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TELEPHONE CABLE MANUFACTURE

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Synopsis: A telephone cable is required to provide in compact form a reliable means whereby a desired number of subscribers may be connected to an equal number of distant subscribers, each pair being able to talk to one another on an exclusive circuit. Each circuit usually consists of two insulated wires, and cables containing from one to a thousand or more such pairs are commonly manufactured.

The conductors used in telephone cables invariably consist of annealed high conductivity copper wires, and these wires are insulated with air-spaced paper. The individual wires, after being insulated, are formed into twisted units comprising a single pair or two pairs of wires. The required number of such units is stranded together to make a circular core, which is wrapped overall with paper; the whole is thoroughly dried and then sheathed with a pipe composed of either pure lead or lead alloy.

For external work, dry core paper-insulated lead-covered cables are generally used, and cables of this type are drawn into ducts or pipes of suitable composition. Where cables are required for laying direct in the ground, or for crossing creeks or estuaries, mechanical protection is given to the lead sheathing by serving it with jute yarn and steel tapes or steel wires.

For internal work, enamelled and textile-insulated lead-covered or cotton-braided cables are widely adopted. This type of cable is impregnated with wax, and if the outer protection consists of cotton braid the latter is treated with a flame-resistant compound.

This paper describes the manufacture of telephone cables, and for clarity the subject is divided into the following sections:—

(1) Factors influencing the design of telephone cables.
(2) Types of cable construction and their use in Australia.
(3) Cable-making materials, including an account of the manufacture of annealed copper wire.
(4) General features of cable-making machinery.
(5) Cable manufacturing operations and equipment for paper-insulated and textile-insulated cables.
(6) Testing.
(7) Other types of communication cable.
(8) Conclusion.
(9) References.

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1. Factors Influencing the Design of Telephone Cables

Attenuation: Cable pairs are used to transmit one conversation each at voice frequencies, or several conversations over a range of carrier frequencies.

In all cases, attenuation of the signals occurs with distance, to an extent determined by the magnitudes of four parameters—the effective resistance R, of the conductors, their mutual electrostatic capacity C, their self-inductance L and leakage G. With the exception of L, an increase in any of these quantities affects the attenuation adversely, and in particular the rise of R with frequency due to the occurrence of skin effect and the proximity of other wires and the sheath, is largely responsible for the high attenuations observed at carrier frequencies.

R and C are most conveniently selected as the independent variables in design, and the main problem of manufacture in this regard is to obtain the lowest values of these characteristics consistent with the amount of space which can be economically allowed for each pair. Therefore, annealed copper is used for the conductors, because of all commercial metals it provides a given resistance with the smallest cross-sectional area.

As a dielectric, air has ideal electrical properties, but cannot of course be used alone. To provide mechanical separation and support for the wires, paper is outstanding, since when dry it combines good insulating properties and a relatively low dielectric constant with physical properties which allow of its application in such a way that the desired large amount of air-space is incorporated in the construction. In typical cables as much as 70% of the non-copper space may be occupied by air.

The choice of appropriate values for R and C will be discussed at a later stage: assuming these have been fixed, the value of L can be selected within rather narrow limits only. In any case it is usually too small to benefit the attenuation appreciably, and to obtain any material improvement insertion of series inductances (loading coils) at intervals along the cable is necessary. Loading increases the importance of the leakance G, and in fact in all cables this characteristic is reduced to a small value by careful attention to the drying process.

Cross-talk: Cross-talk arises chiefly from unbalanced electrostatic and electro-magnetic couplings between pairs of conductors, and the two types of unbalance are respectively measured in terms of capacity unbalance and mutual impedance.

Cross-talk currents are proportional to the magnitudes of the unbalances causing them. They vary, directly in the case of capacity unbalance and inversely for mutual impedance, with the characteristic impedance of the circuits (if these are similar), and in all cases increase with frequency and circuit length.

