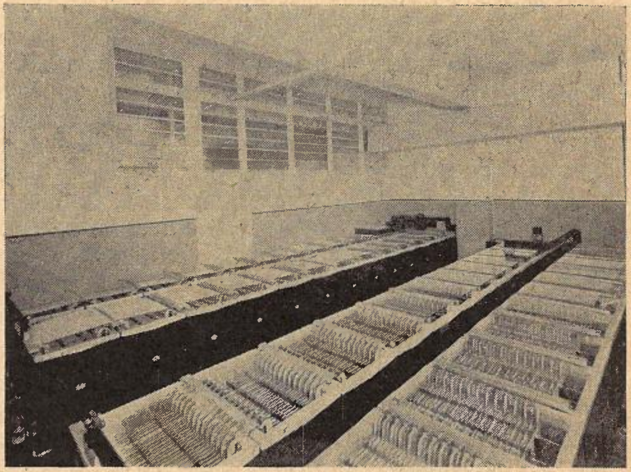


Fig. 1.—North Sydney Battery Room.

(b) **Glass boxes:** For cells of capacity up to 432 ampere hours, glass box containers are used. In this type the plates are supported directly on the sides of the boxes. A sketch of a typical cell of this type appears in Vol. 4, No. 5, p. 317.

(c) **Moulded hard rubber boxes:** These are used in the well-known motor vehicle type batteries and are usually of the multi-compartment type. In this type the plates are supported on raised portions of the bottom of the box. In addition to this, they derive support from the ledge on the top of the box, by virtue of being connected thereto via the lid and the bituminous adhesive material which fixes the lid to the box at the top thereof.

PLATES

(a) **Planté type:** This type is standard for positives in lead lined wood boxes or glass boxes. The Planté plate consists of a lead sheet with deep, finely divided, vertical grooves. The object of grooving the lead sheet is to increase the surface area of the plates, the increase so obtained being of the order of seven to ten times.

The active material on the plate is produced by electro-chemical means. The process is done in three stages. Firstly, the plates are formed by immersion in a solution of sulphuric and nitric acids, together with lead-antimony "dummies," and current passed through the solution between the plates. In the second stage, the plates are charged in the opposite direction in a sulphuric acid solution, and spongy lead formed. They are then thoroughly washed and charged in the original direction, the surface being converted again to peroxide in the form of a film between $^1/_{64}''$ and $^1/_{32}''$ thick. The object of the last two stages is to remove traces of the forming agent, i.e., nitric acid or similar agent.

Planté plates usually maintain their capacity until the end of their useful life. Active material is lost from their surface due to gassing, but this is replaced by the formation of lead peroxide from the underlying lead. Lead peroxide has less density than lead, and the conversion of lead to lead peroxide is accompanied by an increase in the volume of the active material. There is considerable cohesion between the active material and the underlying lead, and the former, due to its increased volume, exerts a stress on the lead, causing it to expand. Due to the construction of the plates with vertical laminations, most of the expansion of the plate

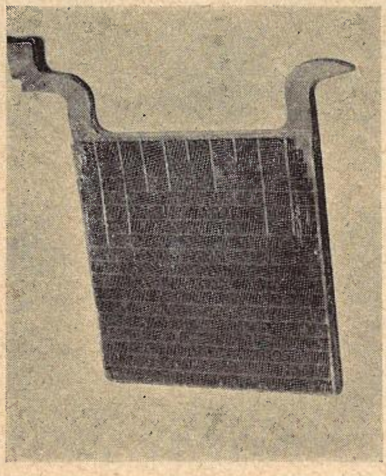


Fig. 2.

occurs lengthwise. A growth of approximately 5% may be expected during the life of a plate under ordinary maintenance conditions. Horizontal reinforcement ribs are spaced at small distances apart, to give stability to the plates.

There are three standard sizes of this plate used in the Department, the nominal ampere hour capacities at the 10 hour rate being 36, 72 and 150, respectively. The first two are used in glass box containers, and the last in lead lined wooden box containers. Fig. 2 is a photo. of a 36 Ah. Planté positive plate.

(b) **Pasted or Fauré plates:** This type is used in enclosed type cells. The active material is mechanically applied and held in a grid which is a lead-antimony alloy, the antimony being added for strength. The paste is made from oxides of lead, litharge being used for negatives and red lead for positives. Various ingredients are added to the paste during manufacture. For instance, the paste is hardened by the addition of glycerine or carbolic acid, thus making it durable and increasing its conductivity. An expanding agent, usually confined to negatives, is also added. This is because the lead

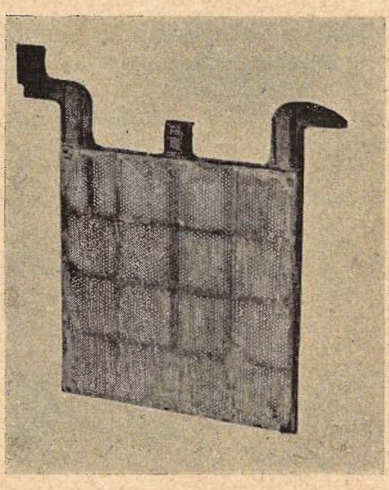


Fig. 3.

particles of the paste tend to consolidate when in service, thus causing reduction of plate capacity. An inert substance such as lamp black or graphite, being insoluble in the electrolyte, tends to minimise this action.

The forming process of pasted plates consists of immersing them in tanks of dilute sulphuric acid and passing current from those which are to be positives, through the acid to those to be formed into negatives. The process is complete when practically the whole of the active material has been converted into lead peroxide on the positive plates and spongy lead on the negative plates.

(c) **Box type negative plates:** This type is standard for use with Planté type positives. It is a special type of pasted plate. The supports for the paste consist of two antimonial lead grids, both having horizontal and vertical ribs spaced at intervals of about 1½". On one side of each grid is burnt a sheet of perforated lead. Each grid, therefore, forms a very shallow tray subdivided into rectangular compartments, the bottoms of the latter being perforated lead sheet. One grid is cast with a number of rivets at suitable points, and the other has holes in corresponding positions. Paste is heaped in each of the compartments in one of the grids. The other grid is then placed in position on the top and the two halves rivetted together. The box type grid, therefore, contains a number of compartments, to which the acid has easy access through the holes in the lead sheets. The result of this form of construction is that the plates retain their capacity over a large number of years.

The standard sizes used by the Department are the same as those of the Planté positives, namely, 36, 72 and 150 Ah. capacity at the 10 hour rate. Fig. 3 is a photo. of a 36 Ah. box type negative plate.

Separators

These are used to keep the positive and negative plates apart. Two types are used, as follow:—

(a) **Woodboard type:** These consist of sheets of cedar or other suitable timber (Queensland Kauri has been used since about 1940), the thickness being $^1/_{16}$". The grain of the wood is horizontal and the size of the sheets when wet are not less than that of the negative plates in the cell. The wood used for separators undergoes special processes for the removal of substances likely to injure the plate and to decrease its electrical resistance by enlarging the pores. In open type cells used by the Department the separators are inserted through slots in rectangular dowel rods. The dowel rods are in turn supported on the plates by means of ebonite pins through them at the top.

(b) **Glass tube type:** These consist of $\frac{3}{8}$" glass tubes, and are used in glass box cells using the 36 Ah. plate. They are kept in place by lead guides burned on to the negative plates. Some are long enough to rest on the bottom of the boxes; others are supported by the lead guides and project only just below the bottom of the plates.

Electrolyte for Cells

The electrolyte used is pure sulphuric acid, the specific gravity of which is approximately 1.84, diluted with distilled water. For the satisfactory operation of secondary cells it is not essential for the electrolyte to be of any definite specific gravity, provided it is within the limits 1.100 to 1.300. If below 1.100, damage may be caused by the plates becoming hydrated, whilst if above 1.300 the plates are liable to be corroded and woodboard separators damaged. Electrolyte having a specific gravity of about 1.210 when the cells are fully charged is used for open type cells. The specific gravity of the electrolyte for enclosed type cells is higher than 1.210, and is usually about 1.260 when the cells are fully charged. The maximum value in this case is determined by the amount of electrolyte and the necessity for obviating very low specific gravity at the end of a discharge.

The decrease in specific gravity caused by a discharge equal to the capacity of the battery at the 10 hour rate is known as the range of specific gravity, and is dependent on:—

(a) the quantity of effective electrolyte in the cell;

(b) the specific gravity of the electrolyte when the cell is in a fully charged condition;

(c) the ampere hour capacity of the cell.

Expressed as a formula, the range

$$= 1000 \left(\frac{0.35 - 0.18G}{CG/A - 0.18} \right) \text{ hydrometer divisions.}$$

where C = volume of effective electrolyte in cubic inches;

G = specific gravity of the electrolyte when the cell is in a fully-charged condition;

A = ampere hour capacity.

(Electrolyte at a greater depth than about one inch below the bottom of the plates does not take part in the reactions of the cell and is ineffective). Enclosed type cells usually have a range of 100 divisions or more, whereas open type cells have ranges which may vary between about 30 to 50 divisions, depending on the construction of the cell.

Chemical and Physical Characteristics

The reversible chemical changes which take place during charging and discharging are as follow:—

	Pos. Plate	Electrolyte	Neg. Plate
Discharged	Lead Sulphate	Water	Lead Sulphate
Charged ...	Lead Peroxide	Sulphuric Acid	Lead

From this it is seen that the amount of sulphuric acid in the electrolyte is proportional to state of charge of the cell. This is indicated by the specific gravity of the electrolyte. Owing to the time taken for diffusion of the electrolyte, the change in specific gravity lags behind the charge or discharge by an amount which depends on the characteristics and dimensions of individual cells and the rate of charge or discharge. Fig. 4 indicates typical curves of variation of specific gravity of electrolyte during charge and discharge at constant rate of current.

Rise of voltage during charge: Fig. 5 shows typical curves of the rise in voltage of the cell during a normal charge at different rates. The rapid rise at the commencement is due chiefly to a polarisation counter EMF. The steady gradual rise which follows is due to the increase in the density of the electrolyte, the concentration of acid in the pores of the active material, and also to the increase in potential of the positive plates. The abrupt rise towards

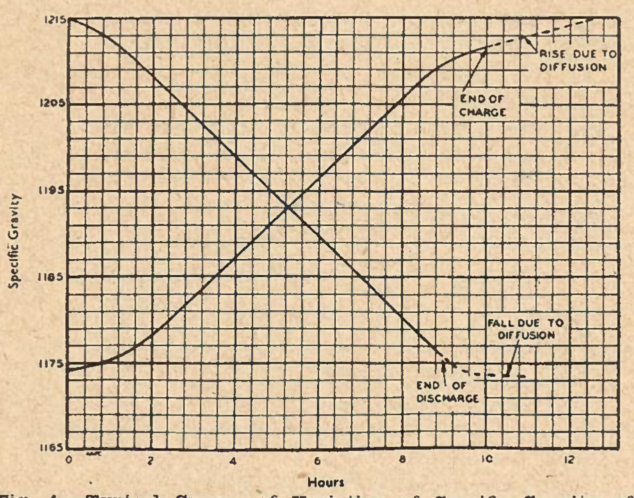


Fig. 4.—Typical Curves of Variation of Specific Gravity of Electrolyte Charge and Discharge at Constant Rate of Current.

the end of the charge commences when the lead sulphate has been reduced to a very small amount, and practically only the water in the electrolyte is being decomposed. The voltage of the cell then depends on the rate of the decomposition of the water, which in turn depends on the magnitude of the current. Hence the voltage at the end of a charge, while the current is still flowing, will depend partly upon the charging rate. In this regard a battery charged at the 2000 hour rate will have a final voltage of approximately 2.15 volts.

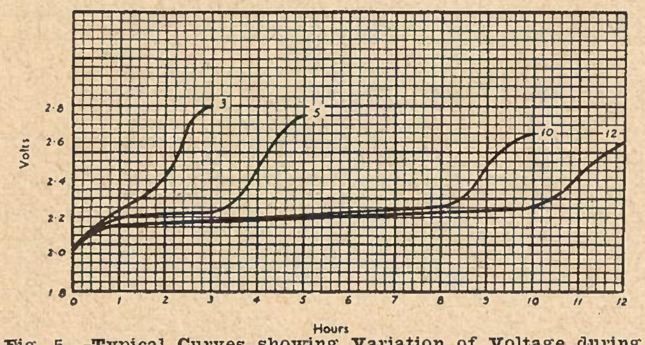


Fig. 5.—Typical Curves showing Variation of Voltage during Charges completed in 3, 5, 10 and 12 Hours.

Fall of voltage during discharge: Fig. 6 shows typical curves showing variation of voltage during discharges completed in 3, 6, 9 and 12 hours.

The decrease in voltage is due to:—

(a) a fall in the potential of the plates as they become converted to lead sulphate; and,

(b) a reduction in the specific gravity of the electrolyte, which gradually increases in resistance as the discharge proceeds. At high rates of discharge, due to the lag in diffusion of the acids, the electrolyte in contact with the plates tends to become weaker than at lower rates, and the internal resistance, which varies inversely as the density, tends to be greater. This tendency, coupled with the greater current, causes a much greater internal drop of voltage in the cell. Hence at low rate of discharge the cell voltage will be greater than if discharged at a high rate.

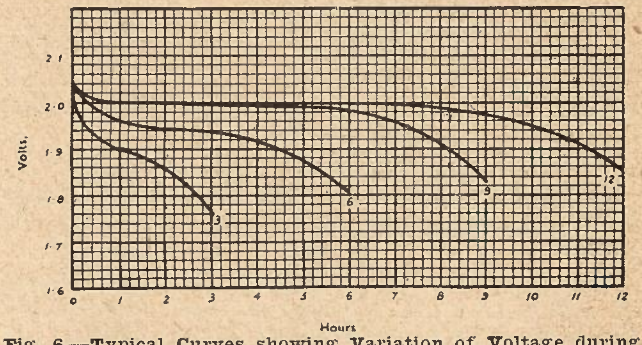


Fig. 6.—Typical Curves showing Variation of Voltage during Discharges completed in 3, 6, 9 and 12 Hours.

Effect of rate of discharge and temperature on capacity: During discharge, the density of the electrolyte in the pores of the plates is reduced, and unless the rate of diffusion is suffi-

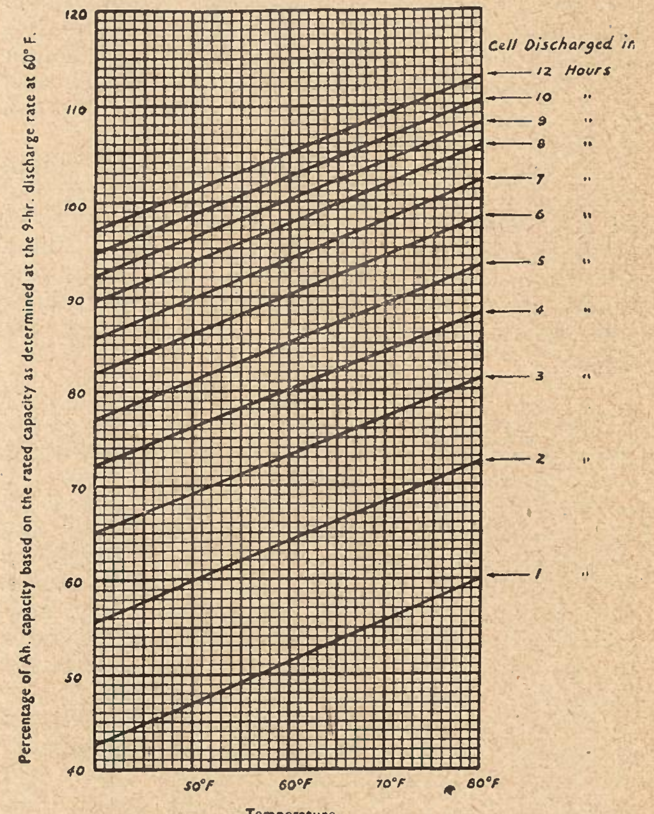


Fig. 7.—Variation of Capacity at different Discharge Rates and Temperatures.

cient to make good the loss of density, the cell ceases to function. As the rate of diffusion for any given cell is practically constant, the capacity is affected by the rate of chemical action, i.e., the rate of discharge. The output, therefore, is less at high than at low rates of discharge. See Fig. 7.

Fig. 7 also shows the variation of capacity at different temperatures. An increase in temperature causes:—

(a) an increase in the E.M.F. directly proportional to the temperature rise;

(b) a decrease in the resistance of the electrolyte;

(c) an increase in the rate of diffusion of the electrolyte, due to it becoming less viscous.

From the above it is seen that at high temperatures the terminal voltage will be greater than it would be under similar conditions at lower temperatures, and the discharge can therefore be continued for a longer period before the voltage falls to the limiting minimum value.

Internal resistance of secondary cells: The internal resistance of a cell varies with the size and number of plates, the distance between the plates, type of separator, the state of discharge of the cell, and the temperature of the electrolyte. Cells in good condition, with glass tube separators and a plate separation of ½″, have a resistance of the following order:—

Internal Resistance $= 1/_{4c}$ ohms
where c = Rated Ah. capacity.

The internal resistance of cells with woodboard separators may be somewhat greater than the above.

Use of various cells: The cells used for major installations in exchanges, repeater stations, P.A.B.X.'s, etc., are of the open type, which use Planté positives and box type negatives. The ranges of capacity available are as follow:—

Plate Serial No.	Approx. Size of Plate (Less Lugs)	Plate Capacity Ah.	Type of Container	Type of Separator	Range of Cell Capacity Ah.
7	7″ x 7″	36	Glass Box	Glass Tube	72-180
13	7″ x 14″	72	Glass Box	Woodboard	216-432
17	14″ x 14″	150	Lead Lined Wood Box	Woodboard	600-4500

Enclosed type cells are used for locations where the amount of space available is a consideration, such as in R.A.X.'s, P.A.B.X.'s, the smaller repeater stations, and miscellaneous uses for which the capacity available with this type is sufficient. The capacities at the 10 hour rate of the 13 and 15 plate 6-volt batteries which are most commonly used are approximately 75 and 95 Ah. respectively. A special form of enclosed type of cell is used for metering purposes in automatic exchanges. It has a glass container and has only two plates, with no separators. Its capacity is 10 Ah.

The initial cost of enclosed type cells using pasted plates is much less than that of the open type, using Planté positives and box type negatives, for cells of equal capacity. In addition, the enclosed type cells take up less space. These considerations are offset to a degree by the fact that a greater life is obtained from open type cells. It is of interest, in the light of the above, to note that some American telephone administrations use only enclosed type cells, and obtain the necessary capacity in particular installations by the paralleling of cells where and when required.

SOME NOTES ON THE IMPEDANCE TESTING OF OPEN WIRE LINES AT FREQUENCIES UP TO 150 kC/s

J. H. White

Preparatory to the installation of a 12-channel carrier telephone system between Adelaide and Melbourne recently, it was necessary to check the selected pairs to ascertain their suitability for this purpose. The wire used is 200 lb. Hard Drawn Copper, attached to insulators mounted in wooden crossarms, with pins at 9″ spacing. The transposition types used were double extras on E sections and equivalent types on shorter sections.

One terminal of the system is located at Adelaide, with repeaters at Tailem Bend, Tintinara and Bordertown, in South Australia. At each station special disc insulated cable is provided for leading in the 12-channel system from the open wire line. The cable is terminated in special cable terminals, loaded where necessary, and the building-out condensers adjusted to give the correct nominal impedance.

Return loss measurements between the open wire line and the loaded cable, plus line filters, were taken on the Adelaide-Tailem Bend section (65 miles), and it was found that at many frequencies it was not possible to meet the required figure of 26 db even after further adjustments to the building-out condensers had been made. Measurements of the line impedance at 5 kC/s. intervals between 35 and 150 kC/s. were made, and were very irregular.

The shape of the curve measured at 5 kC/s. intervals was too irregular to permit an accurate location of the irregularities, so the line was terminated at Stirling (10.6 miles) in 600 ohms, and impedance measurements were taken at 2 kC/s. intervals. This result is shown in Fig. 1A. This curve indicated that considerable irregularities were present between Adelaide and Stirling, and that generally the impedance curve of the Adelaide-Tailem Bend section was very similar to that of the Adelaide-Stirling section. It appeared, therefore, that the impedance of the Adelaide-Stirling section was mainly responsible for the difficulties in the whole repeater section. The frequency spacing of the peaks is irregular, and does not give any accurate indication of the position of the irregularity.

The line was therefore examined to ascertain if any abnormal condition was present, and at a point 3.74 miles from Adelaide it was found that the line wires were bridged through with about three feet of V.I.R. wire. This was removed, and the impedance again measured from Adelaide to Stirling, with the result as shown in Fig. 1B.

The removal of the V.I.R. wire effected a marked improvement in the impedance curve, reducing the limits from a maximum of 635 ohms to 625 ohms and from a minimum of 547 ohms to 565 ohms. The last four peaks also indicate clearly an irregularity at approximately 5.2 miles calculated on an assumed velocity of propagation of 180,000 miles per second. In addition, however, a closer irregularity is indicated by the variation in the height of the peaks, the shape of the curve being shown by the dotted line in Fig. 1B. In an attempt to locate this, the line was terminated at the 3.74

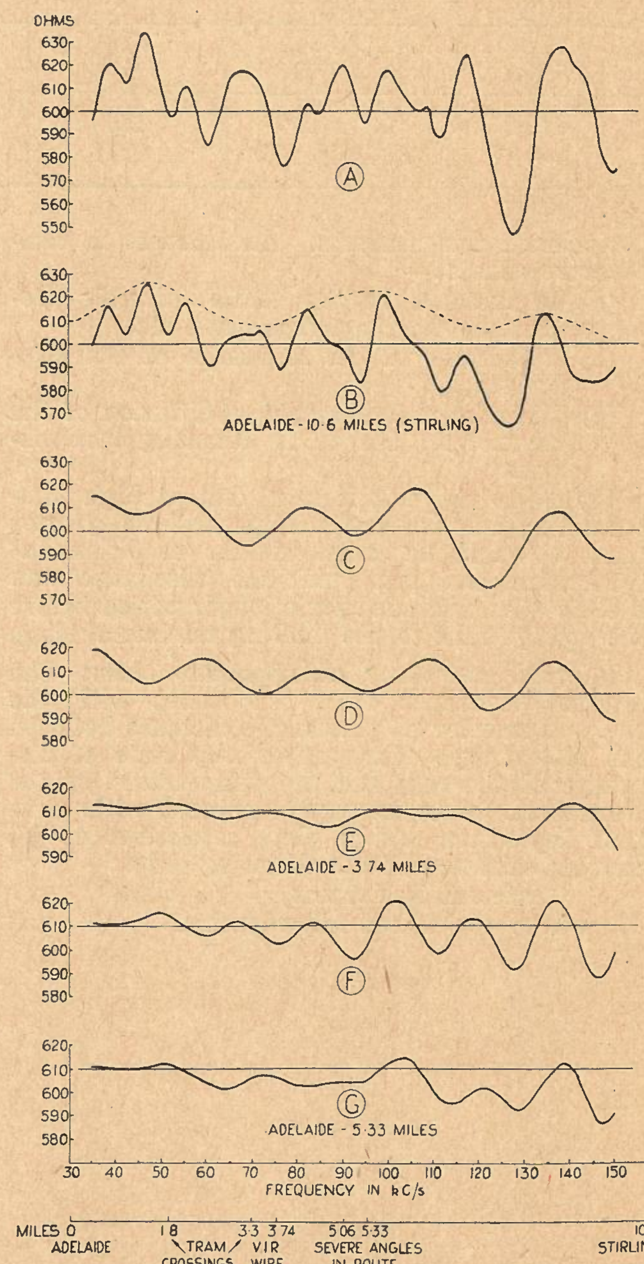


Fig. 1.—Impedance (Resistive Component) v. Frequency Characteristic. Adelaide-Stirling.

miles point, and the impedance measured from Adelaide, and the result is shown in Fig. 1C.

The frequency spacing between the peaks does not clearly indicate the position of any irregularity, so the line was again examined. At the 1.8 mile and 3.3 mile points the wires crossed the trolley wire of an electric tramway, and in each case stranded copper conductors were used. These were replaced with 200 H.D.C. and a further measurement taken, and is indicated in Fig. 1D.

This curve indicated marked improvement and, whilst the maximum impedance is not appreciably affected, the minimum impedance has been raised from 575 ohms to 592 ohms. The close irregularity has been removed entirely, and the remaining irregularity now appears to be at 3.5 miles calculated on the mean frequency spacing of the peaks, which are more evenly spaced now than as shown in Fig. 1C. As it was considered that this irregularity might be due to terminal reflection, the termination at the 3.74 mile point was changed from 600 to 610 ohms and the line was remeasured, with the result shown in Fig. 1E. This curve indicates that the irregularity was due mainly to the termination, and it was considered that the impedance curve was now satisfactory. It will be noted that the mean impedance appears to fall very gradually throughout the test range, and it is quite probable that this small irregularity is due to one or more of the angles in the route between the Adelaide termination and the 3.74 mile point.

The line was then terminated at Stirling in 610 ohms, and the impedance curve, although showing an improvement consequent on the removal of the V.I.R. wire and the stranded wire over the tram track, indicated that an irregularity was still in existence about the 5.3 mile point.

The line was closely examined in the vicinity of this point, transpositions and conductor diameters were checked, but no irregularity of a type normally encountered could be detected. On further examination it was noted that at Pole 45A (5.17 miles), which was a sharp angle, the wires on the Adelaide side of the crossarm appeared to be particularly close together, and on measurement the spacing was found to be 6″ and 8″ on the Adelaide and Melbourne sides respectively. From Pole 45A to Pole 51 there were six angles in seven successive spans, due to the nature of the road survey in the foothills of the Mount Lofty Ranges at this point, and in all cases the wire spacing at the angles varied between 6 and 9 inches.

The line was terminated at the 5.33 mile point in 600 ohms, and the impedance curve shown in Fig. 1F obtained by measuring from Adelaide. Both curves 1E and 1F are taken under similar conditions, the only difference being the inclusion for curve 1F of the section of the route containing the severe angles referred to above. Arrangements were then made to fit longer arms, with pins spaced so that the 9″ wire spacing was preserved whilst turning the angle. After these arms were fitted on four poles, where the angles were 60°, 80° and two of 90°, a further measurement was made from Adelaide, and the result is shown in Fig. 1G. Whilst this curve is not as good as 1E, it is a great improvement over Fig. 1A. Curves 1A and 1G, however, cannot be directly compared, as curve 1A is the impedance of a 10.6 mile section and 1G that of a 5.33 mile section.

At this stage in the investigation a measurement was made from Adelaide to Tailem Bend and, as the overall curve was now satisfactory, further location tests were not carried out.

In the repeater sections Tailem Bend-Tintinara, Tintinara-Bordertown and Bordertown-Nhill, a number of irregularities was located and corrected. All irregularities detected were caused by inaccurately spaced or tensioned wires, and were due to one or more of the following causes:—

(a) Original 14″ spacing between wires of a pair not altered to 9″ in occasional cases;
(b) one wire tied to the wrong side of the insulator, to give either 6½″ or 11½″ spacing approximately;
(c) existing arms rebored inaccurately, forming in some cases wire spacings up to 10½″; and,
(d) excessive sag in one wire of a pair.

It is not proposed to detail all the tests on the various sections, since this will be largely repetition, but a few instances will be given to show the very marked effect on the line impedance due to even one of the spacing irregularities listed above.

A measurement was made of the line in the Tintinara-Bordertown section (52 miles), and the result is shown in Fig. 2A. A large and close irregularity is clearly defined by the general shape of the four large peaks, with a mean frequency spacing of 27 kC/s, indicating the irregularity to be at a distance of approximately 3.3 miles. At this point (Pole 1507) it was found that the original 14″ spacing had not been altered. This was corrected to 9″ and the line was remeasured, with the results shown in Fig. 2B. It will be seen that the irregularity has been reduced considerably, but is still present at almost the same position as previously. Further examination showed that at Pole 1509 (i.e., two spans distant from Pole 1507), another 14″ spaced arm had not been corrected. This was corrected to 9″ and the line was remeasured, with the result shown in Fig. 2C. It will now be seen that the irregularity in question has been removed entirely, and only distant and relatively minor irregularities are now in evidence. The impedance of the line may now be considered reasonably good, as the impedance lies between 600 and 620 ohms throughout almost all of the range 35 to 150 kC/s. The results shown in Fig. 2 are considered very good examples of the serious impedance irregularity introduced into a circuit at "J" frequencies by the inaccurate spacing at one or two poles only.

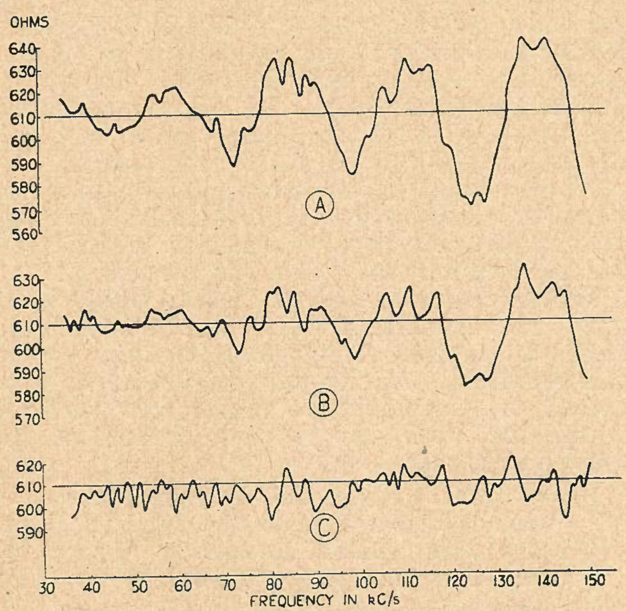


Fig. 2.—Impedance (Resistive Component) v. Frequency Characteristic. Tintinara-Bordertown. Pair 1.

The position of an irregularity is not always as clearly defined as in the previous example, and if there is more than one irregularity the impedance curve may become irregular and the location of the trouble much more difficult. In such cases it may be necessary to sectionalize the line and remove the closer irregularities first, as was done in the case of the Adelaide-Tailem Bend section. An example of the more irregular type of impedance frequency curve, measured on the Tailem Bend-Tintinara section (57 miles), is shown in Fig. 3A. There appear to be two major irregularities in this line, causing impedance peak differences of about 9 to 10 kC/s. and 23 kC/s. respectively, corresponding to distances at approximately 9 to 10 miles and 3.7 miles. On examination of the route at approximately the 3.7 mile point, one wire was found to be wrongly tied, making a spacing of 6½". Between the 9 and 10 mile point about 10 crossarms had been incorrectly rebored to approximately 10½" spacing. The arms were generally alternate, since transposition plates had been fitted on the arms on intermediate poles. These defects were remedied and the line was then remeasured, with the results shown in Fig. 3B. The improvement in the impedance characteristics is very marked, and it will now be seen that a smaller impedance irregularity appears, with a peak spacing of about 8 kC/s. It was ascertained that in the vicinity of this point there was another small section of rebored arms which had not yet been replaced by standard arms.

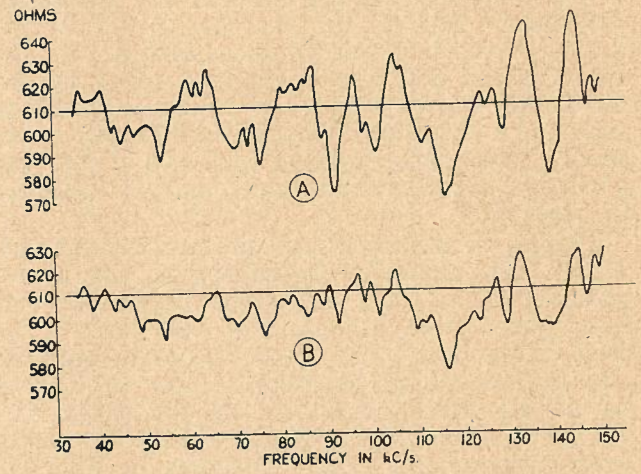


Fig. 3.—Impedance (Resistive Component) v. Frequency Characteristic. Tailem Bend-Tintinara.

On the Tintinara-Bordertown section an irregularity was discovered due to excessive sag. The original measurements on this section are shown in Fig. 4A. On investigation, it was found that in one span a wire was sagging approximately two feet below that of the other wire of the pair. This was probably due to a broken wire in the vicinity, which had allowed the slack wire to run back several spans, and in repairing the fault the sag at this point had evidently not been noticed and corrected. The wire was retensioned and the line remeasured, with the results shown in Fig. 4B. The improvement is very noticeable, particularly at the higher frequencies. The remaining irregularities are not clearly defined, but appear to be between 6 and 12 miles from Bordertown, and although the line was carefully examined between these points no cases of inaccurate tying or 14" spacing were found. It was noticed

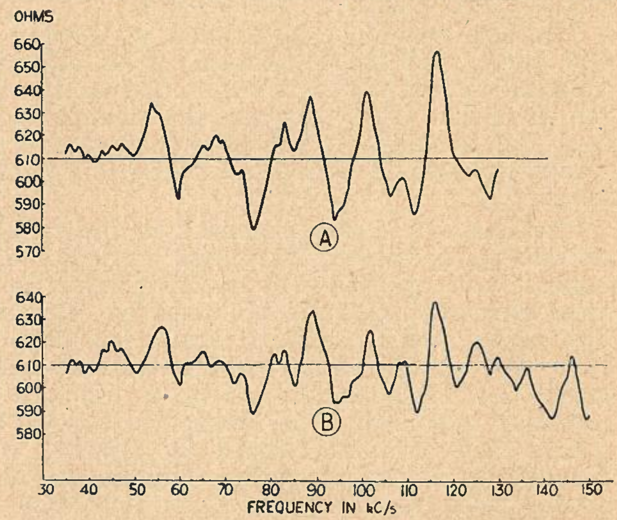


Fig. 4.—Impedance (Resistive Component) v. Frequency Characteristic. Tintinara-Bordertown. Pair 2.

that a number of old type insulators were in use on this section, and on measurement it was found that the wire spacing differed slightly from the standard 9″. In particular, where a brown and a white insulator were used as a pair the wire spacing was almost invariably less than 9″, and in many cases 8½″. There appears to be no doubt that this small difference in spacing is sufficient to affect adversely the impedance frequency characteristics if there is a number of such mixed insulators close together in a section of line, as was the case here.

Appendix

To determine the distance to the irregularity from the point of measurement, the following formula is used, in conjunction with the curves of impedance v. frequency:—

$$d = V/2(f_2 - f_1)$$

where V = velocity of propagation,
f_1, f_2 = frequencies at which adjacent peaks occur in the impedance curve,
d = distance to the fault in miles.

THE DESIGN AND CONSTRUCTION OF UNDERGROUND CONDUITS FOR TELEPHONE CABLES

A. N. Hoggart, B.Sc.

PART VII.: BURIED JOINT CONSTRUCTION PRECAST JOINTING PITS AND MANHOLES (Continued)

Manholes

General: In the Departmental Engineering Instruction No. 5, Part I., the following definitions are given:—

"**Jointing Chamber.** — Any underground structure in which cable joints may have to be made. This includes manholes and joint boxes.

"**Manhole.**—A roofed jointing chamber, access to the interior of which is gained through an opening in the roof.

"**Joint Box.**—A jointing chamber fitted with a cover or covers, the removal of which exposes the whole or a large part of the interior."

It has now become general practice to apply the term "manhole" to any underground structure fitted with a removable cover, in which all jointing operations are carried out below ground level. This would include all but smaller sizes of "joint boxes" which, however, for the most part, are now replaced by precast jointing pits described earlier. The more general definition of manhole now applied will be used in these articles.

Principles of Manhole Design: Increasing thought is now being given to manhole design, as experience has shown that earlier designs did not meet the exacting requirements of present-day cable construction and maintenance. Too little attention has been given in the past to the layout of manholes and the placing of cables. This has resulted in such faulty construction as:—

(1) Inadequately supported cables, many cases of which have resulted in cable breakdowns due to fatigue failure of the sheath.
(2) Manholes badly congested with cables such that certain cables are inaccessible for work to be carried out on them, or insufficient space is left for a jointer to work.
(3) Unsuitable entrances; in many cases, the only means by which a jointer can enter or leave the manhole is by standing on the cables.
(4) Inadequate or no provision for lighting, ventilation or drainage.

The prevention of these objectionable features occurring in new construction can best be achieved by careful selection of the design to be applied to each new manhole, when the detailed survey of each new conduit run is made. Each case should be considered individually; but, generally, a large number of the cases can be made to conform to standard types, the remainder being specially designed to suit the particular conditions.

The design of each manhole should conform to the following fundamental requirements:—

(1) Adequate provision should be made for housing the cables in such a manner that risk of damage to the cables (fatigue failure or other causes) is reduced to a minimum. This requires that supports should not normally be spaced more than 2′ 6″ apart. Cables should be supported at each side of the joint and as close as practicable to the joint.
(2) All joints should be readily accessible for opening or inspection, and it should be practicable to examine the cable sheath for the whole length exposed in the manhole.
(3) Adequate space for pulling in or withdrawing cable and rodding conduits should be available.
(4) Sufficient room should be available for workmen required to work in the manhole drawing in cable, jointing, etc.
(5) Manholes should provide good working conditions in relation to lighting, ventilation and freedom from moisture.
(6) Ready means of entrance and exit should

be available without necessity for standing on cables. Covers should be removable without undue strain to workmen.

(7) The construction should be of adequate strength to meet all loads, e.g., external loads, which may be imposed.

(8) Maintenance costs of manholes and cables should be a minimum.

(9) The foregoing requirements should be met as economically as possible.

From consideration of the above requirements, the following broad principles apply to the design of manholes:—

(1) A suitable layout of cables should be determined first, and the manhole designed to comply with the ultimate cable layout, rather than design the cable layout to fit the manhole. The layout should provide an even sweep of cables from duct-mouth to duct-mouth, without sharp or unnecessary bends, the cables being arranged along the walls of the manhole. (Under special conditions the provision of a centre rack for supporting cables may be desirable; but, as such construction implies access to both sides of the rack, it can only be arranged in very large manholes and, therefore, is seldom economical).

(2) Each joint, in general, should be higher than the duct, and should be capable of being raised from the bearer with a hingeing movement, giving a twist to the cable within the duct, and not by bending the cable. (Placing the cable joint above duct level also has the advantage of reducing the risk of damage to cable joints through flooding of manhole, particularly when a joint is open).

(3) The joint, when raised, should be in a convenient position for jointing; a minimum height of 2 ft. above floor level is desirable, which in turn requires the lowest duct being not less than 12 inches above floor level. On the other hand, unduly deep manholes, in which the lowest duct entry is substantially more than 12 inches above the floor, are to be avoided, on account of greater cost and increased difficulty of drainage.

(4) A clear space in centre of manhole of not less than 2′ 6″ wide, should be available for the jointers.

(5) Where only a small number of cables are to be accommodated, they should be arranged on one wall, and steps for convenient entry and exit provided on the other wall. Where this is not practicable, and cables are to be divided over both walls, a removable ladder should be provided.

(6) In order to provide good lighting and ventilation, the removable cover should be centrally placed, and should provide an opening as large as practicable. (The size of opening is limited by the need to keep the weight of the cover low and to reduce obstructions to traffic).

(7) Some form of drainage should be provided, so as to keep manhole and conduits as free from water as practicable.

Manhole Designs Used to Date: It is proposed at this stage to review the types of manholes which have been more commonly used till the present, and consider where, in the light of the foregoing requirements, these require improvement.

The smallest commonly used type is illustrated in Fig. 55, Joint Box, Footway, Single Cover. The internal dimensions are: Length, 2′ 6″; width, 2′; maximum depth, 2′; and the whole of the interior is exposed by removal of the cover. The duct entry is flared out to form a "bell-mouth"; this facilitates the bending of cables into position and avoids the necessity for sharp bends in the cable. This type is suitable only for joints in small cables and, to a very large extent, has been superseded by the various sizes of precast jointing pits described previously. (Telecommunication Journal, Vol. 5, No. 6).

A similar type of medium size is shown in Fig. 56, the internal dimensions being approximately 4′ long by 2′ 6″ wide, with a maximum depth of 4 ft. A double cover is used, each

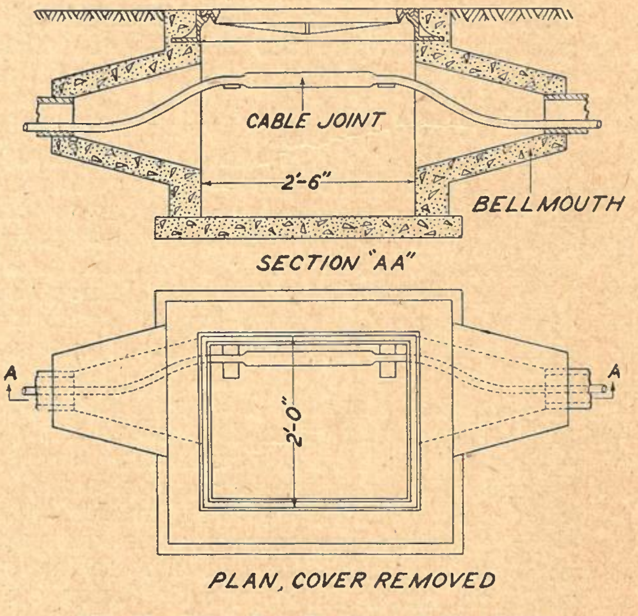


Fig. 55.—Joint Box Footway—Single Cover. (Drainage details omitted.)

cover being of same size as that of the smaller type. This type has proved satisfactory for accommodating two or three medium sized cable joints or one large joint, provided careful attention is given to the arrangement of the cables. It is, therefore, largely used on single or double pipe runs, particularly in the subscribers' distribution network. Provided this

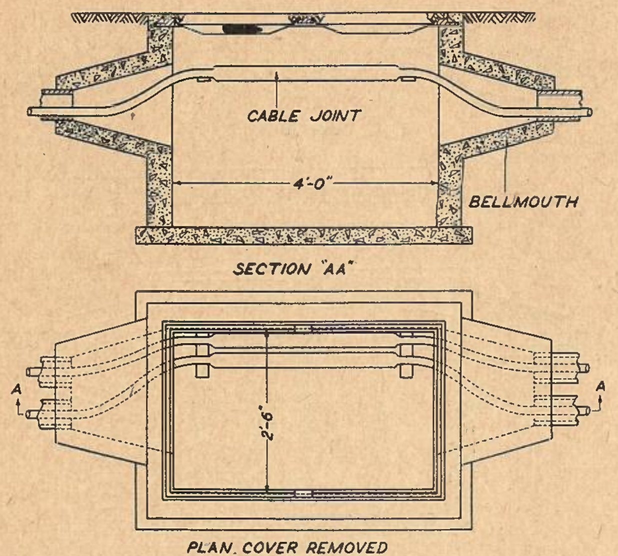


Fig. 56.—Joint Box Footway—Double Cover.

type of manhole is correctly applied to the conditions to which it is suited, and careful attention is given to the location of the duct entries and the arrangement of the bell-mouth, it generally meets the requirements listed. The

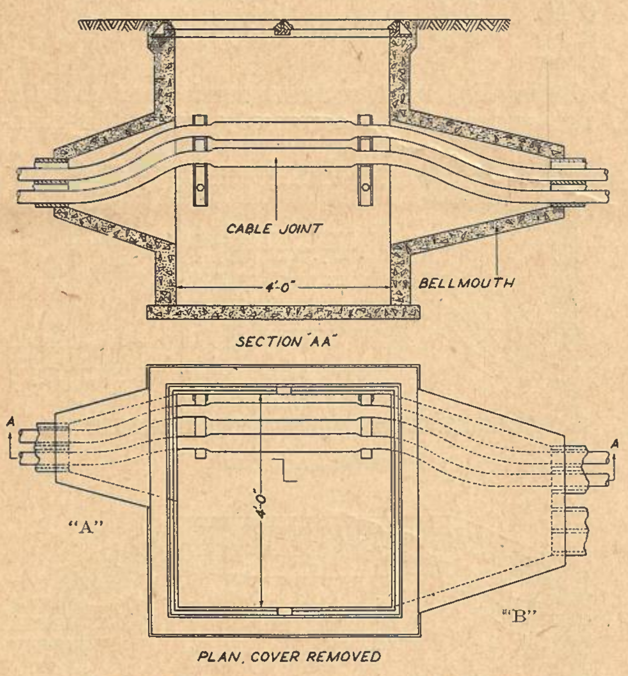


Fig. 57.—Manhole Footway—4′ x 4′ Cover.

width could, however, be, to advantage, increased to 3 ft., giving slightly more room for the cable jointer, and possibly enabling further cables to be accommodated. The extra width can be arranged without altering the cover and frame by arching each side wall for 3 inches at the top.

To provide satisfactory layout of cables, the centre line of the outside duct should be 8 inches from the alignment of the manhole wall. The length of the bell-mouth should be 2 ft., and the height so arranged to permit the cable being lifted out for jointing, and also permit examination of the cable sheath up to the duct mouth. At the same time, sufficient space should be allowed between ground line and the top of the bell-mouth to accommodate lateral cables for distribution purposes.

Fig. 57 shows a larger size of the same general construction, with two alternative arrangements for the bell-mouth. The internal dimensions are 4 ft. by 4 ft., with a depth of up to 6 ft. or more in special cases. The smaller bell-mouth at "A" implies the use of one wall only for supporting the main cable joints, and under this condition a maximum of four large joints, or the equivalent, can be housed. The wider bell-mouth shown at "B" permits dividing the cables between both walls, thereby doubling the number of joints that can be accommodated. With this arrangement it is desirable for the bell-mouth to be at least 30 inches in length, experience having shown that a length of 9 ft. in the manhole from duct mouth to duct mouth is required to provide a satisfactory layout for the cables. With bell-mouths of such length, it is very difficult to inspect the condition of the cables at the duct mouth. This is important, as many cable failures occur at the edge of the ducts. An added difficulty is the arranging of adequate supports for the cable between the duct mouth and the support near the joint. The design involves the use of a large double footway cover, with a 4 ft. by 4 ft. opening. A serious objection to these has been the heavy weight of each cover, consisting of a 4′ x 2′ cast iron frame and concrete surface; the weight is nearly 3 cwt. They are difficult to remove, and there is the possibility of workmen injuring themselves in lifting the cover. A lighter type of cover, using steel chequer plate (1½ cwt.) has been used to some extent, but has not been altogether satisfactory in other respects.

Fig. 58 shows a design which has been used for large footway manholes, or for roadway manholes (with slight structural modifications). The minimum internal dimensions are: Length, 5 ft.; width 4 ft.; depth, 5 ft.; but the actual size is varied to suit local conditions, e.g., increased for greater number of cables. The manhole is completely roofed, except for a small opening in one corner. However, this design does not meet the requirements listed under Principles of Manhole Design. In the first instance, the placing of the cables and joints in an orderly and suitable arrangement is difficult; the cables can be arranged down one side of the manhole only, unless they pass under the cover opening, in which case they affect the access to the manhole, and will almost certainly be stepped on by workmen. The corner location of the cover is not the best from point of view of natural lighting and ventilation for the workmen, and for convenience in cable-pulling operations. The manhole is expensive, owing to the strong roof structure required.

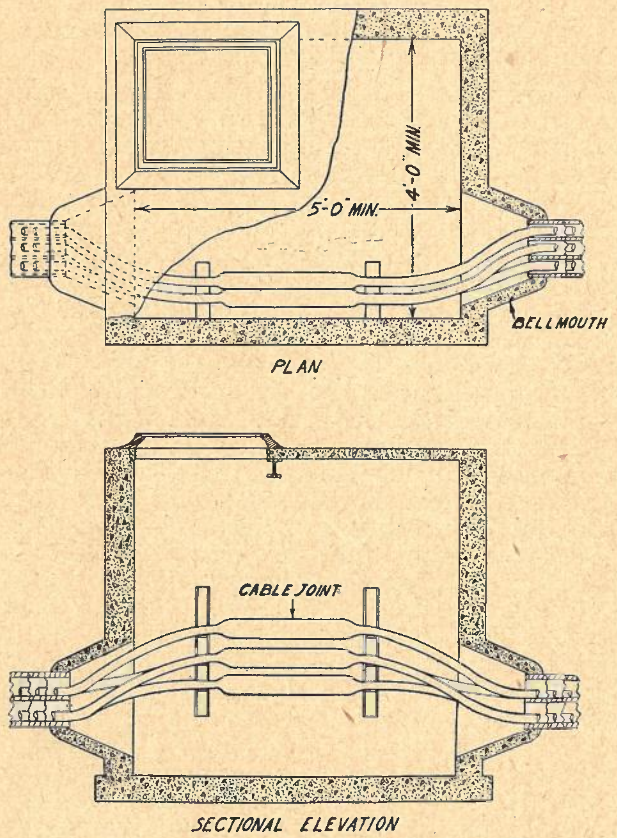


Fig. 58.—Manhole Footway—2' x 2'6'' Cover.

The objections to the last two designs led to the development of the type of manhole illustrated in Fig. 59. The internal dimensions were, normally, 5 ft. long by 4 ft. wide, the depth being according to depth of conduits and drainage requirements. This manhole, which has been used mainly on conduit routes up to four ducts, can be adapted to accommodate up to eight large joints. It will be noted that for use in footways a small double cover is used, opening approximately 4 ft. by 2 ft. 6 in. This cover was chosen as providing reasonable light, ventilation and ease of access, without being unduly heavy. It will be noted that the walls are sloped in at the top, to the bottom of the cover frame. This obviates the necessity for a partial roof; but, on the other hand, makes it somewhat difficult for entry and exit unless a ladder is provided. Bell-mouths are provided for duct entries, as before.