At voice frequencies, capacity unbalance is the major source of cross-talk; but in carrier working, owing to the low characteristic impedance of non-loaded pairs at high frequencies, mutual impedance assumes at least equal importance.

In order to reduce cross-talk in cables, the units are twisted with respect to their own axes, and different twist lengths are used to transpose the circuits continuously with respect to one another.

(The terms "twist length"—sometimes abbreviated to "twist" where the context makes the meaning clear—"length of lay" and "lay" are taken to be synonymous in this paper, and denote the distance in which any particular element makes one complete turn around the axis of twisting.).

If two units have the same twist length they are clearly not effectively transposed, so that serious cross-talk may occur owing to the direct wire to wire couplings not being equalized. In V.F. cables, however, it is found that this is the case only for adjacent units: for all non-adjacent combinations the separation and screening afforded by intermediate wires reduce the capacity unbalances to negligible proportions. Consequently, a relatively simple basic twisting scheme, which provides unlike lays for adjacent units only, may be adopted and repeated throughout cables intended for V.F. working.

Mutual impedances are not reduced to the same extent by mere physical separation, and carrier cables therefore usually employ a separate twist for each unit, which naturally complicates manufacture.

The screening effect of sheathing and armouring materials is of particular interest at high frequencies, where it is very effective. For example, the cross-talk between two carrier cables laid in the same duct for 20 miles and using the same set of twist lengths in each cable is generally better than 130 db. at 60 kC/s.

Choice of Mutual Capacity and Resistance: A given attenuation might be attained with a low mutual capacity involving a large air space and a high resistance small diameter conductor, or vice versa, and the design chosen determines the conductor cost, the core diameter of the cable, and hence the sheathing and installation cost.

The allowable attenuation is primarily a function firstly of the type of service, and secondly of the relative costs of cable and equipment, such as loading coils and/or amplifiers.

In terms of types of service, cables may be classified broadly into:—

(a) Carrier cables.
(b) V.F. Trunk cables.
(c) Junction cables.
(d) Subscribers' cables.
(e) Switchboard cables.

Carrier cables are designed to provide high-quality transmission over long distances, and because of the high frequencies, high attenuations and severe cross-talk requirements are involved. By increasing the space per pair the mutual capacity and attenuation are reduced, and Carrier type cable, using 40 lbs. per mile (.050″ diameter) conductors and a mutual capacity of about .056 mfds. per mile, has been adopted as a reasonable compromise between manufacturing requirements and cable costs on one hand and equipment considerations on the other.

In the case of V.F. Trunk cables, attenuation and cross-talk requirements are appreciably less stringent. The cost of manufacture is less, due to the simplification of the twisting scheme and the higher permissible mutual capacity. Usually 40 lbs. or 20 lbs. per mile (.0355″ diameter) conductors are used with a mutual capacity of .066 mfds. per mile.

In both the above types of cable an extensive factory and field testing programme must be followed, and this contributes materially to the overall cost.

Junction cables supply V.F. connections between exchanges and normally do not exceed 30 miles in length. Less stringent cross-talk and attenuation limits are therefore allowable, and a cheaper and less precise form of construction may be used than is necessary for Trunk cables. 20 lbs. per mile conductors having a mutual capacity of about .075 mfds. per mile are commonly chosen, and the amount of factory and field testing is reduced.

For the cables used to connect subscribers to their local exchanges, the economic considerations are different. Within fairly wide limits, cross-talk and attenuation are relatively unimportant for the reason that the circuits are short, usually less than two miles, and have a low calling rate. Mutual capacities of .075 to .095 mfds. per mile are adopted, the conductors being generally 10 lbs. (.025" diameter) or 6½ lbs. (.020" diameter) per mile. Since, other things being equal, a reduction in conductor size reduces the cable size proportionately, the light gauges enable very large numbers of pairs to be accommodated in cables of reasonable bulk: this in turn permits the most economic use to be made of duct space. For example, the overall diameter of a 1200-pair 10 lb. or a 1400-pair 6½ lb. cable is only about 2¾", thus securing economy in materials and low manufacturing costs due to the carrying out of many of the operations on high-speed machines.