Overseas Practices: There appear to be somewhat varying practices in overseas countries, but a rectangular type of manhole appears to

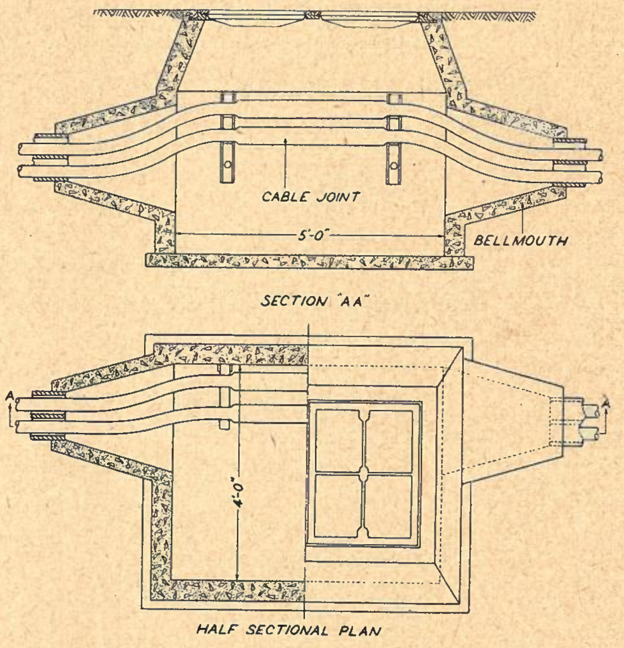


Fig. 59.—Manhole Footway—4' x 2'6'' Cover.

be the most favored, typical internal dimensions being:—

Length	Width	Height	No. of Conduits
6 ft.	3 ft. 6 in.	5 ft.	Up to 3
6 ft.	4 ft.	5 ft. 6 in.	4 to 9
10 ft.	4 ft.	6 ft.	10 to 32

Bell-mouths, in the form used in Australia, do not appear to be commonly used, the man-

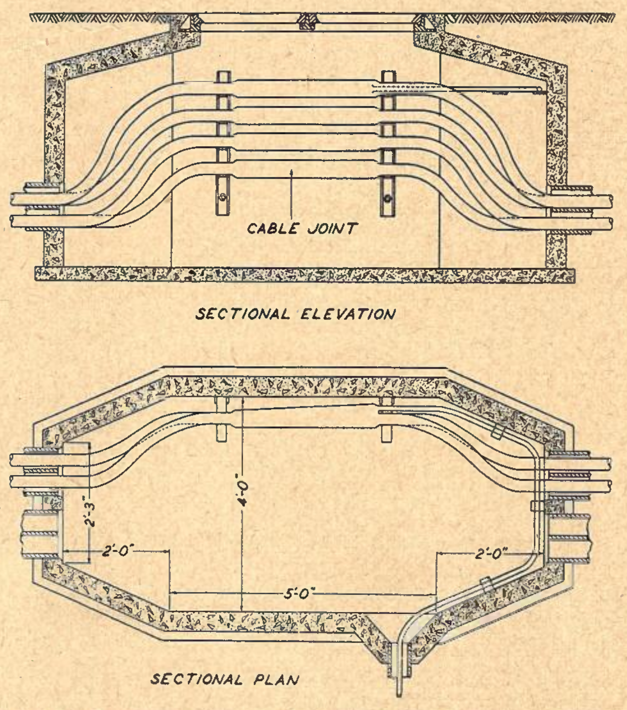


Fig. 60.—Suggested Manhole for up to eight Ducts. (Cables shown on one wall only, but arrangement on other wall will be smilar.)

hole being of adequate length to permit of all necessary bending of the cable within the manhole proper. Except in the case of smaller manholes, small covers situated in the centre of the manhole are commonly used, access being obtained by means of a removable ladder. The fact that a large proportion of manholes is built in roadways is probably a factor in the use of small covers in many overseas countries. In such cases, the cables are arranged along both side walls of the manhole, and the cable joints are staggered in very large manholes.

Suggested Improved Designs: An attempt is now being made to prepare new manhole designs for general adoption, based on the principles enunciated in the foregoing. The use of suitably curved walls for manholes appears to be attractive, as it would permit the cables being close to the wall for the full length of the manholes. Such manholes are liable to be difficult to construct, and so sections of straight walls arranged to approximate the desirable curve are contemplated. From the point of view of accessibility of cable joints, the placing of one cable joint only on each bearer is desir-

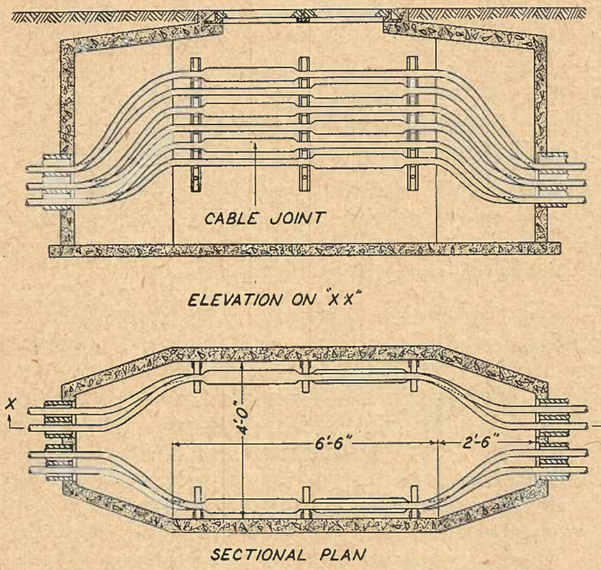


Fig. 61.—Suggested Manhole for 12 to 24 Ducts.

able, and the proposed designs have been prepared on this basis. In certain cases, due to restricted depth of the manhole (such as necessitated by conduits being laid shallow), it may be necessary to provide two cable joints on each bearer. Fig. 60 shows a type of manhole under consideration for use on straight-through conditions on main multi-way routes. A width of 4 ft. has been adopted in all cases, as this provides ample room for workmen; but it is considered that there is no advantage in greater widths for the majority of cases, increased capacity being provided by increased length, as required. Bell-mouths would not, in general, be provided in such designs; this tends to simplifying construction and permitting easy access to the cable right up to the duct mouth. The advantages previously obtained by bell-mouths being now obtained by increased length, combined with walls arranged in the shape shown. Bell-mouths would, however, still be used for leading one or two pipes into the manhole from branch runs and, for this purpose, are preferred.

The design shown in Fig. 60 is suitable for

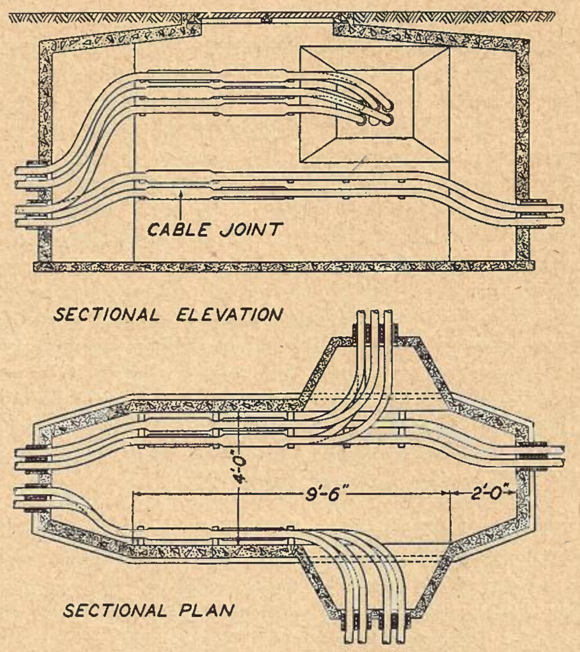


Fig. 62.—Suggested Manhole for junction of Conduit Routes. (Two cables per bearer provided on one wall to economise in space.)

use on conduit runs up to eight ducts for normal depths, and 12 ducts if the manhole is of sufficient depth. For not more than four ducts, all cables are arranged on one wall, and steps can be provided in the opposite wall for access. Where a larger number of cables is to be catered for, the cables would be arranged on both walls, and a removable ladder provided for access purposes.

For larger conduit runs, up to 16 and possibly 24 ducts, the design of Fig. 61 is proposed. This is essentially similar to Fig. 60, but is longer, so as to permit of the use of staggered joints.

When used in the footway, it is intended that the above manholes will be fitted with 4′ x 4′ size covers, thus giving maximum light and ventilation. This is subject to the adoption of a new design for manhole covers and frames, in which lightweight, four-part covers will be used. When installed in roadways, the manhole will be roofed, and the present standard double roadway covers and frames (opening 1′ 8½″ x 3′ 5½″) fitted to the centre of the manhole.

The foregoing suggested designs are applicable to straight-through manholes, or at junction manholes with limited cables branching off. The construction at other points, e.g., at major junctions, requires to be specially designed to suit the particular conditions. This can frequently best be achieved by adaptation of Fig. 60 or 61 in a manner such as shown in Fig. 62. It will be noted that increased length is provided in the manhole to permit of the bending of the cable into conduits entering the side of the manhole.

Location of Duct Entries: The position in which ducts are led into the manhole influences the manner in which the cables are arranged, and it is therefore important that care be exercised in locating the entry points. This applies equally to the main run of conduits and pipes from branch runs. In the case of the main "through" ducts, it is advantageous if these enter the manhole at the same level. However, the depths at which these are laid are determined by drainage and grading considerations, and the necessity of avoiding obstructions. It, therefore, frequently occurs that the main ducts enter the opposite ends of manholes at different levels. The depth of the manhole should, in such cases, be such that the floor is 12″ below the lowest duct.

Where bell-mouths are used, such as in Figs. 55-56, the centre line of the first pipe should be about 8″ from the side wall of the manhole, this being about the optimum to provide satisfactory layout of cables. Similarly, where bell-mouths are used for entry of pipes from branch runs, these should be at one end of a side wall, the centre line of the first pipe being 8″ from the end or, in the case of Figs. 60 and 61, 8″ from the end of the parallel walls. The entries for pipes on lateral runs should, as far as can be arranged, be at a higher level than the main run of conduits.

In the case of Figs. 60 and 61, conduit runs three or four ducts wide should enter centrally in the end wall; but, if the run is only two ducts wide, e.g., 4-way conduits, it may be preferable to place the ducts to one side, leaving space in the end wall for additional ducts, if required at some future date. This has the advantage of permitting an increase in the capacity of the duct run, without structural alterations to the manhole.

Materials: Manholes are constructed either of brick or concrete, the latter being more commonly used for normal purposes, and is generally regarded as more economical. Concrete manholes require the construction of special forms, around which the concrete is poured, hence some skill is necessary in the erection of the forms, as well as in the handling of concrete. On the other hand, for building brick manholes, no special forms are required, but expert bricklayers are necessary. Brick manholes are particularly suitable for specially shaped manholes, where the construction of concrete forms may be difficult.

It is not normally the practice in Australia to use reinforcement in the walls of concrete manholes, except where the manhole is likely to be subjected to specially heavy loads. As practically all manholes now being built are situated in footways, they are not required to carry heavy traffic loads, and sufficient strength is usually readily obtainable by a concrete wall of moderate thickness, without reinforcing. Under normal conditions in footways, the following thicknesses of concrete walls are required:—

Figs. 55, 56, 57	4½ inches.
Figs. 58, 59	6 inches.

In the case of roadway construction, the minimum thickness is 6 inches and, in addition, reinforcement is used if heavy loads are likely to be experienced. The structural design of concrete manholes in this country, including greater use of reinforcement, requires further investigation, as economies may thereby be effected. A method of calculating strengths of concrete manholes, and the design of reinforcement systems, has been dealt with by J. P. Harding, B.Sc. (Eng.), in a series of articles entitled, "The Economic Design of Manholes." (P.O.E.E. Journal, Vol. 34, Parts 1, 2 and 3).

Where brick construction is used, 4½ inch walls are provided for the smaller footway manholes, and 9 inch walls for the larger footway and roadway manholes.

Where manholes are to be completely or partially roofed, more particularly roadway types, it has been the practice to provide steel girders (I-beams) to support the roof, which has consisted of reinforced concrete, using steel wire mesh for reinforcement. Alternatively, boiler plate is laid over the steel girders and a layer of concrete poured over the top. The latter method of construction has the disadvantage that moisture readily condenses on the exposed metal, causing rusting to take place.

When carrying out jointing work in such a manhole, it becomes necessary to guard against drips of water falling on an open joint. The former method, although more difficult, on account of the necessity for erecting substantial forms to support the concrete roof until set, is to be preferred, on account of the freedom from condensation troubles. In the design of manhole shown in Figs. 60 and 61, partial roofs at either end are contemplated, and these would be of simple reinforced concrete construction. It is not expected that supporting girders will be required, except for roadway type manholes, where a smaller cover would be used, necessitating special supporting beams for carrying traffic loads.

THE R.A.X. SYSTEM—PROBABLE LINES OF DEVELOPMENT

W. B. Wicking

In this paper it is proposed to examine the part to be played by rural automatic exchanges in the telephone system of the Commonwealth, and to indicate the stages of development in reaching the ideal, when every subscriber will be connected to an automatic exchange. It is obvious that there will be a long transition period during which automatic units installed in the country will have to work in a network with a gradually decreasing number of manual exchanges, and it is desired to discuss the problems which arise because of this mixture of types of plant, as well as to visualize the ultimate fully automatic system of which these same units will form a part.

Of the six thousand odd existing country exchanges only a few—less than two hundred—are automatic at present, and in nearly every case the R.A.X. is placed as a single automatic unit in a network of manual exchanges, the facilities provided being designed particularly for such conditions. There has been no serious attempt to provide for linking-up chains of R.A.X. units into a network. The formation of the ultimate plan has been delayed because of the changes taking place in standard equipment, the lack of a basic trunk line switching plan, and the desire to obtain experience with new ideas introduced in the early units. The stage has now been reached when at least the broad features of the ultimate plan can be formulated with advantage, and provision made for all units to be installed to satisfy not only the present requirements, but be capable of forming part of the final network.

In determining the conditions to be met and the design requirements, it is desirable to adopt an outlook unprejudiced by past practice, as there are grounds for believing that many practices accepted as static for manual or city automatic conditions are unnecessary, and even a hindrance to automatic development in the country. An instance of this is the practice of preparing subscribers' accounts showing separately the charges for local and trunk line calls. By extending the unit fee area or alternatively adopting automatic multi-metering for trunk calls, at least up to fivepence, economies can be effected in plant and maintenance. The latter entails giving the subscriber an account which lumps the cost of such calls with those of local calls, details being given for only those connections entailing higher charges. It is important to know whether a designer should be tied down to our established practices for manual conditions when automatic conditions are far better suited by some changes thereto. It seems reasonable to ascertain how the best service can be given, and then to examine the effect with a view of modifying our practices to take full advantage of those arrangements.

It is natural to consider what developments have taken place in other countries which can assist our problem. A brief examination only is necessary to indicate that conditions in other countries differ materially from those which apply to a complete automatic network here, and it is not to be expected that the units developed to meet the methods adopted by overseas administrations will be directly applicable to Australian conditions. While it is most unlikely that any complete system is suitable for adoption, many facilities from those units —such as multi-metering, referred to above— will have application, and the experience of them by other administrations will be of great assistance.

In considering the many industrial, geographical and political conditions of other countries which affect their requirements, it is of particular importance to appreciate our great advantage of having one administration covering the whole continent, and a comparatively clear field in which to plan development free from control of a neighbour's activities. At the same time, the growth of the international telephone system makes it essential that the facilities and, to some extent, the type of apparatus used, be such that developments in overseas practice can be incorporated in our system.

Another consideration of importance, apart from the engineering problems, is the effect of our political structure on the conditions to be met. These affect the plans, firstly, in the desire to distribute the available automatic units as evenly as practicable between the States, and even between political divisions; and, secondly, because the year-by-year provision of funds tends to give a start-stop effect inimical to long-range planning. In practice these factors frequently operate against the concentration of effort on a network of exchanges in a particular area, which from an engineering viewpoint may be most desirable, and have tended to limit the provision of automatic equipment to single exchange installations, working to small "parent" manual exchanges, many of which would themselves be more economically operated as automatic units. These practical considerations will modify the ideal plan and influence particularly the arrangements for the transition period, as in this period a selection has to be made of the exchanges to take precedence over others for installation of the units as they become available. There are also unusual technical requirements arising principally from the dispersion of population and the comparatively great distances between community centres. This involves long, costly trunk and subscriber routes with low traffic densities which, in the absence of reliable sources of local power at the majority of these small community centres, not only bring special engineering problems, but tilt economics heavily against automatic working.

There are about 6200 country exchanges in the Commonwealth, and of these 4720 have under 20 lines, 650 have 20-50 lines, 550 have 50-150 lines and 280 over 200 lines. It will be noted that the number with less than 20 lines far exceeds all the others together. Such small exchanges are served under manual conditions by a single trunk or share a multi-office trunk with other similar offices. For automatic working one trunk line direct to the parent exchange is suitable only for the lightest traffic, and in practically every R.A.X. installation an additional trunk must be provided, either to give a reasonable grade of service or to provide a low resistance circuit for charging the batteries over the trunk line. This may be as costly as the exchange equipment itself, and often the economics largely depend on the line work necessary. It will be appreciated that in considering whether a trunk line is to be built the eventual arrangement of the network should be known and all work made to fit in with the ultimate plan for the automatic network, which may differ considerably from the trunk line layout most suitable for manual conditions.

In deciding on a plan for the progressive conversion of any particular network to automatic working, it is necessary to take account of the probable lines on which development may be expected to occur. Assume, for example, a country district of approximately the same area as a large Metropolitan network, i.e., 15 miles in radius. The earliest stage of development is a few small, widely separated exchanges, linked together and to other centres by a minimum trunk line system. Gradually, these exchanges will grow in size, and simultaneously other small offices will be established, this process continuing until the whole area is served by a system of large and small offices sufficiently closely spaced to permit any potential subscriber being given service without having recourse to an unduly long line. As country industries are established, the community of interest will grow, tending to create networks of the Metropolitan type. This is already happening around some of the larger country towns. Such well-developed networks serving relatively thickly populated areas will be interspersed with others in various stages of development. The progressive stages of automatic exchange provision will therefore be:—

(a) Single R.A.X. units working direct to a parent manual exchange through which all inward and outward traffic will be routed.

(b) Small groups of R.A.X.'s within unit fee distance of each other obtaining service with each other by dialling and service costing more than the unit fee through a manual parent.

(c) Complete conversion of all the exchanges in the area to automatic working, mostly as R.A.X.'s, forming a complete network, with either unit fee or multi-metering, and obtaining service outside the network via a central trunk exchange.

(d) Continued growth of the exchanges forming the network warranting the provision of main and branch exchanges using standard equipment, a closed numbering scheme, unit fee calls throughout the network and a single trunk exchange for inward and outward trunk service to other similar networks.

This raises the question why the large metropolitan areas have a unit fee charge for calls within a 15-mile radius, while country subscribers have this fee for only a 5-mile radius. The upper limit has been fixed after considering transmission and dialling standards, and the 15-mile radius has much to commend it for universal adoption. The division of the country into such areas would permit the immediate planning of such regions as closed networks which could ultimately develop like metropolitan areas without disturbing the line of progress or the metering arrangements throughout the country. The cost of recording equipment would be considerably reduced, and it is not unlikely that the increased calling rate would go far to compensate for the reduction of trunk line fees for the short calls. It would certainly go far towards balancing the telephone conditions between the country and metropolitan dweller, which would not be unreasonable for a country which depends to so great an extent as we do on primary production.

The grounds on which the adoption of larger unit fee areas is advanced are, however, the help that would result in reducing the cost of providing automatic equipment, and the value of the early stabilization of conditions in planning for the future. A selection could be made now of a suitable trunk line centre in each area and a "star" type of trunk line network laid down both within the network, and as between networks, thereby enabling all new trunk lines, as they become necessary, to be built in conformity with a definite plan for interlinking the exchanges with junctions and the networks with low-loss V.F. dialling lines. Initially, it is likely that exchanges within each network would be spaced at considerable distances. Subsequent growth would make it more economical to reduce exchange areas ultimately to approximate in dimensions those of Metropolitan networks. At present, under manual part-time conditions, many of the subscribers prefer to pay extra charges on miles of line erected past small part-time exchanges in order to obtain the benefit of continuous service and unit fee working to a large group of subscribers at a major exchange. With the adoption of a larger unit fee area, these facilities would be available to such subscribers without recourse to the present practice of using long, privately-erected lines and party-line services, with their attendant sub-standard transmission and low standard of maintenance.

The development of an area and the conditions which would need to be satisfied at various stages can be illustrated by an example. Fig. 1 shows an area located in northern Victoria which may be taken as typical of a number of others where development is likely to be comparatively rapid. This district is in the irrigation area and is closely settled, with a well-established centre at Shepparton and several secondary centres. Local industries have already been started, and the district has a definite and increasing community of interest. At present, service is provided by means of manual switchboards at the centres shown, which are linked by trunk lines to each other and to Melbourne and the surrounding centres. Two R.A.X.'s are located in the area, one at Wyuna, with Kyabram as parent, and one at Barep, with a parent outside the network and therefore not shown.

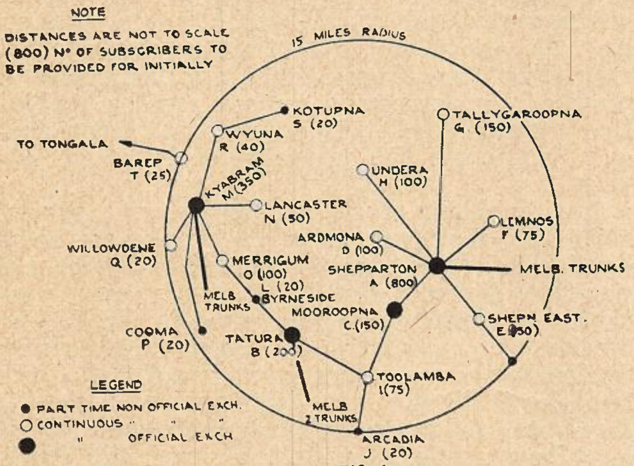


FIG 1

At present, all calls into and out of the R.A.X. units are obtained through the manual parent exchange. The circle shown in the figure marks the 15-mile radius from a theoretical centre point. Under existing conditions, trunk lines from Melbourne terminate at several exchanges in the area, as shown. Trunks from other exchanges outside the area also terminate at various exchanges, but these are not shown.

To meet the growing requirements of this district for improved telephone service, R.A.X. equipment should be provided early at existing part-time exchanges leaving Shepparton, Kyabram, Tatura and possibly some of the other manual offices to serve as parent exchanges for the surrounding R.A.X.'s. A commencement has already been made with this conversion by installing R.A.X.'s at Barep and Wyuna; and, by continuing on these lines, all of the exchanges, with fewer than 150 lines connected, could be replaced. So long as each R.A.X. is given separate trunks or junctions to one of the larger manual exchanges, no difficulty arises with regard to charges, all except local calls being docketed by the manual telephonist at the parent office. The benefit of continuous service can therefore be greatly extended without any major alteration in existing practices. The next stage is the conversion of those remaining manual exchanges serving as parents which can be replaced by R.A.X.'s. This necessitates provision being made for the R.A.X.'s dialling each other through automatic equipment, and where more than unit fee is charged, multi-metering facilities must be provided. In the next stage, automatic equipment of the standard type would be installed at Shepparton, Kyabram and in other remaining manual offices. This would enable all subscribers in the network to dial each other direct, a system of codes being arranged in order to route calls to the desired office. A manual trunk exchange at Shepparton would be necessary, where all trunks to places external to the network would be concentrated, enabling outgoing calls to be set up and the details docketed by the trunk telephonist.

Fig. 2 shows the area arranged for automatic working, with only one manual trunk exchange, located at Shepparton. As the standard 50/200 line R.A.X. provides for through service with one digit for calls over a trunk or junction to a neighbouring office, and for local service with a three-digit call, it is possible, by calling a number of single digits in succession, to route a call through several such offices. R.A.X.'s would be installed at all exchanges, except Shepparton, Kyabram, Tatura, Mooroopna and, possibly, Tallygaroopna, where standard automatic equipment, if necessary with provision for multi-party-line working, would be utilized. The local number of the subscriber connected to an R.A.X. will be in the range of 211 to 300. The telephone directory will show subscribers' numbers in conjunction with the name of the local office, thus:—

Shepparton	—	2345
Kyabram	—	4123
Undera	—	234
Arcadia	—	245, etc.

The prefix or code number for each exchange will vary with the office from which a call is originated, varying from one digit for calls to an adjacent office to six or even seven for calls between small offices on the extremes of the area. It will be necessary to issue lists to all subscribers showing the codes of the various exchanges. To call a number a subscriber,

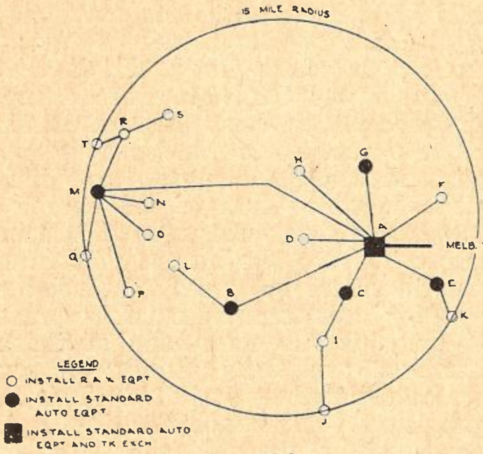


FIG 2.

after consulting the directory, refers to the list of codes to ascertain the prefix corresponding to the local exchange of the required number. In case of difficulty, reference would be made to the manual telephonist at Shepparton for assistance. Although the number of digits to be dialled for a through connection between Arcadia and Barep (seven digits, plus the local number) may appear somewhat formidable, the number of calls to be so routed will be very limited and, if necessary, such calls could be handled through the manual operator, as described above.

As further development takes place in the network some of the R.A.X.'s will be displaced by standard equipment, and no doubt a number of new R.A.X.'s will be needed to enable intending subscribers in isolated parts to be given service on a satisfactory basis. Some of the existing centres, such as Kyabram, Tatura, Shepparton East, Undera, etc., will tend to become main switching centres for groups of branch exchanges, while underground cables will gradually replace aerial routes for junctions and subscribers. Such development will eliminate the present need for long lines and party lines, both Departmentally and privately constructed, enabling continuous service to be given to subscribers from local exchanges within reasonable distance. As the area approaches more closely the conditions found in Metropolitan networks, standard automatic main and branch exchanges will replace R.A.X.'s, with a consequent change from open numbering to the normal closed numbering scheme. This change will, of course, be gradual, each part being undertaken as the growth in traffic makes it economical to provide the necessary plant.

The part to be played by the R.A.X. in developing a national service, while an important one, is chiefly a pioneering role. It enables continuous service conditions to be given at an early stage by providing a satisfactory automatic service at substantially lower cost than can be given with the city system of automatic equipment. It also provides additional facilities, such as party line and trunk line service, which are very necessary in our scattered country areas, but are not required in metropolitan areas, for which standard automatic equipment is primarily intended. As the country areas develop and standard equipment becomes economical, these requirements, particularly multi-office trunks and party lines, become less essential, and can finally be dispensed with. The early provision of R.A.X.'s tends to stimulate development, and show at an early stage the probable trend of growth, allowing substantial savings to be made in providing line plant and also exchange and sub-station equipment, which can be so located as to meet both immediate and future needs to the best advantage and with the minimum of wastage. Its outstanding and immediate advantages are, however, economy and the provision of continuous service; and experience has shown that once the latter is provided development increases rapidly, making the provision of better facilities economical, and facilitating the provision of improved services.

The foregoing gives the background against which the requirements of the future are being developed. Now that the concentration on the war-time demands has lifted, it has been practicable to consider the requirements for the extension of automatic to assist the country dweller to the maximum extent practicable. The facilities to be met have been reviewed, circuits developed as necessary and prototype models have been made of a unit to meet the conditions discussed above. In a subsequent article it is proposed to give details of these units.

CROSSTALK REDUCTION IN TELEPHONE CABLES

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PART 2 — BALANCING OF CARRIER CABLES

General: In the operation of multi-channel cable carrier systems it is the practice to use separate cables for the two directions of transmission. This allows the employment of the same group of carrier frequencies in each cable, because crosstalk between pairs in cables laid side by side is not worse than about 130 db. at 72 kC/s. Hence in a repeater section with a circuit attenuation of 60 db., the near-end crosstalk due to coupling between pairs in the "go" and "return" cables is not worse than about 70 db. below the received signal, and may be regarded as having negligible influence on the total interference due to crosstalk. The balancing of the cables therefore involves only the control of far-end carrier frequency crosstalk within each cable.

Fig. 6 illustrates the more important types of far-end crosstalk coupling. Path (a) is one of those followed by the direct crosstalk components. As the total distance travelled from the near to the far end of the section by each of these components is the same, they arrive at the receiving end of the disturbed pair in approximately equal phase at all frequencies. Paths (b) and (c) represent two of the many reflected near-end crosstalk components. As these crosstalk currents in general traverse different lengths of cable, they differ in phase from each other and from the direct crosstalk currents, and the phase relations vary with frequency. Path (d) represents the crosstalk coupling via a tertiary circuit, such as a longitudinal circuit (equivalent to the phantom circuit in a V.F. cable), or the cable sheath. As the propagation characteristics of these circuits differ from those of a cable pair, the crosstalk currents from these sources are not in phase with the direct crosstalk.

The final crosstalk balancing of each cable is carried out by means of adjustable condensers (and, where necessary, resistors) located normally at the far end of each repeater section. The crosstalk can only be reduced to a satisfactory value if the currents to be balanced have the same phase relations to each other, at all frequencies. Hence it is necessary to reduce as far as possible, by controlled jointing of the cable as it is laid, the crosstalk components represented by paths (b), (c) and (d) of Fig. 10.

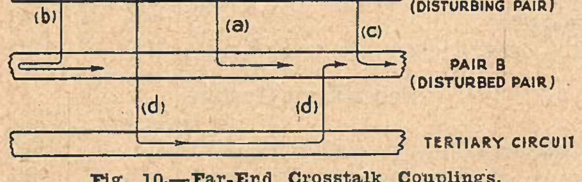


Fig. 10.—Far-End Crosstalk Couplings.

The control of "side to side" capacity unbalance between adjacent cable lengths is of importance in reducing the direct far-end crosstalk due to capacity unbalance. It should be noted that as the capacity unbalance does not vary appreciably with frequency, measurements on carrier cables can be carried out with a testing frequency of 1 kC/s as in the case of voice frequency cables.

The reflected near-end crosstalk can be reduced considerably by:—

(i) close matching of the impedance, particularly at the higher frequencies, where the near-end crosstalk is greatest;

(ii) reducing the near-end crosstalk as far as practicable.

The terminal apparatus can be matched to the cable impedance to give a satisfactory "Return Loss," provided that the cable impedance is constant and substantially non-reactive at the highest frequency in use. This requires close matching of the impedance of adjacent groups of cable lengths by the selection and jointing of pairs based upon their mutual capacity characteristics. "Return Loss" expressed in db. is a measure of the similarity between the characteristic impedances of two successive sections of line (or line and terminal apparatus), and is determined by the formula:—

$$\text{Return Loss} = 20 \log_{10} (Z_1 + Z_2)/(Z_1 - Z_2)$$

It is not practicable to reduce appreciably the carrier frequency near-end crosstalk between cable pairs by means of capacity balancing between manufactured lengths (nominally, 200 yards), due to the large phase change over each such length (about 19° at 60 kC/s.). Improvement in the near-end crosstalk at carrier frequencies must, therefore, be achieved mainly by control during manufacture.

Since the far-end crosstalk due to third circuit effects occurs via two tertiary crosstalk coupling paths in series, it can be controlled by the reduction of "side to phantom" and "side to earth" capacity unbalances between adjacent cable lengths. To ensure satisfactory results, uniform propagation characteristics are necessary. For this reason, and to assist the field matching of mutual capacity, the cable lengths are allocated at the factory to their positions in the repeater section on the basis of the mutual capacity per mile of each length.

Electrical Characteristics of Carrier Cable

As the electrical characteristics of the 24 pair 40 lb. star quad carrier cable, as received from the manufacturer, have an important influence on the results to be achieved in the balancing processes and the final overall results, the more important of the specification requirements will be listed:—

Cable type: Carrier type cable consists of 24 pairs of 40 lb. per mile paper insulated conductors laid up in star quad formation with a core of three quads and an outer layer of nine quads. The cable is not loaded.

Factory allocation: The factory allocation provides for the disposal of the drum lengths of manufactured cable (nominally 200 yards in length) to such positions in each repeater section as will ensure a minimum deviation of average mutual capacity from length to length. Where practicable, consideration is also given to other electrical characteristics which influence the overall crosstalk limits of the complete cable system.

Mutual capacity: The mean mutual capacity of every length of cable measured at 800 C/s shall be within the limits 0.054-0.060 mfds. per mile, the nominal mutual capacity being 0.057 mfds. per mile.

Deviation from the mean mutual capacity: For cable lengths in the range 176 to 200 yards, the deviation in mean mutual capacity of one length from the mean mutual capacity of all the cable lengths involved in a particular cable system shall not exceed 2.5%. An individual pair in a particular drum length is permitted to have a deviation up to 7.5% from the mean mutual capacity of the cable system.

Capacity unbalance: Expressed in mmfds. and measured at 800 C/s, the limiting values for normal lengths in the range 176-200 yards are:

Combination	Mean of all combinations in a particular length	Individual Readings
Between pairs in same quad	33	125
Between pairs in adjacent quads	10	60
Between pairs in non-adjacent quads	—	20
Between pairs in centre three quads and pairs in first layer	10	60
Between any pair and earth	100	400

Mutual impedance: Measurements are made at 5 kC/s and expressed in terms of magnetic couplings in microhenries the limits are:

Combination	Mean of all combinations in a particular length	Individual Readings
Between pairs in same quad	0.150	0.600
Between pairs in adjacent quads	0.070	0.400
Between pairs in non-adjacent quads	0.050	0.350
Between pairs in centre three quads and pairs in first layer	0.100	0.600

It will be appreciated that the foregoing limits are specification requirements, and that normally the values obtained on manufactured lengths will be appreciably below the figures quoted.

Testing Procedures

In the course of the development of carrier cable several methods of testing have been evolved. Generally speaking, the methods differ only in relatively minor details, and the overall results achieved are similar. In the following notes a brief description is given of the various methods which have been or are being used in Australia:—

Siemens Bros'. method: In this method, which was used in the balancing of the Sydney-Maitland carrier cables, the first unit tested in the field, called a primary group, consisted of four factory lengths (nominally 200 yards each). The joints between the four lengths were selected on the basis of factory test results, so as to reduce to the specified limits the capacity unbalance and mutual capacity deviations of the pairs. In addition, the resistance unbalance of each pair was reduced as far as possible. A further requirement was that each of the 12 quads in the primary group must appear as an inner quad in one length, so that each completed quad consisted of one inner and three outer quad appearances. Four primary groups formed a secondary testing group. The joints between the primary groups were selected to reduce the unbalances to the specified limits.

Far-end admittance unbalance tests were then made on all combinations of pairs over each completed secondary testing group. The unbalance test set used for these measurements measured the admittance necessary to neutralize the far-end crosstalk voltage in terms of the capacity ("c" in mmfds.) and leakance ("g" in micromhos) components at 60 kC/s. The secondary groups were then combined to form quarter-repeater, half-repeater and finally the whole repeater sections, the selections at each joint being aimed at reducing the resultant far-end admittance unbalance to the greatest possible extent. Particular attention was given to high values of leakance unbalance, as this factor was not readily reduced in the final balancing on the crosstalk balancing frame.

The specified unbalance limits expressed in mmfds. were:—

Primary Groups

	Selection	Field
Mutual capacity deviation	100	200
Side to side capacity unbalance	20	40
Phantom to side capacity unbalance	50	100
Side to earth capacity unbalance	100	200

Secondary Groups

	Selection	Field
Mutual capacity deviation	200	200
Side to side capacity unbalance	15	25

Phantom to side capacity unbalance	30	50
Side to earth capacity unbalance	50	100

The resistance unbalance limits were 0.25% for Primary Groups and 0.20% for Secondary Groups. For the admittance unbalance tests at 60 kC/s the limiting values were: c = 125 mmfds., and g = 5 micromhos.

A more complete description of this method is given in Vol. 3, No. 2, October, 1940.

Standard Telephones & Cables' method: In each repeater section, the "go" and "return" cables are divided into a number of "slings" of eight factory lengths of approximately 200 yards each. There are seven testing joints per "sling," designated thus:—

___ A ___ B ___ A ___ C ___ A ___ B ___ A ___

At "A" joints the three centre quads are joined to three quads in the outer layer. Mutual capacity deviations are reduced to stated limits. Before selecting the quads in the outer layer to which to connect the three centre quads, the measured mutual capacity of each of the pairs in the centre quads is decreased by 2% and these "corrected" capacity values used in determining the average, in selecting the quads and in computing the deviations. In check-testing from "B" joints, a corresponding correction (of 1% if the jointed lengths are equal) must be made in the mutual capacities of the group containing centre quads. At the "A" joints also, phantom to side capacity unbalances are reduced to the specified values, and side to side unbalances are reduced as far as possible. The reason for the reduction of the capacities of the inner pairs is that the nine outer quads, being close to the cable sheath, have a lower inductance per unit length, and therefore lower impedance than the inner quads. The reduction of the capacities of the inner pairs ensures that, on the average, these pairs will be connected to the outer pairs of higher capacity, so that the true capacity of the combination of inner and outer pair will be greater than that of the outer plus outer pair. It will be seen that the two groups of pairs formed at the "A" joint will thus have approximately the same ratio of inductance to capacity, and therefore any residual inequalities in impedance are removed by the method of jointing the two groups of pairs at the "B" joint.

On each side of a "B" joint, the cable is divided into two jointing groups. No 1 group consists of the six quads which lie in the outer layer throughout the two lengths jointed together at the "A" joint. No. 2 group consists of the six quads which lie in the centre over one or other of the two lengths jointed at the "A" joint. At the "B" joint the quads of No. 1 group are connected to quads of No. 2 group on the other side of the joint. Subject to the above limitation, the capacity unbalances are reduced as far as possible.

At "C" joints the twelve quads are treated as a single jointing group. Capacity unbalances are then reduced as far as possible to the specified limits.

Joints between 8-length slings: At the alternate joints between "slings," the twelve quads are treated as a single jointing group, and resistance unbalance is reduced to meet the specified requirements. The remaining joints can be made "straight," except that the centre joint of the repeater section is left unjointed for distant-end admittance unbalance tests over each half-repeater section.

Poling tests: The side to side far-end admittance unbalance is measured "straight" and "reversed" at 60 kC/s on all quads in each completed half-repeater section (each pair of the quad is taken in turn as the disturbing pair). On the basis of these tests, a jointing schedule designed to reduce the differences between straight and reverse readings of the leakance component on the whole repeater section is prepared. The effect of this balance is checked after the completion of the centre joint by measuring the admittance unbalance "straight" and "reversed" over the whole repeater section. The joints to the terminating frame at the "country" end of the cable are made in such a way that the pair numbering is correct at each repeater station.

Unbalance limits: The capacity unbalance in mmfds. expressed in terms of results over a complete repeater section are not to exceed:—

	Av. Av.	Av. Max.	Max. Av.	Max. Max.
Side to side on 8-length slings	10.6	32	16	50
Phantom to side on pairs of adjacent lengths	85	255	128	425

In each pair of lengths connected by an "A" joint the deviations of individual mutual capacities from the mean capacity of all the pairs in the cable shall not exceed the following percentage limits:—

Av. Av.	Av. Max.	Max. Av.	Max. Max.
0.5	1.5	0.5	2.5

The difference in resistance between wires of a pair shall not exceed 0.25% of the loop resistance of the pair.

Present testing procedure in Australia: Using actual test results from the Sydney-Maitland cable as a basis, a comparison was made of the Siemens' and S.T. & C. methods. Conclusions reached from this analysis were:—

(a) There was some value in selecting the four drum lengths forming a "half-sling" as a group, providing this could be done without affecting the essential requirements of the S.T. & C. "A" and "B" joints.

(b) An improvement in characteristics could be obtained by testing and jointing 800 yard cable lengths on Siemens' "secondary group" basis, involving normally four such lengths in a group.

(c) Extension of the resistance unbalance and mutual capacity tests to the 800 yard lengths and the selection of these characteristics in the "secondary" or "2-sling group," as far as practicable, was desirable.

(d) The considerable additional work involved in Siemens' method by the testing of the far-end admittance unbalance at 60 kC/s on all combinations of secondary groups was not essential.

The testing procedure based on these conclusions was applied to the Melbourne-Seymour cable, and is being applied to the Sydney-Bathurst cable at present being installed. A description of this method is set out in the following:—

1 A_1 2 B 3 A_2 4

← half-sling →
Nominally 4 × 200 = 800 yds.

Half-sling groups: The primary testing group, called the "half-sling group," consists of four factory lengths. The joints between these lengths are designated "A_1," "B" and "A_2" respectively. The rules for the selections at these joints are as specified in the S.T. & C. procedure. The factory measurements of mutual capacity, capacity unbalance and resistance unbalance, are used in the selections.

The reduction of mutual capacity deviations at the "A" joint is of primary importance, due to the method of allocating the drum lengths to their positions in the repeater section. Although the mean mutual capacities of the two drum lengths connected together at an "A" joint may differ to some extent from each other, the mean capacity of the combined lengths should match, as closely as possible, those of the adjacent groups. Therefore it is necessary to join pairs of high capacity, that is, high positive deviation from the mean, to pairs of low capacity, or high negative deviation from the mean.

In order to facilitate balancing of the capacity deviations and adherence to the balancing rules, which are the same as those specified in the S.T. & C. method, a "mutual capacity deviation" sheet is used. A sample sheet giving actual test figures is shown in Fig. 11. The mutual capacity figures obtained from the factory test sheets for the two drum lengths to be jointed are entered in columns 4 and 12 respectively of the sheet, those for the "city" side of the joint being placed on the left-hand side.

POSTMASTER-GENERAL'S DEPARTMENT Sheet No. 20

MUTUAL CAPACITY DEVIATION SHEET

Section 120-2/130-4
Test from FACTORY SHEETS
Date
Weather
Temperature

Cable DALLEY ST - PARRAMATTA - GO

Standard Capacity	Side	Wire to Wire	=
	Side	Wire to Wire	=

Section 120 - 2 / Section 123 - 30

Quad. No.	Mutual Capacity: Order of Mag.	Sum	Pr. 1 / Pr. 2	Dev.	Jntg. Diagram	Mutual Capacity: Pr. 1 / Pr. 2	Dev.	Quad. No.	Calculated Resultant: Pr. 1 / Pr. 2	Dev.	Mutual Capacity: Pr. 1 / Pr. 2	Dev.	Sum	Order of Mag.	Quad. No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	8	1329	665	-3	X	517	-3	5	1180	-7	518	-2	1039	7	1
			664	-4		515	-5		1181	-6	521	+1			
2	11	1314	657	-11	X	524	+4	7	1177	-10	522	+2	1041	4	2
			657	-11		520	0		1181	-6	519	-1			
3	7	1335	667	-1	—	518	-2	8	1185	-2	521	+1	1041	5	3
			668	0	—	514	-6		1182	-5	520	0			
4	12	1309	655	-13	—	529	+9	12	1184	-3	518	-2	1031	11	4
			654	-14	—	526	+6		1180	-7	513	-7			
5	4	1346	671	+3	X	518	-2	1	1192	+5	517	-3	1032	10	5
			675	+7		521	+1		1193	+6	515	-5			
6	3	1347	673	+5	—	522	+2	2	1195	+8	525	+5	1046	2	6
			674	+6	—	519	-1		1193	+6	521	+1			
7	6	1338	669	+1	—	522	+2	10	1191	+4	524	+4	1044	3	7
			669	+1	—	518	-2		1187	0	520	0			
8	9	1325	662	-6	—	523	+3	11	1185	-2	518	-2	1032	9	8
			663	-5	—	516	-4		1179	-8	514	-6			
9	10	1316	658	-10	—	525	+5	6	1183	-4	518	-2	1028	12	9
			658	-10	—	521	+1		1179	-8	510	-10			
10	1	1374	687	+19	X	518	-2	9	1197	+10	522	+2	1040	6	10
			687	+19		510	-10		1205	+18	518	-2			
11	5	1344	672	+4	—	521	+1	3	1193	+6	523	+3	1039	8	11
			672	+4	—	520	0		1192	+5	516	-4			
12	2	1348	672	+4	—	518	-2	4	1190	+3	529	+9	1055	1	12
			676	+8	—	515	-7		1189	+2	526	+6			

Computations: 24)16025(667.7 24)28493(1187.2 24)12468(519.5

Total		Remarks: A1 JOINT		Total
Mean 00668				Mean 00520
M.E.C.				M.E.C.
M.E.C. per mile				M.E.C. per mile
Tester:		Test Set No.	Calculated by: M.L.	
Jointer:			Checked by: V.E.	

Q.4797/42.

Fig. 11.—Mutual Capacity Deviation Sheet.

The figures for the three inner quads in each length are reduced by 2% before transfer to the mutual capacity deviation sheet, as in the S.T. & C. method. In columns 2 and 15 the order of magnitude is listed on the basis of the sum of the mutual capacity of the two pairs and the quad and order of magnitude figures associated with the three inner quads underlined. The quads are then allocated in order of magnitude, maximum values being connected to minimum values, subject to the limitation of jointing centre quads to outer layer quads as mentioned previously. The figures in column 12 are transferred to column 7, with the corresponding quad numbers to column 9. The jointing of the pairs of the selected quads (not wires of a pair), either straight or crossed, is shown in column 6, this being determined by the requirement that the larger pair value be connected to the smaller pair value.

The calculated resultant is determined by the addition of the appropriate figures in columns 4 and 7, and entered in column 10. The mean mutual capacity is computed, and the deviations (+ or —) entered in appropriate columns. Where the total mutual capacity of two quads is the same, the order of magnitude is determined by the highest pair value. Where the total mutual capacity of both quads and pairs is the same, the same magnitude numbering is used. Unless high values of phantom to side or side to earth occur in one drum length, and the limit for these characteristics would otherwise be exceeded, the jointing of quads at "A" joints should not vary from that determined by the order of magnitude. Where necessary, the unbalance characteristics in the order phantom to side capacity unbalance, side to side capacity unbalance, resistance unbalance and side to earth capacity unbalance should be reduced as far as possible by cross-splicing within the quad. Phantom to side unbalance is given first preference (after mutual capacity deviation) at "A" joints, in order to limit the length and consequently the phase change over which balance is made. The reason for this will be apparent from the earlier discussion of indirect crosstalk components. The mutual capacity deviation, capacity unbalance and resistance unbalance values for the two individual drums and the resultant values obtained by the "A" joint balance are recorded on a balance checking sheet. The unbalance limits in mmfds. for the "A" joints are as follow:—

	Selection	Field
Mutual capacity deviation	150	300
Side to side capacity unbalance	20	40
Phantom to side capacity unbalance	100	200
Side to earth capacity unbalance	150	300

Having completed two adjacent "A" joints, the calculated resultant mutual electrostatic capacities are transferred in order of quad numbering to a "B" joint mutual capacity deviation sheet, being entered in column 4 or 12, depending on whether the "City" side or "Country" side of the "B" joint is concerned. In making this transfer the values for each of the six quads associated with the centre group of three quads in one of the factory lengths are increased by 1%. (If the lengths of the two drums on each side of the "B" joint differ materially, the percentage increase in the mutual capacity is adjusted accordingly.) The allocation of quads and the computation of the deviations are carried out in the same way as for "A" joints, with two exceptions. First, the quads on each side of the sheet are divided into two groups of six quads, each group having its own order of magnitude. Those quads comprising a centre quad in one length and an outer quad in the other, form the first group. Quads which are entirely in the outer layer form the second group. As in the S.T. & C. procedure, quads from the first group on the left-hand side of the sheet must be jointed to quads in the second group, and vice versa. The quads selected in this way for jointing together are then cross-spliced as required to reduce the within quad capacity unbalance and resistance unbalance to the specified values, having regard to the important condition that the mutual capacity characteristics are not materially affected. The unbalance limits in mmfds. for the "B" joints are as follow:—

	Selection	Field
Mutual capacity deviation	100	200
Side to side capacity unbalance	20	40
Phantom to side capacity unbalance	50	100
Side to earth capacity unbalance	100	200

The resistance unbalance limit expressed as a percentage is 0.25.

The mutual capacity deviation, capacity unbalance and resistance unbalance for the groups of drum lengths on each side of a "B" joint are recorded on a balance checking sheet, and jointing sheets and ringing schedules are prepared from the selection in the series of three balance and checking sheets (two "A" and one "B" joints).

It was found desirable, in addition, to prepare a balance schedule setting out, for each quad, the unbalances in each length, the quad jointing and resultant unbalance. This sheet is very helpful to the field testing officer in cases where errors have been made, either in the factory testing or in the office balancing or field jointing. A space is left after the resultant unbalance figures for each quad to allow the recording of the results of the check tests in the field.

Two-sling groups: The results of the field check tests on four adjacent half-slings are transferred to a selection form, in which the results for the four groups are placed side by side to facilitate selection of the quads to be jointed together. The initial selection is made between the first and last half-slings, with the object of bringing the quads straight at the end of the two-sling group. The three test joints between half-sling groups are designated in the following manner:—

1 C_1 2 D 3 C_2 4

←——— Two-sling ———→

Nominally 4 × 800 = 3200 yds.

The following unbalance limits in mmfds. should be satisfied for the joints C_1 and C_2 between the sections 1-2 and 3-4 respectively:—

	Selection	Field
Mutual capacity deviation	200	200
Side to side capacity unbalance	25	50
Phantom to side capacity unbalance	50	100
Side to earth capacity unbalance	100	200

and the overall values for the two-sling group should be reduced to the following:—

	Selection	Field
Mutual capacity deviation	200	200
Side to side capacity unbalance	15	25
Phantom to side capacity unbalance	30	50
Side to earth capacity unbalance	50	100

The resistance unbalance limit expressed as a percentage is 0.20.

Half-repeater sections: These nominally consist of six two-sling groups. In jointing the two-sling groups together, the quads are jointed "straight" and the resistance unbalance for the completed half-repeater section reduced to a limit of 0.10%. Check tests of far-end admittance unbalance are made over each half-repeater section between all pair combinations. In jointing the two half-repeater sections together, the resultant far-end unbalance is reduced as far as possible, particular attention being given to large values of leakance unbalance.

Field Testing

Having outlined the cable balancing methods applicable to carrier cables, the more important of the field practices will be described.

Testing equipment: As indicated previously, the testing equipment is housed in a test van. The operator is provided with a telephone to enable communication with the jointers and connecters, so that alterations to jointing can be carried out rapidly as required during the testing of the cables.

The most important item of testing equipment is the Siemens trunk test set, which has been described in Part 1, Vol. 5, No. 6. This set is used to measure mutual capacity deviation, capacity unbalance and resistance unbalance. Fig. 12 shows schematically the circuit arrangement of the set when used for the measurement of resistance unbalance. A standard three decade condenser box, range 0 to 1.11 mfd., and a variable air condenser having a range from 0 to 1000 mfd. are used in conjunction with the trunk cable test set for the measurement of mutual capacity.

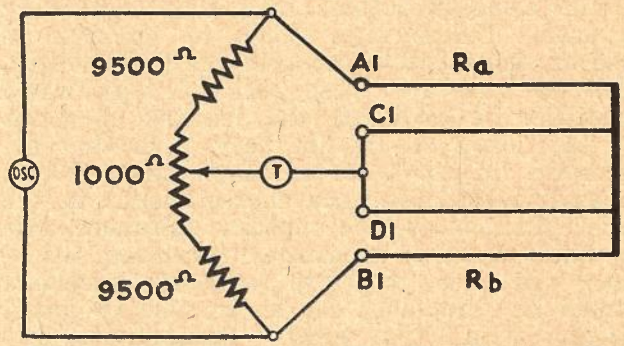


Fig. 12.—Simple Circuit for Measuring Resistance Unbalance. Dial of Potentiometer is calibrated to read Percentage Unbalance.

Far-end admittance unbalance is measured by means of an admittance unbalance test set, a schematic circuit of which is shown in Fig. 13. An oscillator having a frequency of 60 kC/s, and a detector amplifier, are also required for these measurements. A 500-volt bridge megger, driven by a battery-operated 12-volt motor, is used in the systematic testing of the cables at each stage of jointing.

Testing staff: The testing staff and their functions are as follow:—

Senior Technician: Carries out cable tests; directs jointers.

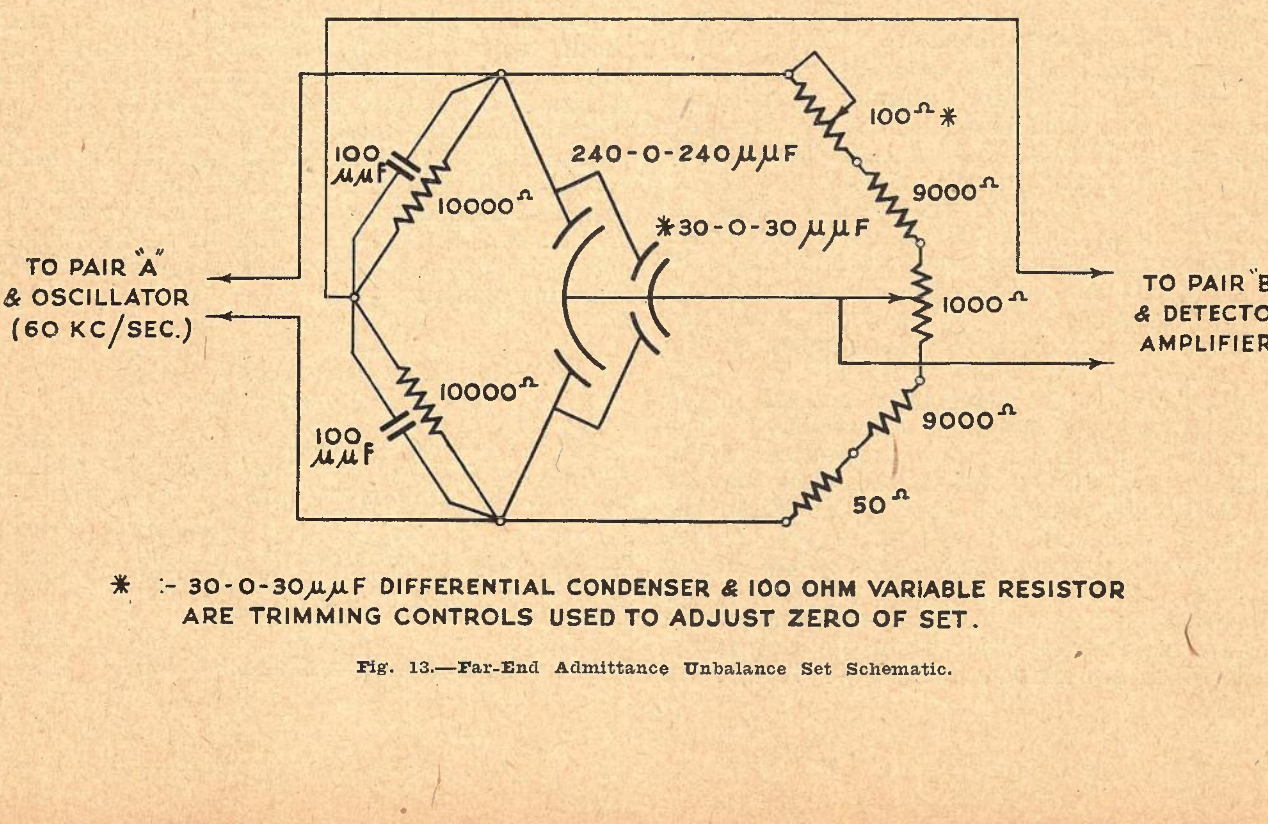


Fig. 13.—Far-End Admittance Unbalance Set Schematic.

Three Linemen, Grade 2: Joint cable in accordance with jointing sheets; alter jointing as required by testing officer.

Three Linemen, Grade 1: Assist Linemen, Grade 2 (above), in preparing cable for jointing, etc.

Two Linemen, Grade 2: Prepare cable ends for testing; identify cable pairs; connect cable pairs to test lead as required.

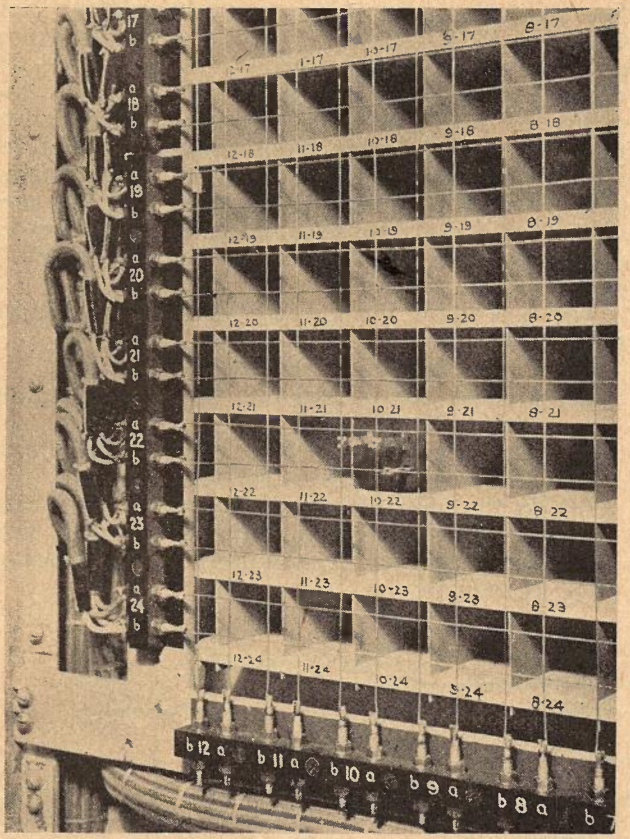


Fig. 14.—Network Chassis in position showing Terminals engaging Cross-connecting Wires.

Half-sling and two-sling groups: The testing procedure for two-sling groups and half-sling groups is similar. The jointers are supplied with the jointing sheets, on which the jointing of both "go" and "return" cables is indicated. The jointing of the "go" cable is proceeded with first, and the jointing of the "return" cable follows during the testing of the "go" cable. One pair in each cable is marked on each jointing sheet as the "talking" pair, and this pair is connected through by each jointer as soon as possible, and communication established with the other jointers as a check against possible errors in identifying the "go" and "return" cables. The cable sheaths are bonded through at each joint with a lead strap. The trunk cable test set is then connected to the test lead, the earth clip of which is attached to the cable sheath. The selector switch is placed at "C_1" position. The main condenser dial is then set at the zero position on the lower window. The three dial decade condenser box is set at zero on all dials. The bridge is then balanced to the null-point by adjusting the variable air condenser and the resistance unbalance dial of the trunk test set. In this way, the mutual capacity of the first pair of the test lead is balanced out. This procedure is repeated with the selector switch set to "C_2" to check that a balance is obtained with the same settings as before. If necessary, a short twisted pair of insulated wires can be used to make the setting of the variable air condenser the same for both pairs of the test lead. The selector switch is then set in turn to each of the five capacity unbalance settings, and the adjustable condensers appropriate to each position are adjusted to give a null balance of the bridge. The main differential condenser is, of course, set at zero on the upper window.

The next step is to connect a quad, usually quad 1 of the cable, to the test lead. The mutual capacity of the first pair is measured by adjusting the three decade condenser and the main dial of the bridge, the reading being made on the lower window. The setting of the auxiliary air condenser is not altered during this measurement.

The setting of the main differential condenser is then adjusted so that the predicted deviation from the mean of the pair under test, as indicated on the balance schedule for the testing group, is read on the upper scale. The bridge is again balanced to the null point by adjusting the auxiliary air condenser. This condenser is then left at this setting for all subsequent measurements on the cable under test.

The mutual capacity deviation of the second pair is then measured, followed by the five capacity unbalances of the quad, and the resistance unbalances of each pair of the quad. In order to check the accuracy of the measurements of capacity unbalance, the connections of pair one of the quad, i.e., wires 1 and 2, are reversed in the test shoe; the same values, but with reversed sign, should then be obtained for pair 1 to phantom, side to side, and pair 1 to earth unbalances. Pair 2 is then reversed and the unbalances measured to check that the same values are obtained with the appropriate reversals of sign. If necessary, small adjustments are made to the trimming condensers at the top left-hand corner of the trunk test set.

The remaining quads of the cable are then measured, the unbalance figures being recorded in the space provided under the predicted figures on the balance schedule.

When the measured residuals are outside the tolerable limits, alterations must be made in the joints to bring the residuals down. The error can often be deduced by comparison of the measured values with those anticipated and with the unbalances of the component sections, and two typical cases are:—

(a) Crossed wires in previous test: If one of the component sections had been tested with an erroneous wire cross in the connection to the test set, the side to side, side to phantom and side to earth of that pair would be reversed in sign. Hence the residuals would be in error by double the value of the characteristics concerned; by halving the discrepancies between the anticipated and measured residuals and comparing the result with the values of the component sections, it is usually possible to identify the section at fault. The error can be remedied by crossing the wires of the pair concerned in the joints at both ends of the affected section.

(b) Incorrect sign in previous test: If, instead of the crossed wires in (a), the error had been due to the incorrect recording of the sign of one characteristic, the result would be the introduction of a discrepancy in the residual of double the value of the affected characteristic, and here also the fault can often be located. The remedy is to re-balance, and to disturb as few joints as possible in so doing.

When no indication can be obtained in this way, and the schedules have been checked, the joints in the affected quad must be broken down to determine the true values of the individual sections and thus permit a re-balance to be made.

The joints are broken down in turn, starting from the one most remote from the testing end. The differences between each successive test give the values of the section last cut off, as they should appear in the balance schedule. For example, in a group containing four sections, A, B, C, D, test (1) of the whole group gives values corresponding to A + B + C + D. When section D is cut off, test (2) gives the values of A + B + C. Hence D is equal to (1)—(2). The values corresponding to the remaining sections can be obtained by repeating this procedure. The process need only be continued until the fault is discovered. The correct values are then inserted in the balance schedule, and a re-balance made.

The procedure for making an alteration is as follows:—

(a) Check the arithmetic of the balance;
(b) inspect for either of the two common faults;
(c) check the balance figures against the test schedules of the component sections;
(d) in the case of two-sling groups, check the ringing-through of the component sections against the primary group balance schedules;

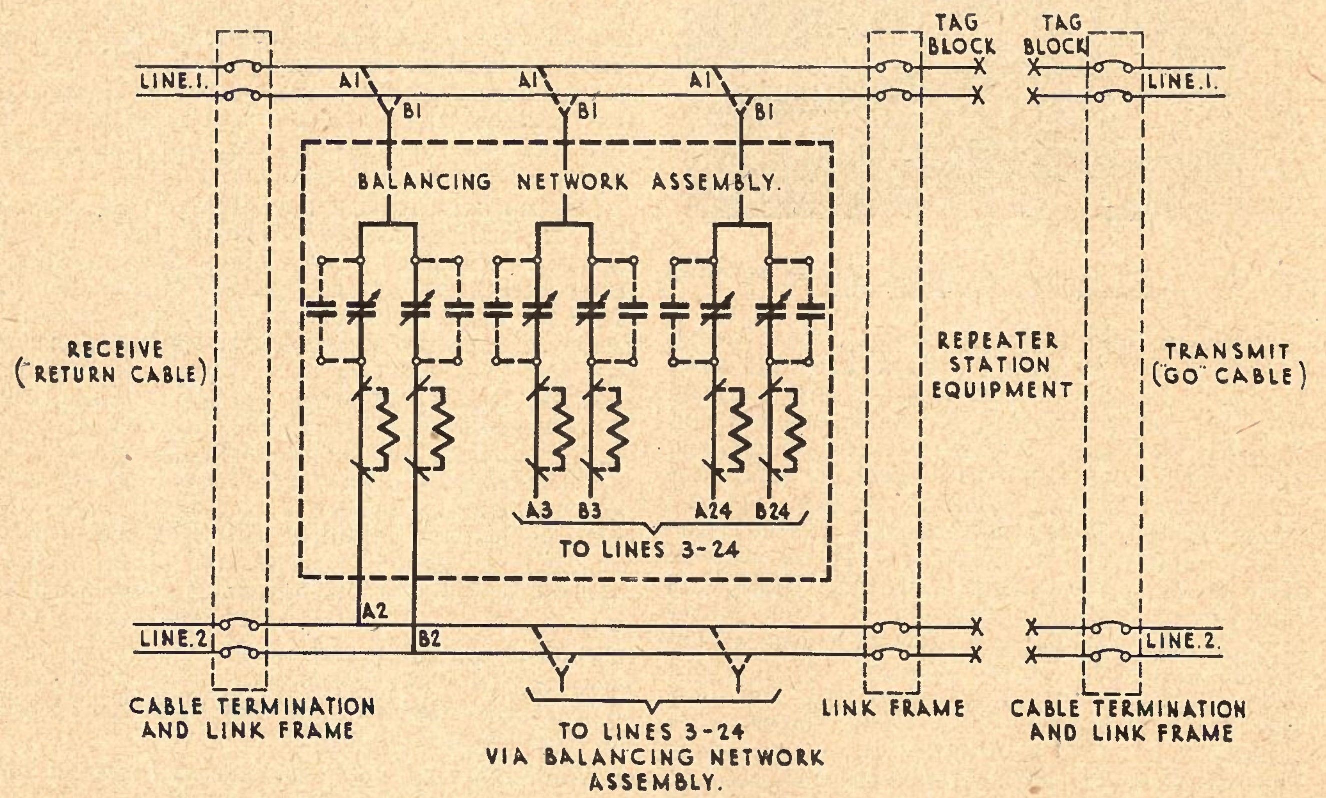


Fig. 15.—Balancing Network Bay Schematic.

(e) check the jointing and ringing-through schedules against the balance schedule;
(f) check the ringing-through of the faulty quad;
(g) instruct the jointers to check their joints;
(h) break down the joints in turn.

These steps are carried out one by one until the fault is discovered, when the subsequent steps are, of course, not required. Then re-balance, make the corrections to the jointing and ringing-through schedules, make the alterations to the joints, and re-test. It is important to ensure that the alterations are recorded in the balance and test schedules.

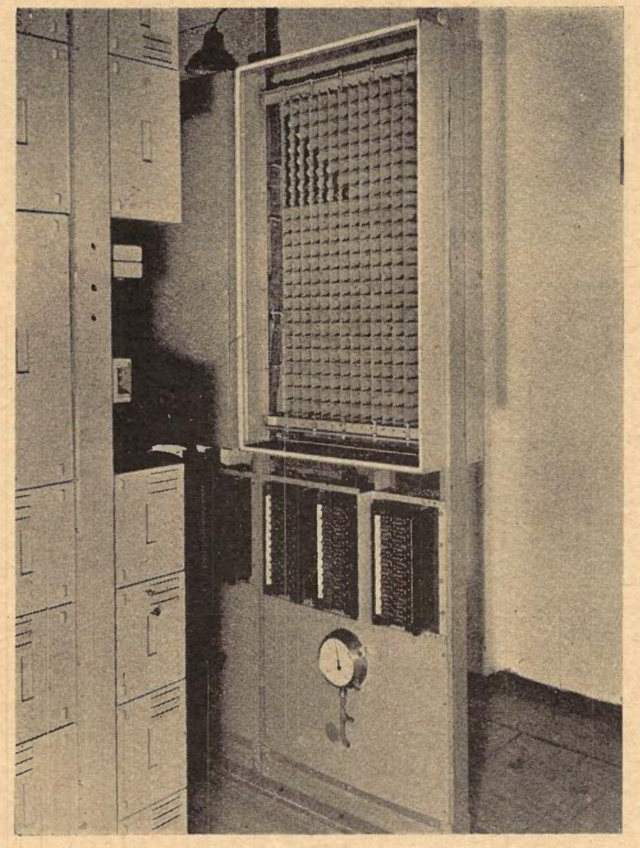


Fig. 16.—Front view of Balancing Network Bay showing Cable Terminals, Gas Alarm Gauge and Network Unit.

Half-repeater and full repeater sections: The tests carried out over these sections consist of checking the resistance unbalance of each pair, and the far-end admittance unbalance of all pair combinations in each cable. The apparatus used for these tests has already been mentioned, and a more detailed description is given in Vol. 4, No. 5, October, 1943. There are some features of the field measurement of far-end admittance, however, which need description. In order to facilitate measurements of unbalance between pairs not in the same quad, and to eliminate couplings in the test leads, the test set has two sets of four terminals, to which two quad test leads are connected. Two keys are provided to enable the selection of one or other of the two pairs in each quad at the

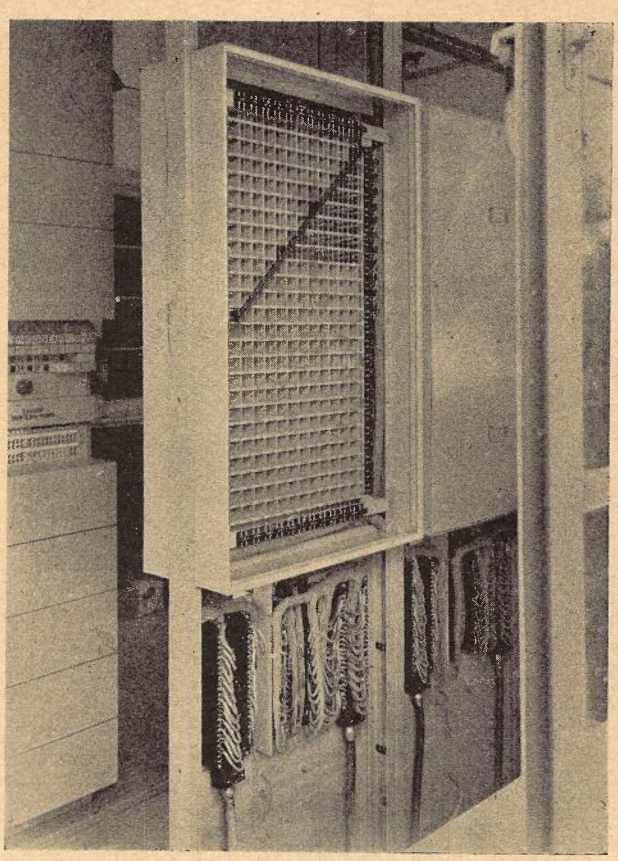


Fig. 17.—Rear view of Balancing Network Bay.

"disturbing" and "disturbed" pairs respectively. When measuring the within-quad unbalances, one pair of the quad is connected to the "disturbing" test lead, and the other to the "disturbed" test lead. As it is generally desirable to house the test oscillator (frequency, 60 kC/s) in the test van, the oscillator output is fed to the distant end of the section under test by means of a pair in the second cable. A change-over key is provided at the testing end to enable the switching of the test current from one pair to the other of the disturbing quad. Two 150 ohm resistors are provided to terminate the pairs of the disturbed quad at the far end of the cable. The results of the far-end admittance unbalance measurements, both "c" and "g" components, together with their sign and magnitude, are recorded on the form provided for this purpose, and are used in the subsequent balance or as a guide in adjusting the balancing networks on the crosstalk balancing frame at the repeater station. The relationship between the far-end crosstalk at 60 kC/s and the far-end admittance unbalance is given by the equation:—

Crosstalk (in db.) = 20 $\log_{10} 8/Z_0 (g + jwc)$
Z_0 is the characteristic impedance, g is expressed in mhos and c in microfarads.

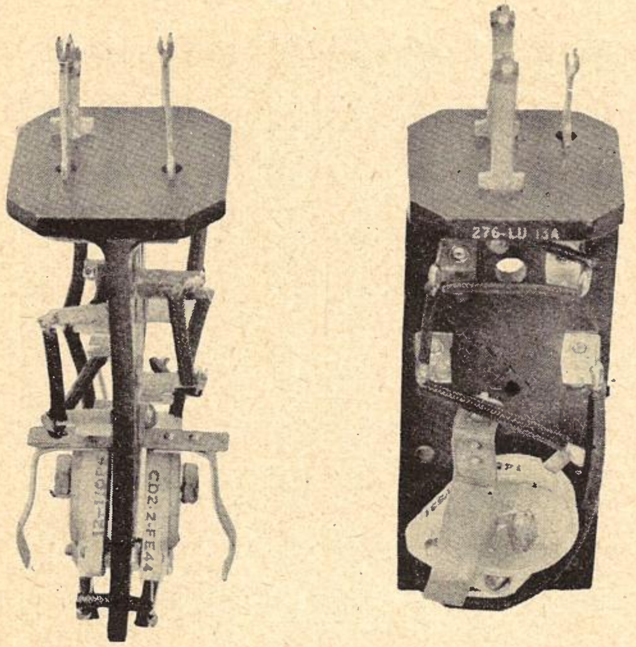


Fig. 18.—Network Chassis showing Ceramic Trimmer Condensers.

Final crosstalk balancing of repeater section: The residual crosstalk couplings between all combinations of pairs in the cable, after completion of intermediate joints throughout the full repeater section, are finally reduced, where necessary, to a predetermined maximum value by connection of appropriate condensers or condenser-resistance networks at the terminal or repeater station located at the receiving end of the section. In practice, the cable is terminated on a special bay on which, by means of a system of crossed wires (see Fig. 14), the connection of a network between any two pairs is facilitated. Fig. 15 shows in schematic form the wiring arrangement, and Figs. 16 and 17 show front and rear views of the bay equipment.

Adjustable condensers of the ceramic trimmer type are used. These combine maximum stability with smoothness and ease of adjustment, and have a capacity range of the order 10 to 100 mmfds. Higher values may be obtained by connecting a fixed ceramic condenser in parallel. Resistors are commercial ¼-watt type of appropriate value. Each network is assembled on a small chassis for insertion in a nest on the bay. The network consists normally of two adjustable condensers differentially connected, with facilities for adding fixed condensers in parallel and resistors in series. The network mounting is illustrated in Fig. 18, and Fig. 19 shows the manner of insertion into the nest of screened compartments at the rear of the bay.

Fig. 20 shows diagrammatically the manner in which the trimmer type condensers are used for neutralizing a capacity unbalance between two pairs. In any particular case, only one condenser is normally required between one wire of each pair; but for convenience in initial and possible subsequent adjustment of the net-

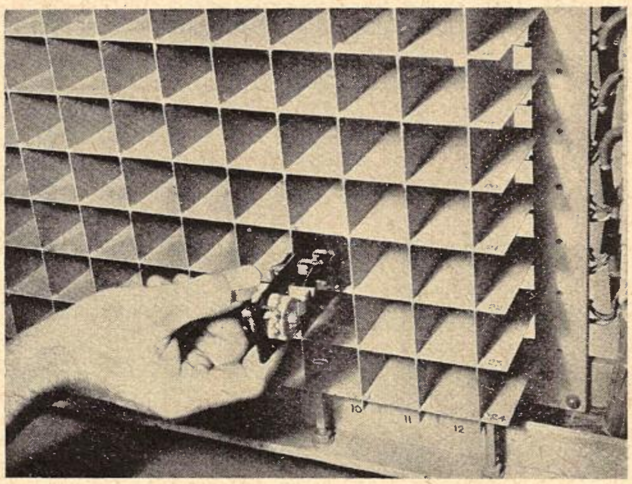
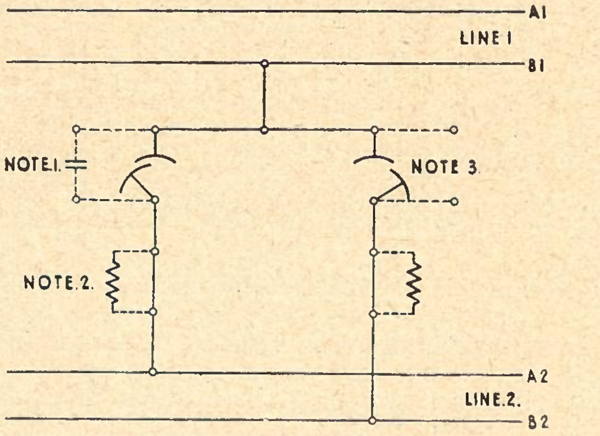


Fig. 19.—Insertion of Network Chassis into Screened Compartment.

works, it is the practice to fit two condensers for each pair combination. The one condenser in each case not required for balancing purposes is set to its minimum position. The neutralizing capacity may be connected between the A wire of the first pair and either the A or B wire of the second pair. The choice, in the latter case, will be determined by the sign of the unbalance. The choice of the A or B



NOTE.1-FIXED CONDENSER FITTED IF REQUIRED
2-RESISTANCE FITTED IF REQUIRED
3-CONDENSER NOT IN USE IS SET AT MINIMUM VALUE.

Fig. 20.—Method of connecting Condenser Network to reduce a Positive Unbalance. (Similar result would be obtained by connecting same Condenser between A1 and B2 Wires.)

wire of the first pair is so arranged as to distribute the balancing capacities equally between A and B wires throughout the frame.

Far-end admittance unbalance measurements are made between all combinations of pairs, and the value of condensers and resistors, where necessary, adjusted to neutralize the measured values of capacity and leakance unbalance. Normally, only a very small proportion of the pair combinations requires the connection of resistors.

Bibliography

1. "Crosstalk," H. C. S. Hayes, R. A. Seymour and P. R. Bray, Institution of Post Office Electrical Engineers, Paper No. 169.

2. "Multi-Circuit Carrier Telephony," E. M. Richards and F. J. D. Taylor, Institution of Post Office Electrical Engineers, Paper No. 171.

3. "Telephone Cable Capacitance Test Set," A. Rosen, Engineering Supplement, Siemens' Magazine, No. 165, February, 1939.

4. "Crosstalk in Telephone Cables," R. W. Gandy, Engineering Supplement, Siemens' Magazine, No. 208, December, 1942.

5. "The Sydney-Newcastle-Maitland Cable," W. Engeman, Telecommunication Journal of Australia, Vol. 3, No. 2, October, 1940.

6. "Transmission Measurements to 150 kilocycles per second," J. D. Uffindell. Telecommunication Journal of Australia, Vol. 4, No. 4, June, 1943; Vol. 4, No. 5, October, 1943.

A CONVENTION OF HISTORIC IMPORTANCE

J. F. Ward, B.A., B.Sc.

Comments on the Symposium on Radio Location conducted by the Institution of Electrical Engineers, England, March, 1946

A secrecy so complete, consistent and enduring as surrounded the use of radio location during the war leads inevitably to a widespread demand for the release for peace-time applications of the information so long withheld. In Britain, the corner of this veil of security was lifted by Sir Edward Appleton, F.R.S., in a lecture after the defeat of Germany, but whilst Japan was still at war. It was, however, the Convention referred to above, and now under review, which set out to answer the demands of scientists, engineers and technical workers, who were so deeply interested because of the part each had played in one or more of the innumerable ramifications of this high priority project of technical warfare.

To present the overwhelming volume of information available, the Institution arranged a series of lectures, which occupied the greater part of four days. Even then, despite sessions which ran with few breaks from 9.30 a.m. till 8.30 p.m., it was found necessary for a number of lectures to be held simultaneously. Altogether, excluding the discussions, over eighty lecturers took part in the presentation of at least two hundred papers. The subject matter was dealt with in sections—aerial and wave guides, propagation, cathode ray tubes, valves, radio measurements and test gear, transmitters and receivers, circuit techniques, naval gunnery and precision radar systems—each of which, after introduction by an integrating lecture, was elaborated in detail by specialist papers and, in some cases, also by practical demonstrations and films. Many of these papers had been printed and were available for perusal prior to the lecture. As might be expected, so great was the interest evinced, that an overflow meeting was necessary at the Institution building itself, whilst the addresses were relayed by landlines to audiences at the Royal Naval Establishment, Whitley, and the Telecommunication Research Establishment, Malvern.

The Rt. Hon. John Wilmot, M.P., Minister of Supply, whose Department had been responsible for much of the radar production programme, opened the proceedings on Tuesday, 26th March, 1946, and the principal addresses were then delivered by Sir Robert Watson Watt, C.B., F.R.S., and by Dr. F. Llewellyn, President of the Institute of Radio Engineers (America), who had flown to England for the occasion.

Sir Robert Watt dealt with the highlights of the past ten years of intensive research and application which had led to the present highly developed state of the art. He mentioned the early experiments at television frequencies; the race against time to provide initial installations to increase this defence potential of the Royal Air Force before the declaration of war; the contribution of the U.S.A. and the Dominions, and the fine example in mutual co-operation this afforded; and, finally, the overwhelming superiority of Allied radar in the latter stages of the war. Although the U.S.A. had carried out, at its Radiation Laboratory, in the Massachusetts Institute of Technology, and associated institutions, the vast project of microwave radar design and production, Britain herself had been heavily committed throughout the war, both financially and in manpower. During the ten years of progress since 1936, her expenditure alone had been greater than the fantastic outlay involved to date in the atomic energy project.

Dr. Llewellyn, in his address, spoke of the complete change in outlook of American scientists and engineers occasioned by the visit of the British scientific mission in the summer of 1942, when was announced the discovery of the cavity magnetron of Randall and

Boot,* which enabled the production of far higher powers at 3000 Mc/s than were then obtainable in America at 400-600 Mc/s. The principle of "strapping" the cavities to give higher power and greater frequency stability employed in this magnetron was an entirely new concept to him and to his fellow-workers at that stage. He then outlined the widespread American participation in the radar programme from this time onwards.

To review, in this account, the technical sessions which followed, would be out of the question; but, of them, the one devoted to propagation was of outstanding topical interest. An outline, by Dr. H. G. Booker, of the numerous experiments on super-refraction at many stations throughout the world, was followed by an account of the elaborate set of observations made by the Department of Scientific and Industrial Research over the experimental three- and ten-centimetre radio links at Cardigan Bay, on the Welsh Coast. Sir Edward Appleton, F.R.S., fascinated all present with an address, delivered with great clarity, on Extratrophospheric Influences on Ultra-Short Wave Radio Communications. He mentioned scattering from within the ionosphere, radiation from the milky way (extra-galactic) and radiation from the sun (solar), and pointed out that these latter had been observed because modern U.H.F. receivers could detect this energy, which had to be of sufficiently high frequency to penetrate the ionosphere from outer space towards the earth's surface. He anticipated that further observations during the sunspot activity predicted to occur within the coming year would furnish additional information of use in the correlation of radio propagation conditions and terrestrial magnetic variations with the sunspot cycles.

In a paper also contributed to this session, T. L. Eckersley, B.S., B.Sc., F.R.S., urged the importance of relating, from stage to stage, the experimentally observed phenomena with mathematical theory, if the present rapid rate of progress was to be maintained. The discussion which followed the propagation papers was made memorable to all present because of the comments by Professor A. Clavier concerning his work on micro-wave propagation under great difficulties during the German occupation, and by Van der Pol, who recounted experiences whilst hiding in Holland.

A lecture by W. A. S. Butement, B.Sc., the originator of the "split beam" system of bearing determination used almost universally in modern precision radio location, was illustrated most strikingly by a short film. In this, the exposures were taken by a cine-camera bent to the aerial system of an aircraft radar fitted with control mechanism for automatically following the target. At no time was the detected aircraft completely outside the cone, which would correspond to the firing cone of the armament of the attacking aircraft. An adaptation of the automatic following system to light beams provided for those present a conclusive demonstration of the persistence of follow that can be obtained with existing equipment. The lecturer quoted an order of accuracy in radar ranging of approximately twenty yards in twenty miles, and illustrated the operational significance of this by examples of coastal and naval gunnery in which, at this extreme range, during darkness, direct hits were obtained with first salvoes. Applied to anti-aircraft gunnery, and in association with radio fusing of shells, a similar precision meant effective kills of the order of 98% during the latter stage of the V.1 bomb onslaught, despite target speeds, in this case, of up to 350 m.p.h.

Mention was made of the application of the plan position indicator form of radar presentation to peace-time navigation, and of the birth of radar television; whilst of more general interest, the display of sectionalised cavity magnetrons, klystrons, cathode ray tubes and crystal detectors received favorable comment.

A symposium such as this, in which many of the papers were delivered by the men so intimately connected with the pioneer developments, leaves strong impressions upon the observer. The sterling quality and outstanding originality of British scientific research must rank high amongst these, as also must the flexibility of the avenues of production, which allowed a tradition for first-class workmanship to be degraded temporarily to third-class levels in the name of quantity of output and operational urgency. The debt of the Allied nations to this enterprising spirit cannot be computed, whilst the publication of the results of the work in the forthcoming issues of the Journal of the Institution will mark an epoch in the dissemination of scientific knowledge.

*In his remarks as chairman at a meeting of the Royal Society of Arts, on 20/2/46, Sir R. Watson Watt, C.B., F.R.S., pointed out that, although available to German investigators, due to capture of Allied aircraft, the theory and design principles of the cavity magnetron appeared to be imperfectly understood by them at the conclusion of the war.

ANSWERS TO EXAMINATION PAPERS

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

EXAMINATION No. 2586—SENIOR TECHNICIAN—TELEPHONE

W. King

SECTION A—GENERAL

Q. 1.—A moving coil milliammeter gives a full-scale deflection with a current of 10 milliamperes. The resistance of the meter is 5 ohms.

(a) Describe with the aid of circuit diagrams how you would use the instrument to measure:—

(i) A direct current of 10 amperes.

(ii) A direct voltage of 100 volts.

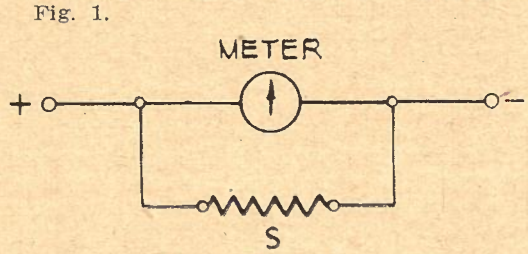
What additional apparatus would be required?

(b) If the 100 volts in (a)(ii) was that of a dry battery having an internal resistance of 100 ohms, what would be the error in the reading obtained?

A.—(a) The voltage drop across the milliammeter coil with full-scale deflection is given by Ohms Law as follows:—

$E = IR = (10/1000) \times (5/1) = 0.05$ volts.

(i) To measure a current of 10 amps., it is necessary to shunt the excess of current over 10 milliamps away from the meter as shown in Fig. 1.



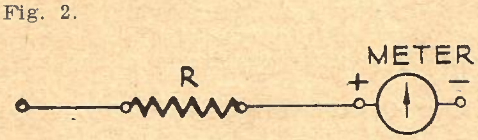
Q. 1, Fig. 1.

The excess current through the parallel shunt resistance S is $(10 - 0.01) = 9.99$ amps., and as the voltage across S is 0.05,

then $9.99 = 0.05/S$ by Ohms Law,

and $S = .005$ ohms approximately.

(ii) To measure 100 volts with a full-scale deflection a series resistance R is necessary to absorb the excess voltage over 0.05 volt as shown in Fig. 2.



Q. 1, Fig. 2.

This excess is $100 - 0.05 = 99.95$ volts, which will be the voltage drop across R with 10 milliamps flowing;

hence by Ohms Law $R = E/I = 99.95/0.01 = 9995$ ohms.

The additional apparatus required would be:

(i) One 0.005 ohm shunt to carry 10 amps.

(ii) One 9995 ohm resistance to carry 10 milliamps.

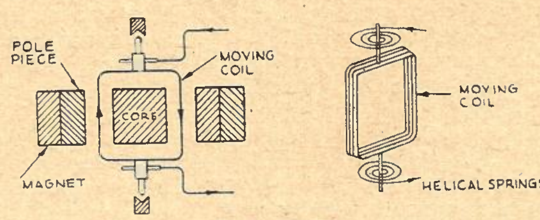
(b) If the internal resistance of the 100-volt battery is 100 ohms, then the total resistance in the voltmeter circuit will be $9995 + 5 + 100 = 10100$, and the current through the meter will be:

$I = E/R = 100/10100 = 9.9$ ma.

Thus the voltmeter would read 9.9 divisions, which would represent 99 volts. The error, therefore, is 1%.

Q. 2.—(a) Describe, with the aid of a sketch, the action of a moving coil voltmeter.

(b) How would you use the instrument to measure the resistance of the coil of a telephone relay?



Q. 2, Fig. 1.

A.—(a) A coil of fine wire is wound on a light aluminium former which is pivoted so that it can rotate in the intense magnetic field between the pole pieces of the permanent magnet. A soft iron cylinder is fitted inside the moving system in order to intensify the field in the air gaps and also to make the field radial at all points within the movement range of the coil. The force on any conductor in a magnetic field is proportional to $H \times L \times I$; where H = field strength, L = length of conductor, and I is the current in the conductor. Since H and L are constant for a particular instrument the force on the conductors of a coil is proportional to the current. This electromagnetic force produces a turning moment about the pivot which is opposed by the torque of a pair of helical hair springs. The springs are designed so that, when the pointer is at zero, the torque due to one spring is balanced by the torque of the other. When, however, the moving system is displaced the resultant torque of the two springs increases in direct proportion to the angle through which the coil is turned. Hence when a current is passed through the instrument the moving coil rotates until the electromagnetic torque is balanced by the torque due to the hair springs. The springs also serve to carry the current to and from the moving coil.

Although a moving coil instrument measures current, it is apparent from an examination of Ohms Law ($E = IR$) that the voltage is proportional to the current and, therefore, any moving coil meter can be calibrated to read the voltage applied to its terminals provided that a suitable resistance is provided in the moving coil circuit.

(b) The resistance of a relay can be determined by joining it in series with a voltmeter and a battery of negligible internal resistance. It can be shown that if

D = E.M.F. of the battery (volts).

D1 = reading on voltmeter (volts) with resistance in series.

V = resistance of voltmeter (ohms).

The resistance of the relay in ohms = $V(D/D1 - 1)$.

This is the formula used for measuring resistance on Test Desk voltmeters.

Q. 3.—(a) Outline the principles employed in three different types of meters used for measuring alternating currents.

(b) What are the relative advantages of these three types of meters for the measurement of alternating currents of from 1 to 10 milliamperes at speech frequencies?

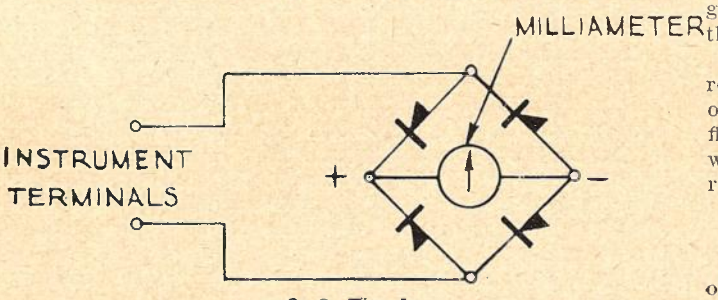
A.—(a) Three types of meters suitable for measuring alternating currents are:—

(i) hot wire ammeter;
(ii) moving iron ammeter;
(iii) the moving coil instrument used with a thermo-couple or rectifier.

(i) The hot wire ammeter depends upon the increase in length of a wire when heated; the heat being generated by the passage of the current to be measured through the wire itself. The increase in length of the wire is proportional to the rise in temperature, which in turn is proportional to the heat generated in it. This again is proportional to the square of the current flowing. It follows, therefore, that a hot wire instrument will have a scale following a square law and its deflection will be independent of the direction of flow of current, and it will measure alternating and direct currents equally well.

(ii) The moving iron ammeter depends on the mutual repulsion exerted between similar magnetic poles. The two soft iron strips, one fixed and the other free to revolve on a pivot, are magnetised by the same electromagnet which carries the current to be measured. The mutual repulsion causes displacement of the free strip, and this is indicated by the movement of a pointer over a scale.

(iii) The moving coil ammeter is described in Question 2 (a). This instrument measures direct current only, and to measure alternating currents it is necessary to use it in conjunction with either a thermo-couple or a rectifier. The rectifier used is usually the full wave or bridge rectifier consisting of four metal rectifiers arranged as shown in Fig. 1.



Q. 3, Fig. 1.

(b) The hot wire instrument has the advantage that it is practically non-reactive; its readings are, therefore, independent of frequency and wave form. It is sluggish in operation, however, suffers from creepage of the zero point and also is rather delicate, in that relatively light overloads are likely to burn it out. The moving iron instrument has a relatively high inductance, has a high power consumption and is not independent of frequency, on account of eddy currents and hysteresis effects in the iron. It is liable also to be affected by stray magnetic fields and by change of resistance of the coil, due to change of temperature. The advantage of the instrument is that it is simple and robust. The moving coil instrument itself is reasonably robust and its inductance is not high. Used in conjunction with a bridge rectifier, the moving coil instrument is also reasonably non-reactive and independent of frequencies over the speech range. For these reasons the moving coil instrument with a rectifier is the most suitable instrument for the measurement of alternating currents at speech frequencies.

Q. 4.—(a) When the coil circuit of a telephone type relay is disconnected the armature does not release immediately. Explain the reason for this.

(b) What methods are employed to increase the release time of a relay?

(c) What is the effect on the release time of varying the following adjustments:—

(i) The spring tension.
(ii) The length of stroke of the armature.
(iii) The residual air gap.

A.—(a) When a telephone relay is disconnected the magnetic field produced by the coil dies down very rapidly. In doing so it causes eddy currents to flow in the core, yoke and armature, which are all composed of conducting materials. These eddy currents produce a magnetic field which is in the same direction as the main field, and this is strong enough to hold the armature for a short period after the current through the coil is disconnected.

(b) The release lag or time of a relay may be increased by the following methods:—

(i) Fitting a slug on the armature or heel end of the core.
(ii) Using a short-circuited coil.
(iii) Shunting the relay with a rectifier.
(iv) Shunting the relay with a resistance.
(v) Shunting the relay with a condenser.

(c) (i) The effect of increasing the spring tension of a relay is to reduce the release time. If the spring tension is decreased the release time is lengthened.

(ii) The greater the stroke of a relay, the further the springset is moved from its normal position and, therefore, a slight increase of the armature load follows, which reduces the release time. However, in general, the length of stroke has very little effect on the release time of a relay.

(iii) Increasing the residual air gap reduces the release time of a relay and vice versa. The reluctance of the magnetic circuit is increased and, therefore, the flux, when the relay is operated, is reduced, so that when the current is disconnected the falling flux reaches the armature release value sooner.

SECTION B

Q. 1.—(a) Draw a sketch showing the components of a secondary cell (accumulator) of a capacity of approximately 1000 ampere-hours at the normal discharge rate.

(b) What indications are given of a short circuit between two plates in a secondary cell?

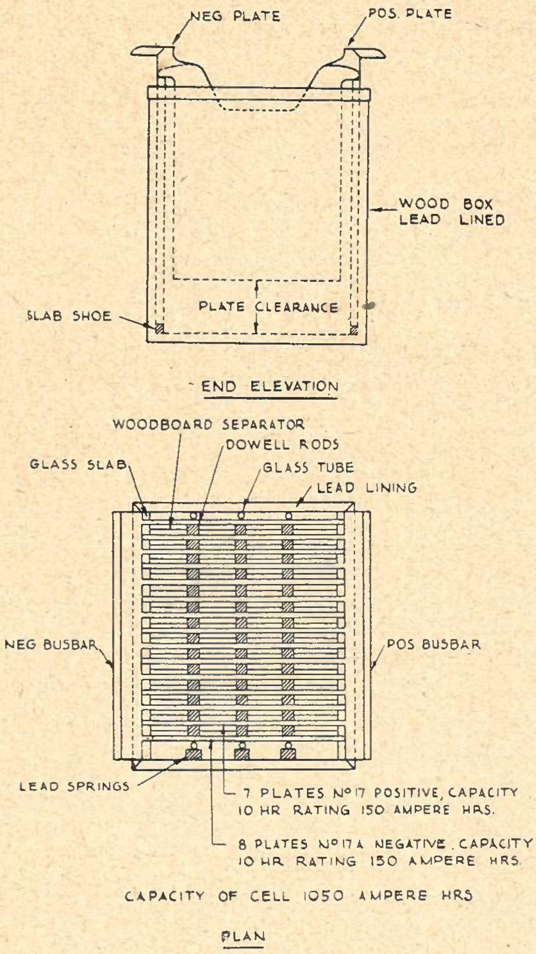
(c) How would you locate such a short circuit between plates?

A.—(a) See diagram, Section B, Q. 1, Fig. 1.

(b) A cell in which a short circuit exists may be detected by the following symptoms:—

(i) The cell in which the short circuit exists will not gas as freely as the remainder of cells on charge.
(ii) High temperature of the electrolyte.
(iii) Low specific gravity if the short circuit has been evident for some time.

(c) A short circuit in a cell may be located by means of a small compass which should be placed in succession on the smaller lugs of the plates of one polarity, between the lugs of the plates of opposite polarity. As long as the plates are free from short



Q. 1, Fig. 1.

circuits, the needle will show little or no variation in its deflection as it is moved from lug to lug. However, when a plate is reached on which a short circuit exists, the deflection suddenly changes and it retains its new position on the remaining plates in the cell. This plate is marked and the lugs on the adjacent plates at the opposite side of the cell are tested in order to determine which pair of plates are short circuited.

Q. 2.—(a) Draw a schematic diagram of the power circuit of an automatic exchange in which automatic voltage regulators are provided.

(b) With the aid of a sketch, briefly describe the general construction and operation of any type of automatic voltage regulator with which you are familiar.

A.—(a) See Vol. 3, No. 5, p. 273, for diagram.

(b) Refer to Vol. 3, No. 5, p. 270, where Fig. 1A illustrates the principle of the carbon-pile type regulator. A number of carbon discs are arranged in a pile, one end being fixed and the other end attached to the operating arm of the control coil armature. The control coil is connected to the exchange busbars, and the carbon pile is connected in the charging generator field circuit. While the exchange voltage remains constant no variation of the resistance of the carbon pile is necessary. Should the exchange voltage fall, however, the resistance of the carbon pile is reduced by the compression on the pile caused by the movement of the armature away from the pole pieces. This causes the generator output to change to meet the load requirements. As the exchange voltage rises the pressure on the carbon pile decreases as the armature tends to take up a position across the pole pieces and the resistance of the carbon pile increases. This, in turn, regulates the generator output.

Q. 3.—(a) Draw a schematic circuit of a constant potential type metal rectifier suitable for operating a small automatic exchange.

(b) Describe the method of operation of the unit over a typical day.

A.—(a) See Vol. 2, No. 6, p. 371, or Vol. 1, No. 1, p. 21, for circuit.

(b) Assuming that the battery is in the fully charged condition, at the beginning of a typical day, the method of operation would be as follows:—

As the load on the battery increases the battery voltage will fall eventually below the output voltage of the rectifier, which is then called on to supply current. This increased current flow from the rectifier causes a phase shift of transformer voltages and a building up of three-phase output with a corresponding mean voltage of D.C. output. This action keeps pace with the increase in load and boosts the D.C. output voltage to compensate for the voltage drop caused by the increased load on the exchange battery.

The boosting effect reaches a limit at the full current output of the rectifier, and any further current demand on the rectifier only reduces its D.C. voltage below that of the battery. From this point, although the rectifier continues to supply to its rated output, the excess current demand must be carried by the battery. This "Cut Off" point in the rectifier ensures that it cannot be overloaded and damaged.

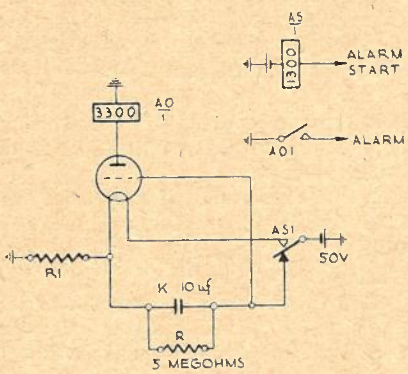
When the exchange load falls off the battery voltage is probably below the rectifier voltage, and the rectifier continues to re-charge the battery. As the battery voltage rises due to the charge, the three-phase boost is gradually reduced and the charge rate tapers off until only a trickle charge remains.

Q. 4.—(a) Describe, with the aid of a circuit diagram, a method of obtaining a delayed alarm of 30 seconds or longer using a thermionic valve. Indicate on the circuit the approximate values of the various components.

(b) What factors limit the maximum reliable delay period obtainable with this circuit?

(c) If the above circuit is to be installed in an automatic exchange, what features need to be considered in choosing the valve to be used?

A.—(a) The timing element is a charged condenser connected to a charge dissipating resistor, the time of discharge being dependent on the respective values of the condenser and resistance. If the condenser is charged, and afterwards connected to a resistor, the charge on the condenser maintains a negative potential on the grid of the valve, so preventing the flow of current to the anode. As the condenser discharges, the negative grid potential decreases and the grid bias will reach a point where anode current commences to flow and later to reach a suitable value to operate the alarm relay AO which is connected in the anode circuit. On the release of the alarm relay, the condenser will be re-charged practically instantaneously and the circuit will be ready for re-operation and will again provide the normal delay period. For a delay period of 30 seconds or longer a 10 mf condenser and a 5 megohm resistor would be the approximate values required.



Q. 4, Fig. 1.

(b) The factors which limit the delay period are:—

(i) The capacity of the condenser.
(ii) The value of the resistance.
(iii) The type of valve used.

By suitably choosing different capacity values of the condenser and making a corresponding selection of the discharge resistor, a wide range of discharge times is available, allowing that the delay period will also depend on the type of valve used.

(c) The type of valve used should be suitable for operating on the exchange voltage (50 volts). A power amplifier valve having a directly heated filament would be suitable. These valves are designed to function with anode voltages up to 150 volts, but, when used in the delayed action circuit, the anode voltage may be 50 or less.

EXAMINATION No. 2586.—SENIOR TECHNICIAN—TELEPHONE—(C) TELEPHONY II.

A. W. McPherson

SECTION I.

Q. 1.—(a) What do you understand by the following terms:—

Space charge,
Amplification factor,
Mutual conductance,
Negative feedback?

(b) What are the advantages of negative feedback as applied to an amplifier?

A.—(a) Space Charge.—The number of electrons emitted from the cathode in a vacuum tube is dependent upon the temperature of the cathode, and in the case of a diode the rate at which these electrons are attracted to the plate is determined by the positive potential applied to the plate. Assuming a fixed-plate voltage, the space current will rise as the temperature of the cathode is increased until a point is reached when an increase in cathode temperature will have no effect on the space current. This occurs when the cathode is emitting more electrons than are being attracted by the plate and consequently free electrons surrounding the cathode being themselves negatively charged tend to repel the similarly charged electrons leaving the cathode and so counteract further emission. This is called the space charge effect. If a third element called the control grid is inserted between the cathode and plate, the space charge effect can be controlled by the voltage on this grid.

Amplification Factor.—The amplification factor (μ) is the measure of the amplification of which a tube is capable and is numerically equal to the ratio of the change in plate voltage (dEp) required to effect a given change in plate current, to the small change in grid voltage (dEg) necessary to produce the same change in plate current; all other electrode values being maintained constant.

That is, $\mu = dEp/dEg$.

Thus if a 10-volt change in plate voltage is necessary to produce the same change in plate current as a 0.1-volt change in grid voltage, then

$\mu = 10/0.1 = 100$.

Mutual Conductance.—The mutual conductance (gm) or grid-plate transconductance of a tube is the rate of change of plate current (dIp) with respect to a small change in grid voltage (dEg), all other electrode values being maintained constant.

That is, $gm = dIp/dEg$.

The mutual conductance is expressed in micromhos (microamperes per volt) and is also equal to μ/RP where RP is the plate resistance of the tube. It provides an indication of the design merits of the tube and actually represents the slope of the plate current-grid voltage characteristic curve.

Negative Feedback.—When some of the amplified energy in the output of a circuit employing electron tubes is coupled back to the input circuit to be re-amplified this process is called "feedback." If the impulses fed back are in phase with the input signal, the feedback is said to be positive. If the energy fed back is in phase opposition to the input signal the feedback is said to be negative, and since the resultant grid voltage is lower in the case of negative feedback the amplification is decreased. Negative or inverse feedback can be applied to one stage of amplification or a number of stages as a whole.

(b) By constructing an amplifier with a higher gain than is required for the particular application, and then using negative feedback to offset this high gain a greatly improved amplifier is obtained. The advantages of negative feedback are:—

(i) Change of tubes in the amplifier circuit will not materially affect the gain.
(ii) Gain of amplifier is unaffected by slight changes in filament and plate supply voltages.
(iii) The gain frequency characteristic can be made "flat" over a very wide range of frequencies. Alternatively, the feedback circuit can be employed for equalisation purposes if required.
(iv) The harmonics produced by the amplifier are considerably reduced.
(v) The maximum power output for a certain percentage harmonic distortion is increased and the gain load curve considerably improved.
(vi) The noise level is reduced.
(vii) Output and input impedances can be controlled and these impedances are substantially independent of tube changes and supply voltage variations.

Q. 2.—You are required to measure the frequency-loss characteristics of a 3 kC high and low pass filter group. Describe the testing equipment you would require and give a diagram illustrating the test circuit

you would employ. Describe the procedure of the tests and state what precautions would be necessary to ensure correct results.

A.—The items of testing equipment required to perform the tests are:—

(a) Variable frequency oscillator to cover a frequency range of 100 C/s to 50 kC/s with an output impedance of 600 ohms. The output should be free from harmonics.

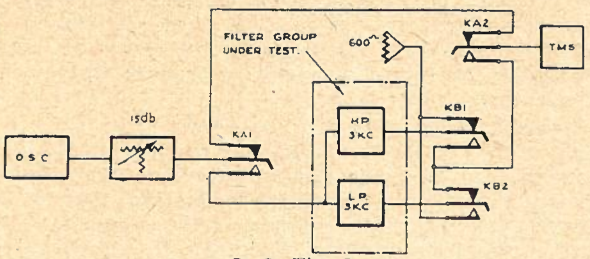
(b) Transmission Measuring Set suitable for operation over above frequency range.

(c) Variable attenuator—600 ohms.

(d) 600 ohm termination.

(e) Switching keys.

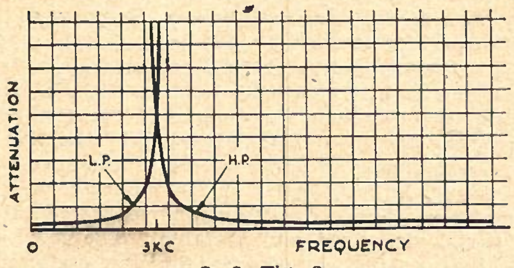
Fig. 1 shows in block schematic form the arrangement of the equipment.



Q. 2, Fig. 1.

Testing Procedure: With the keys in the position shown in Fig. 1 the oscillator frequency is set at 100 C/s and the attenuator adjusted until a suitable output is indicated on the transmission measuring set. A convenient figure in this case would be 1 mW. KA is then operated and in this position the signal is measured through the L.P. filter. The difference between the two readings on the T.M.S. represents the loss through the L.P. filter, and this figure should be very low at 100 C/s. The operation of KB inserts the H.P. filter in the testing circuit and again the T.M.S. reading is noted. The loss through the H.P. filter should be high at this frequency.

The above procedure is repeated at intervals of 200 C/s up to 2500 C/s, after which measurements should be made at 100 C/s intervals up to 3.5 kC/s so that the slope of the cut off of each filter may be determined. Subsequent measurements are made at 0.5 kC/s intervals up to 50 kC/s. A gradual increase in attenuation of the L.P. filter will be noted as the nominal cut-off frequency of 3 kC/s is approached, and between this frequency and 3.5 kC/s approximately a progressive decrease in attenuation of the H.P. filter will be observed. The attenuation frequency characteristics exhibited by the filter group under test should approximate the shape of the curves shown in Fig. 2.



Q. 2, Fig. 2.

Precautions:

(a) The tests should be conducted with the filters connected as a group as shown in Fig. 1.

(b) When the L.P. filter is being tested the H.P. filter should be terminated in 600 ohms and vice versa.

(c) The output of the oscillator should be checked on the T.M.S. at each testing frequency.

(d) If the oscillator output contains harmonics, false readings may be obtained through the H.P. filter at frequencies within the pass range of the L.P. filter, especially between 1500 C/s and 3 kC/s. These effects can be minimised by the insertion of a 3 kC/s L.P. filter between the oscillator and the variable attenuator at the frequencies concerned.

(e) If the impedance characteristics of the filter group vary with frequency, reading errors in the pass range of each filter due to this cause may be minimised by ensuring that the loss in the attenuator is at least 15 db. and also by inserting an additional variable attenuator set at 15 db. between the filters and the measuring equipment. This provides masking impedances sufficient to enable reasonably accurate results to be obtained.

Q. 3.—(a) Define the terms "decibel," and "the transmission equivalent of a circuit." Why is it that loss measurements referred to a level of 6 milliwatts are approximately 8 db. less than when referred to a level of 1 milliwatt?

(b) The input of an amplifier having 600 ohm input and output impedances is connected to a sine wave generator of equal impedance, and the output of the amplifier is terminated in a 600 ohm load impedance. The generator output is 30 db. below 1 milliwatt and the gain of the amplifier is adjusted until the amplifier is dissipating 1 watt into the load. Determine the gain of the amplifier.

A.—(a) **Decibel.**—The decibel notation is used to express the relative magnitude of two amounts of electrical power. When the common logarithm of the ratio of any two quantities of electrical power is unity the difference in level between them is defined as 1 bel. The bel is too large for practical purposes and consequently the decibel, which is 1/10th of a bel, is employed. For two electrical powers P1 and P2 the difference in level between them expressed in the decibel notation is given by:

$$\text{decibel (db)} = 10 \log_{10} (P_1/P_2).$$

If the impedance at both power levels is the same, then the difference in level may be calculated thus:

$$\text{db} = 20 \log_{10} (E_1/E_2) \text{ or } 20 \log_{10} (I_1/I_2)$$

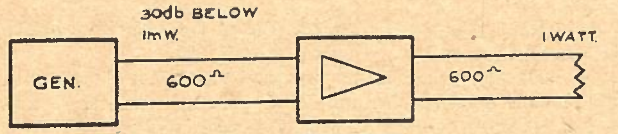
where E and I are voltage and current respectively.

Transmission Equivalent.—In general, the power transmitted along a telephone circuit is subjected to both losses and gains, the former due to lines, exchange and other apparatus, the latter due to amplifying equipment. The resulting net efficiency of transmission is known as the overall "Transmission Equivalent" of the circuit and is computed by prefixing the appropriate signs to the various losses and gains and determining their algebraic sum. If the resulting quantity is positive there is an overall gain, and if negative there is an overall loss.

Levels of 6 mW and 1 mW respectively represent a fixed ratio of 6 : 1 and, therefore, any measurement referred to either one of these reference levels may be expressed in terms of the other by the use of the following conversion figure:

$$\begin{aligned} \text{db.} &= 10 \log_{10} (6/1) \\ &= 10 \times 0.7782 = 7.782 \text{ db.} \\ &= 8 \text{ db. approx.} \end{aligned}$$

Thus, a measurement of —10 db. with respect to 1 mW is —18 db. with respect to 6 mW, and similarly a measurement of +10 db. with respect to 1 mW is +2 db. with respect to 6 mW.



Q. 3, Fig. 1.

(b) The conditions of the problem are shown in Fig. 1.

The output power referred to 1 mW is:

$$\text{db.} = 10 \log_{10} (P_1/P_2) \text{ where } P1 = 1 \text{ watt and } P2 = 1 \text{ mW.}$$

$$\therefore \text{db.} = 10 \log_{10} (1/0.001) = 10 \log_{10} 1000 = 30 \text{ db.}$$

Therefore, the power measured at the output of the amplifier is + 30 db. with respect to 1 mW. The gain of the amplifier is + 30 — (—30) = 60 db.

SECTION II.

Q. 1.—One channel of a three-channel carrier telephone system equipped with normal 1,000 c.p.s. ringers is reported faulty due to intermittent bursts of 17 c.p.s. current during conversations. Discuss the possible causes of the trouble and describe the steps you would take to rectify the fault.

A.—The 1000 C/s ringer is normally in circuit across the line during conversations and consequently it is necessary to include a guard feature in the design of the ringer to ensure that only pure 1000 C/s or 1000/17 C/s applied to the channel will cause the ringer to transmit 17 C/s to the switchboard. Intermittent bursts of 17 C/s during conversations indicates that the guard feature is not functioning correctly, thus allowing the ringer to operate on speech currents.

It is assumed that the ringer under consideration is of the type which includes two tuned circuits in the output of the ringing receiver. The first is sharply tuned to 1000 C/s and will respond only to a pure tone of this frequency or 1000/17 C/s. The output of this tuned circuit is applied to a rectifier bridge to operate a relay which sets up the condition to transmit 17 C/s to the switchboard. The other tuned circuit is anti-resonant at 1000 C/s and the output of this circuit is applied to another rectifier bridge containing a guard relay. When frequencies other than 1000 C/s, such as those which occur during a conversation, are applied to the channel at a level sufficient to be capable of energising the ringer, they are accepted by the anti-resonant circuit and the guard relay operates to prevent 17 C/s from being transmitted to the switchboard.

In order to prevent false operation of the ringer upon receipt of short bursts of 1000 C/s which may occur during speech, a delay is introduced in the relay train which applies 17 C/s to the switchboard.

The faulty condition reported in this case could be caused by a failure of the guard circuit or the relay delay circuit. Alternatively, an excessively high level on the channel concerned, excessive channel noise, or channel interference may render the guard circuit ineffective.

In order to isolate the trouble it would be advisable to first check the line-up and noise level of the channel and make adjustments as necessary. Assuming, however, that the fault is in the ringer, the correct procedure is to patch the ringer out of service and insert a spare ringer in its place. This will provide service on the channel while the fault is being located.

The delay and guard circuits would then be tested with the aid of the facilities provided on the ringer test panel.

Delay Circuit: The time response of the ringer is tested by the application of a test tone of 1000 C/s to the line side of the ringer for periods of 0.4 sec. and 0.7 sec. through the agency of a telephone dial associated with the ringer test panel. In this test condition the full operation of the ringer for the application of 17 C/s to the switchboard is indicated by the lighting of a lamp on the ringer test panel. The lamp should not light when the tone is applied for 0.4 sec., but should light momentarily when the tone is applied for 0.7 sec. If these conditions are not obtained it will be necessary to check the relays concerned for faulty operation and make adjustments as required.

Guard Circuit: This may be tested by using a convenient telephone circuit in the carrier station as a medium for the application of speech to the line side of the ringer at a level approximating that of the channel. If the ringer operates fully to apply 17 C/s to the switchboard during this test it will be necessary to check the operation of the guard relay and associated equipment in the guard circuit until the source of the trouble is located.

An alternative method of checking the guard circuit would be to use a variable frequency oscillator as a source of energy for the observation of the response of the ringer to frequencies in the V.F. range.

Q. 2.—Describe the functions of the following equipment when used in conjunction with a three-channel carrier telephone system:—

(a) Equalisers between the receive directional filter and the receiving line amplifier.

(b) Volume limiters.

(c) Balance networks.

A.—(a) One of the factors which tends to decrease the intelligibility of telephone speech is unequal attenuation of different frequencies as they are transmitted over various circuits. For example, the attenuation of a non-loaded open wire circuit is greater for the higher frequencies than for the lower frequencies and this difference in attenuation is directly proportional to the length of the line. Therefore, on long circuits it is frequently necessary to employ attenuation equalisers to correct the unequal attenuation of the line. An equaliser consists of a network of inductances and capacitances so arranged that the attenuation v. frequency response of the network is the inverse of that encountered on the normal aerial or cable circuits concerned.

In a three-channel telephone system the equalisers between the receive directional filters (RDF) and the receiving line amplifier are employed for the purpose of correcting the unequal attenuation of the line (and certain equipment) so as to maintain the level on all channels substantially equal at the input to the receiving amplifier. These equalisers are separated into two main parts, viz., fixed and variable. The fixed equaliser is designed to compensate for any distortion introduced by the attenuation v. frequency characteristics of the R.D.F. preceding the equaliser, and the transmitting directional filter (T.D.F.) at the distant terminal or repeater, and also to compensate for the frequency v. attenuation characteristics of a fixed length of open wire line over the band of frequencies being received. The variable equaliser is for the purpose of making adjustments upon installation, and subsequently as necessary, to suit the length and characteristics of the actual line section preceding the particular terminal or repeater.

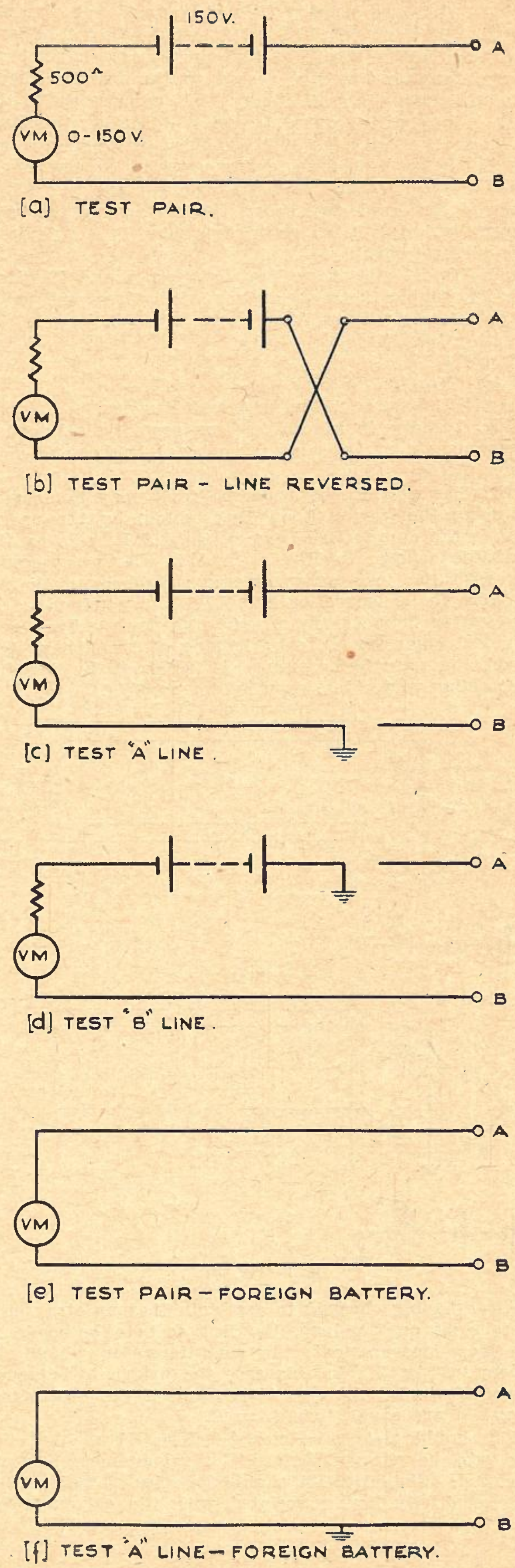
(b) The characteristics of metal rectifiers used as modulators require that the voice input voltage shall be low in comparison with the applied carrier voltage. Fixed pads are employed in some systems between the hybrid coil and the modulator on each channel to reduce the level of the V.F. to a suitable value, but it is usual to precede modulators of this type with a volume limiter whose function is to keep the V.F. input voltage to the modulator from exceeding a predetermined value regardless of the level delivered by the subscriber. Volume limiters usually take the form of neon tubes or metal rectifier elements. At signal amplitudes below those at which limiting takes place the volume limiter produces negligible loss in the speech circuit.

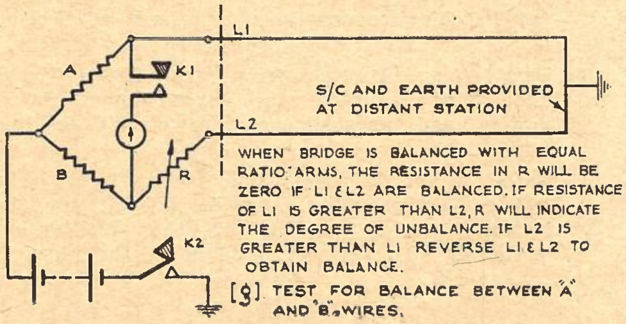
In cases where one channel of a three-channel system is used for V.F. telegraph transmission, pads are preferred to the volume limiter on this channel, as the latter may cause mutilation of the telegraph signals, but it is important that the other two channels be fitted with volume limiters to prevent peaks of V.F. from the speech circuits from interfering with the telegraph signal frequencies.

(c) In order to couple together the V.F. transmitting and receiving sides of each carrier channel for connection to the two-wire line to the switchboard, it is necessary to employ a 2 wire-4 wire terminating network or hybrid coil. The efficiency of the hybrid coil depends upon the amount of loss which can be introduced between the receiving side and the transmitting side of the 4-wire circuit. This loss would be infinite under the conditions that the impedance of the 2-wire V.F. line is accurately matched by an artificial network connected to the hybrid coil. This network is known as a balance network and in a carrier system, where the equivalent of 4-wire working is obtained from terminal to terminal by the grouping of the send and receive carrier frequencies, a simple series network consisting of 600 ohms and $2\mu F$ is a reasonable simulation of the 2-wire V.F. circuit.

Q. 3.—(a) A physical open wire trunk circuit terminating on a combined bridge and voltmeter trunk test board is reported out of order. Describe the tests you would carry out to ascertain the nature of the fault.

(b) Assuming that one side of the circuit is earthed, describe the test employed to locate the position of the fault. Give a diagram of the bridge circuit and derive the formula applicable.





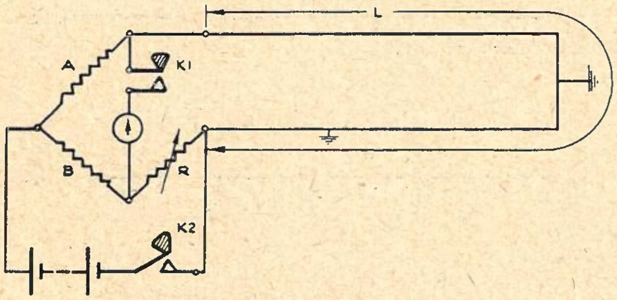
Q. 3, Fig. 1.

A.—(a) When a trunk line is reported out of order a fault docket is received by the engineering staff, and in a large centre the trunk-line master card is attached to the fault docket and passed to the testing officer, who first makes a preliminary test to ascertain if the fault is in the line or equipment. Assuming the fault to be in the line, the testing officer proceeds to test the line after first making any patching arrangements as necessary. Line tests are made from the LINE jacks of the trunk test board (T.T.B.), using the voltmeter test set and bridge to determine if the fault is any of the following:—

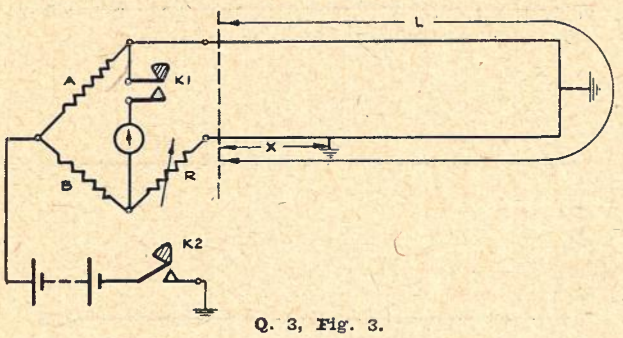
(i) Short circuit or loop between A and B wires.
(ii) Contact between one or both wires and earth.
(iii) Cross with another pair.
(iv) Open circuit.
(v) L.I.R.
(vi) Foreign Battery.
(vii) Unbalance between A and B wires.

Fig. 1 shows in schematic form some typical testing arrangements available at a combined bridge and voltmeter T.T.B.

(b) The position of an earth fault may be located by using the Varley Loop Test which, by the operation of the appropriate keys on the T.T.B., sets up the conditions shown in Figs. 2 and 3. Before proceeding with the tests arrangements should be made for the line to be looped on the T.T.B. or patch panel at the station immediately beyond the fault. The location test could be made by looping at the distant terminal, but greater accuracy is obtained by keeping the section under test as short as possible.



Q. 3, Fig. 2.



Q. 3, Fig. 3.

After having checked to ascertain that no stray currents exist on the loop, the first test to be made is the loop measurement, the conditions for which are shown in Fig. 2. In this case the bridge is balanced when $AR = LB$ $\therefore$ $L = AR/B$, and if the ratio arms A and B are equal, then $L = R$.

K2 should always be closed before K1 so that the line will be charged before the galvanometer circuit is closed. Similarly, K1 should be released before K2. The sensitivity keys associated with the galvanometer should be operated progressively as the balance condition is approached.

When the loop reading is determined the appropriate keys on the T.T.B. are operated to obtain the conditions shown in Fig. 3. A balance is obtained when

$$B(L - X) = A(R + X)$$
$$\therefore BL - BX = AR + AX$$
$$\text{and } AX + BX = BL - AR$$
$$\therefore X = (BL - AR)/(A + B).$$

When the ratio arms A and B are equal

$$X = \tfrac{1}{2}(L - R).$$

The resistance of the fault forms part of the battery circuit and, therefore, does not affect the location test, provided that the resistance is low compared with the normal I.R. of the line. When the balance condition is reached the reading is checked by reversing the polarity of the testing battery, and having obtained a resistance value of X, which is the resistance of the faulty wire from the testing office to the fault, the distance to the fault can then be computed from the line data recorded on the trunk-line master card.

The formula $X = \frac{1}{2}(L - R)$ is the fundamental Varley loop formula for equal ratio arms and can be applied to a circuit even though the two wires of a pair are of unequal resistance.

Where it can be safely assumed that the two wires of a pair are of equal resistance a simplification is possible and the formula reduces to $X = L - R$. In order to obtain the distance to the fault in this case, it is necessary to divide the loop resistance to the fault by the loop resistance per mile of the wire gauge concerned.

In the former case, where $X = \frac{1}{2}(L - R)$ it is necessary to divide the single wire resistance to the fault by the single wire resistance per mile of the wire gauge concerned.

Q. 4.—(a) Fig. 1 attached represents in single wire form the Nelson office circuits of lines 1040/1, 95/6, 277/8, and 10/11. Line 1040/1 is proved open circuit and it is necessary to preserve service on the following circuits:—

(a) Telephone traffic circuits—
Nelson-Waterloo Nos. 1 and 2;
Nelson-Wellington Nos. 1, 2 and 3;
Waterloo-Wellington No. 1.

(b) The physical program circuit.

(c) Cailho Morse No. 2.

List the patching connections you would carry out in the Nelson office assuming that line 95/6 is available as a spare high pass circuit; e.g., patch jacks 50L to jacks 81D, etc. In making these patches what terminations would be necessary and what precautions would you take in using the patch cords?

(b) Referring to Figs. 2, 3 and 4 attached, give a list of errors, if any, in each circuit. Supporting reasons for any necessary corrections are required.

A.—(a) Patching connections required at Nelson office:—

(1) Patch A and B wires from jacks 21L to jacks 1D. This transfers the three-channel S.O.T. system and physical program circuit to line 95/6.

(2) Patch A and B wires from jacks 6L to jacks 17L. This provides a carrier circuit for the Nelson-Waterloo section of the Wellington-Waterloo No. 1 circuit in place of the physical

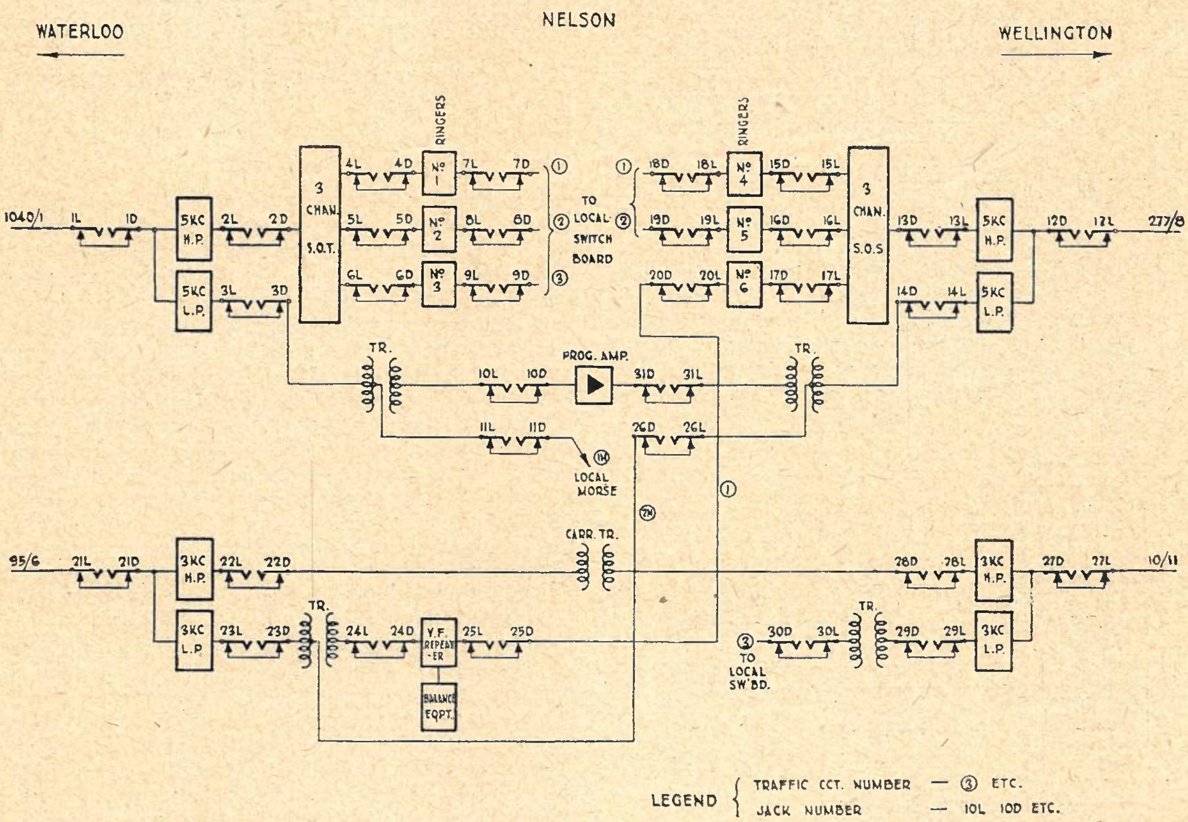
circuit which was disconnected when No. 1 patch was made.

(3) Patch from jack 11L to jack 26L (single wire) to restore Cailho Morse No. 2.

(4) Place 600 ohm terminations in jacks 24D and 25L to prevent V.F. repeater from singing.

(2) The cailho telegraph circuit shown in conjunction with the C.X. set is incorrect. The C.X. set allows the use of each leg of the line as an earth return telegraph circuit and consequently prevents the use of the cailho circuit for D.C. operation.

(3) The duo-directional channel of the type "B" telegraph system should be connected through a telegraph repeater for duplex working via the C.X. set.



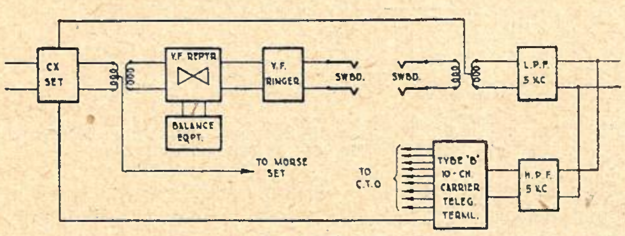
Q. 4, Fig. 1.

Precautions:

(i) Ensure that all patching cords are in good condition.

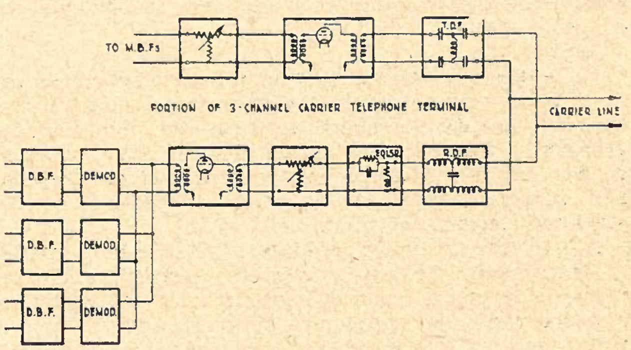
(ii) In using the patch cords for (1) and (2) above, it would be necessary to ensure that the A and B sides of the lines are not reversed.

(iii) Patches 1, 2 and 3 should be done simultaneously, with similar appropriate patches at Waterloo by arrangement with the officer concerned at that station.



Q. 4, Fig. 2.

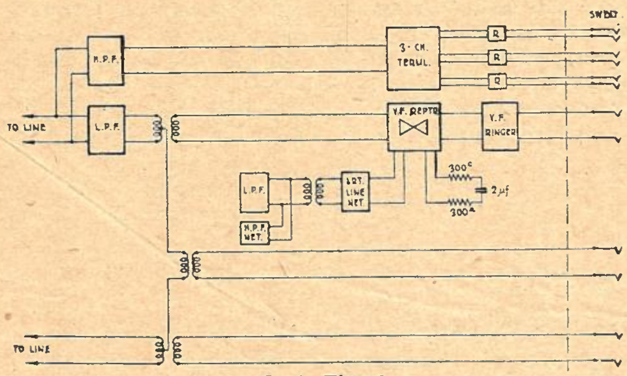
(b) **Fig. 2.** (1) The line filters shown should be 3 kC/s in lieu of 5 kC/s. A type "B" carrier telegraph system transmits a band of frequencies of 3.3 to 5.5 kC/s in the B-A direction and 6.5 to 10.25 kC/s in the A-B direction. The 5 kC/s filter group shown would cut off most of the frequencies in the B-A direction.



Q. 4, Fig. 3.

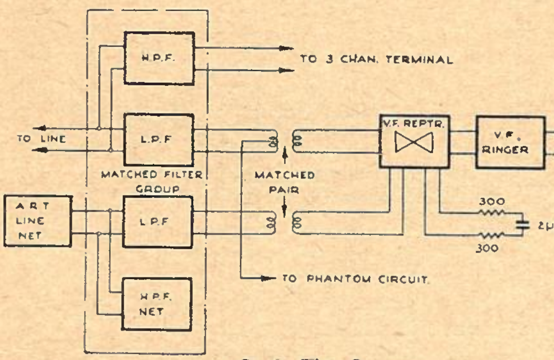
Fig. 3. (1) The demodulators and demodulator band filters (D.B.F.) are reversed in position. It is necessary to separate the three-channel frequency bands by means of the D.B.F.'s before demodulation takes place.

(2) A transformer should be inserted between the R.D.F. and the equaliser. The equaliser is of the unbalanced type and the transformer is necessary to isolate the equaliser from the line and provide a correct termination for the R.D.F.



Q. 4, Fig. 4.

Fig. 4. (1) The balance network on the line side of the V.F. repeater is shown incorrectly. In order to obtain an accurate balance of the line equipment and the line, the elements comprising the network should bear the same relationship to the hybrid coil as the line equipment. The correct method of connection is shown in Fig. 5.



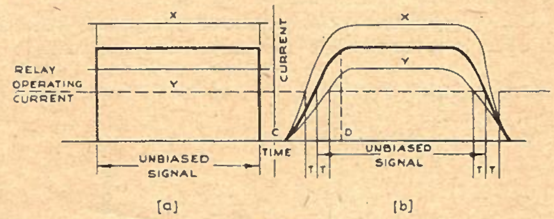
Q. 4, Fig. 5.

(2) A filter group or equivalent network to match the filter group shown is required on the second line comprising the phantom group in order to balance the phantom circuit.

Q. 5.—In any voice frequency telegraph channel why is it necessary to control, within fairly close limits, the received carrier signal level at the input to the detector? Describe the action of the A.V.C. feature of any amplifier detector with which you are familiar and illustrate your answer with a diagram of the essential elements of the circuit.

A.—In carrier telegraph transmission where carrier is transmitted during a marking element and suppressed during a spacing element the equivalent of single current transmission is obtained, and the receive relay requires a bias (either mechanical or electrical) in order to restore its tongue to the spacing contact on cessation of a marking signal. As the restoring force is fixed when the channel is lined up for operation by reversals transmitted from the distant terminal, any subsequent variations in received signal level will result in bias distortion.

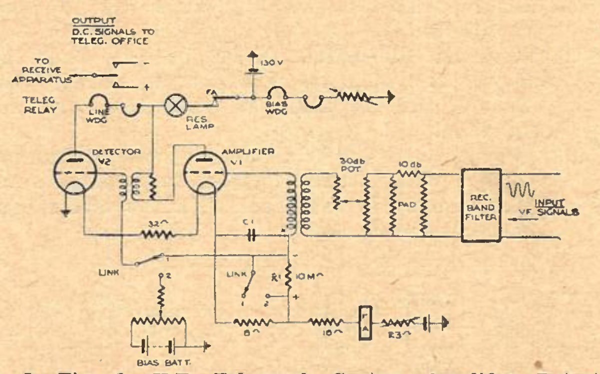
In V.F. telegraph working the necessity for maintaining constant amplitude of the received signals is dependent upon the shape of the signal envelope. If the signal were square topped in form, as shown in Fig. 1 (a), the bias distortion introduced by small changes in amplitude would be zero, whereas when the signal envelope is of sinusoidal shape small changes in amplitude are sufficient to cause considerable distortion.



Q. 5, Fig. 1.

The signal applied to the channel band pass filters takes a definite time to build up to a steady state value. The extent of the building-up time is largely a function of the filter characteristics and increases with reduction of filter bandwidth. This building-up time causes the applied signal to be tapered and the resultant effect of line-level variations on the rectified current is shown in Fig. 1 (b), where the horizontal dotted line represents the steady bias condition and indicates the point where the incoming signal strength is sufficient to operate the receive relay from space to mark. With respect to the normal line-up signal, the effective mark signal (X) commences earlier and finishes later, whereas signal (Y) commences later and finishes earlier, with a resultant distortion in either case equal to 2T. (It will be appreciated that in Fig. 1 (b) one particular fixed bandwidth having a constant building-up time represented by C, D, is dealt with and, therefore, any change in the amplitude of the applied signal will produce a change in the slope of the signal envelope as indicated.)

It is evident, therefore, that some form of regulation is necessary in order that signals of constant amplitude are applied to the receive relay. This can be achieved either by ensuring that the telephone bearer circuit is held regulated to very close limits or by incorporating a level control feature in the telegraph system.



Q. 5, Fig. 2.—V.F. Telegraph System Amplifier Detector Circuit (with Automatic Volume Control).

The essential elements of the A.V.C. feature of a typical amplifier detector is shown in Fig. 2. The unit comprises a high-gain amplifier tube, V1, followed by a detector, V2, and links 1 and 2 provide for the A.V.C. to be disconnected from the circuit. When the links are in the position as shown, the input level to the detector determines the grid bias of the amplifier stage. In this position the bias for both tubes is derived from point X in the sketch so that, under static current conditions, the normal bias on the detector will be 12 volts with respect to the filament, whilst that on the amplifier will be approximately 2 volts.

A normal signal amplified by V1 makes the grid of V2 slightly positive, with the result that grid current flows in V2 via resistor R1. This flow of current through R1 causes a voltage drop across it which increases the negative bias across V1 and thus reduces the amplification of this tube. This negative bias will be reduced to a more normal value during an interruption to the incoming carrier, provided that the interruption is of sufficient duration to allow condenser C1 to discharge through R1. The capacity of C1, however, and the resistance R1 ensure that C1 will hold its charge for a time at least equal to the time length of the maximum telegraph spacing signal. The flow of detector grid current through R1 also affects the grid bias voltage of V2 slightly, but the change from its normal value of 12 volts is not large enough to move its operating point appreciably and, therefore, the effect on the signals delivered is negligible. If the level of the signal input to V1 increases, the grid bias on V1 is further increased and the gain is reduced accordingly. On the other hand, if the incoming signal decreases, the grid current through R1 is reduced, the condenser C1 discharges slightly, and the gain of the amplifier tube is increased.

By this means a constant output is obtained from V2 over a wide working range.

EXAMINATION No. 2473.—ENGINEER—LINE CONSTRUCTION

J. W. Pollard, B.Sc.

GROUP 1—GENERAL

Q. 1.—Tabulate the principal likely causes of deterioration of underground cable sheathing under the following headings only:—

(i) Electrolysis.
(ii) Chemical Corrosion.
(iii) Intercrystalline Fracture (fatigue).

A.—(i) Electrolysis.

(a) Stray traction currents from railway and tramway services.
(b) Currents from D.C. power supply systems.
(c) Fire-alarm systems.
(d) Telephone exchange currents such as P.B.X. and R.A.X. battery charging.
(e) Telegraph and signalling currents.
(f) "Galvanic" or "long-line" currents due to differences in soil conditions.
(g) Local action in a cell composed of an iron pipe and a lead cable sheath and with an alkaline solution as electrolyte.

(ii) Chemical Corrosion.

(a) Acetic acid from decaying wood.
(b) Contact with fresh cement.
(c) Drainage from stables or other contaminated sources.
(d) Ashes and cinders.
(e) Corrosive soils, both alkaline and acidic.

(iii) Intercrystalline Fracture (fatigue).

(a) Excessive handling and bending of cable.
(b) Vibration of ducts in roadway or on bridges due to heavy traffic.
(c) Expansion and contraction of lead sheath when exposed to direct rays of the sun, such as on walls.
(d) Vibration of aerial wires transmitted to cable on cable head poles and affecting cable underneath the cable box.
(e) Continued rocking of cable head pole causing fatigue at foot of pole.
(f) Transport of cable on drums for long distances.

Q. 2.—Detail the methods of preservative treatment you would recommend for the following items of line plant:—

(i) Wooden Crossarms.
(ii) Steel Bolts and Spindles.
(iii) Wooden Poles.
(iv) Steel Poles, namely—rails, girders and pipes.

Explain briefly the principal causes of deterioration you would require to guard against in each case, assuming average city and country atmospheric conditions.

A.—(i) Wooden Crossarms.

Deterioration of wooden crossarms is caused mainly by decay and fungus growths and chiefly occurs around the section where the arm is in contact with the pole. This deterioration can be largely prevented by the use of creosote, which is fairly cheap, readily obtainable and easy to apply. Before issue from the store the arms shall be creosoted and except in dry areas all cut faces and bolt holes should be treated with creosote. After cutting the joggle in the pole, creosote is applied to the pole before fitting the arm. In addition to preventing decay and fungus growths, creosoting will also prevent attack by termites.

(ii) Steel Bolts and Spindles.

The chief cause of corrosion in this case is rusting due to atmospheric conditions. In some cases, such as beside the sea, chemical corrosion will also occur. To prevent this corrosion, all steel fittings are galvanized by the hot-dip process.

(iii) Wooden Poles.

As for wooden arms the main causes of deterioration are decay, fungus growths and termite attack. Wooden poles erected in wet areas are more liable to attack by decay than those in drier localities, and consequently such conditions call for more effective treatment to obtain the maximum life from the poles. The severity of termite attack varies in different districts and is dependent on the species found in the locality. In bad areas attack is very severe and can quickly weaken a pole, so that constant inspection and treatment are necessary.

The preservative used is creosote and is effective in preventing poles from decay, and except in extreme cases from termite attack.

The treatment can be divided into two sections—

(a) before and during erection of the pole;
(b) standing poles.

Where poles can be treated in main depots, the most suitable method is the hot and cold tank process and consists of immersing about 6′ of the butts of the poles for about 4 hours in a tank containing creosote heated to about 200°F. The tank is then allowed to cool and when the temperature is about 100°F. the poles are removed.

Although the penetration of creosote in hardwood poles is mainly confined to the sapwood, this layer of treated wood will prevent decay or termite attack for up to 10 years or more.

If it is not possible to apply the hot and cold tank method the pole should be placed over the hole and creosote either brushed or poured over the butt to a point which will be about 18″ above the ground when the pole is erected. When applied by this method, the creosote does not penetrate the sapwood to any great depth and re-treatment soon becomes necessary.

If termites are likely to attack the pole, creosote is also poured into the hole before erecting the pole and also during erection so as to provide a collar of treated earth.

For standing poles, creosote should only be applied in warm, dry weather to ensure satisfactory absorption. The ground around the pole is removed for a depth of 18", all decayed wood removed and creosote then applied by either brushing or spraying, the latter being preferable. The creosote is contained in a drum and with the aid of a semi-rotary pump forced through the hose to an iron pipe on which is mounted a semi-circular spray. The spray is kept horizontal and is moved downward, spraying creosote on to the pole. It is then turned over and the other side of the pole treated. If necessary the whole of the pole can be treated and any surplus creosote runs down the pole into the hole, where it forms portion of that required for puddling. Additional creosote is poured into the hole and mixed with the earth which is being replaced.

(iv) Steel Poles—rails, girders and pipes.

Generally rails and girders have no preservative treatment applied, the amount of metal below the ground level being sufficient to ensure adequate strength for long periods other than in exceptional cases. In some districts, where the earth may contain chemicals which are of a corrosive nature, the pole below the ground and for 18" above should be liberally coated with a bituminous compound or preferably tar obtained from horizontal retorts. An alternative to this is to completely surround the pole with a collar of concrete.

Pipe poles are generally galvanized and this provides a good protection against corrosion both above and below the ground level except in the worst cases. In localities where the earth may be of a corrosive nature, the base of the hole can be either surrounded with a collar of concrete or a large mass of metal such as a cast-iron cylinder.

Q. 3.—Discuss preventive or precautionary measures you would propose to guard against deterioration of lead sheath on—

(i) Aerial Cable.

(ii) Underground Cable laid in conduits and manholes.

(iii) Underground Cable in tunnels.

A.—(i) Aerial Cable.

The chief cause of deterioration in this case is intercrystalline fracture due to vibration and periodic movement between the cable and its supports. This is largely overcome by ensuring that the cable suspension wires are only attached to rigid supports and that an alloy of lead with between 0.8% and 1% of antimony is specified in lieu of a plain lead sheath normally used for underground cable. Trouble has been experienced by the cable rings cutting into the sheath of the cable, and to overcome this there has been developed what is known as the "spinner" or "lashing" method of cable suspension. By means of a small machine which is pulled along the suspension wire, the cable is bound by turns (about 13 to 15 inches apart) of galvanized soft iron wire to the suspension wire. This method stops ring cutting and it is claimed that bowing due to longitudinal motion is also eliminated. Clamps to hold the cable where there is change of grade are not required with this method.

(ii) Underground Cables laid in conduits and manholes.

A lead sheath in these cases can be affected by—

(a) Electrolysis.
(b) Chemical corrosion.
(c) Intercrystalline fracture.
(d) Miscellaneous damage.

(a) **Electrolysis.** One of the contributory causes of corrosion of lead cable sheath by electrolysis is the water which may accumulate in ducts and manholes. This water lowers the resistance of the lead sheath to earth and thus enables the pick-up and escape of larger stray currents than would otherwise be the case. During the laying of the conduits every care should be taken to see that, as far as possible, ducts are made watertight and all manholes drained.

In areas where electrolytic damage is suspected electrolytic surveys should be carried out and necessary remedial action taken. In traction areas this normally is achieved by installing direct or boosted type drainage bonds to the negative bus-bar of the power station or the rail of the traction system. In areas where this type of electrical drainage is not possible zinc plates are connected to the cable when only small currents are involved, but for larger currents cathodic drains are necessary. A special case of electrolytic corrosion is that which occurs on small lead cables laid in iron pipe where an alkaline electrolyte is present. To overcome this type of corrosion it is necessary to prevent access of the electrolyte to the cable sheath by the use of steel tape or wire-armoured cable.

(b) **Chemical Corrosion.** As mentioned in the case of electrolytic corrosion, every care should be taken to see that the duct run is properly constructed and as far as possible does not traverse sources of contamination. Concrete work should be properly cured before allowing any lead cable to come in contact with it.

(c) **Intercrystalline fracture** of the sheath will occur in conduits and manholes and these should not be placed in roadways where heavy traffic is experienced. If it is necessary to cross bridges where bad vibration is experienced, wire-armoured cable should be used.

(d) **Miscellaneous.** The manholes should be so constructed that all cables are adequately supported, and the manhole steps positioned so that it is not possible to stand on the cables when entering or leaving the manhole. The bell mouth should also be constructed so that there is an easy sweep of the cable from the cable bearers to the ducts and the cable, therefore, does not rest on the mouth of the duct.

(iii) Underground Cable in tunnels.

The main cause of deterioration in this case is the lack of adequate support of the cable causing intercrystalline fracture at the cable bearers, and the remedy is to provide a continuous support for the cable. This can readily be done by fitting either corrugated or flat fibrolite sheeting. Action should also be taken to keep the tunnels dry and also to provide adequate means, such as pumps, for removing quickly any water which may enter them.

General. All important cables should be fitted with a gas-pressure alarm system which indicates by a visual or audible signal at a suitable location whenever a break occurs in the sheath. Pressure reading taken along the cable will indicate the position of the fault and suitable remedial action can then be undertaken.

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