In telephone exchanges, space is at a premium, but the runs of cable are usually very short. Switchboard Cable specifications therefore impose practically no attenuation or cross-talk limits. The enamelled and textile insulated conductors used, though rather costly, have several advantages: the cables are very compact, the risk of short circuits and of fire, which loose-ends of paper insulation would engender, are reduced, and with the help of the wax impregnation the entry of moisture is largely prevented.

2. Types of Cable Construction

Insulation: The paper insulation consists of narrow strips helically applied. The width, thickness and overlap of the paper and the size of the die through which the lapped wire is subsequently passed are chosen so that the paper is creased to support the wire approximately centrally in its insulation. Alternatively, the degree of creasing may be reduced and the necessary support afforded by the prior application to the wire of an open helix of paper string of definite diameter. This construction centralises the wire accurately, gives a very favourable ratio of air to paper space, and is used in Trunk cables as a valuable aid in meeting the exacting electrical requirements.

One and Two-Pair Units: The three constructions which have been used to any extent in Australia are the Twin, the Multiple Twin Quad and the Star Quad, and are shown in cross-section in Figure 1.

The Twin is the simplest, and consists of two insulated wires twisted together with a prearranged lay.

The M.T. Quad is a development of the Twin, comprising two units of Twin twisted together, and using in all three different lays—two for the pairs and a third for the quad. Open lappings of cotton, flax or paper applied to the pairs and the quad serve to stabilise the unit. This type is unlikely to be used for new construction in the Commonwealth.

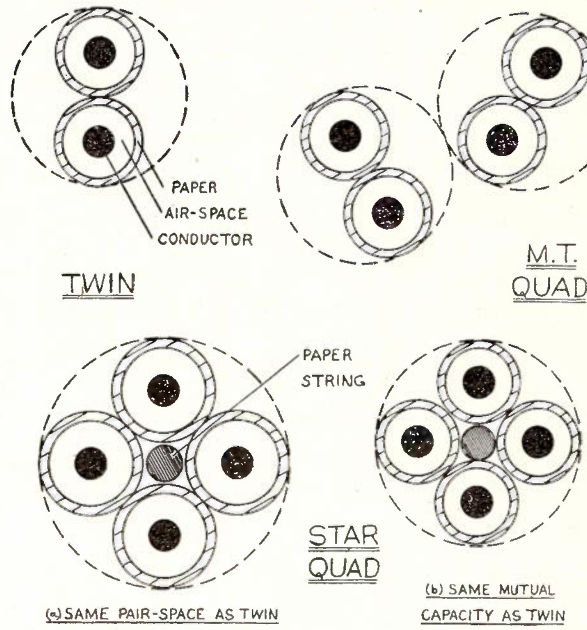

Fig. 1.—Types of Units.

In the Star Quad, four insulated wires are twisted symmetrically with the desired lay round a paper centralising string of accurately chosen size. A single open whipping of flax or cotton overall assists in keeping the wires in their correct positions. The two pairs of diagonally opposite wires form the transmitting circuits, and as shown in fig. 1, this results in low space requirements for a given mutual capacity. Furthermore, as the axes of the two pairs are at right angles, there is theoretically no cross-talk between them, and in practice this condition is approximated to a satisfactory degree.

The simple construction and ease of installation of Twin cable commends it for subscribers' cables up to about 15 pairs. Beyond this its high space factor (about $1^1/_3$ times that of Star Quad for the same gauge and mutual capacity) renders this type uneconomic.

For V.F. trunk purposes the M.T. Quad has a higher space factor than Star Quad, but this disadvantage is largely offset by the possibility of obtaining a satisfactory superimposed or phantom circuit from each quad without affecting the pairs—an advantage not possessed to the same extent by Star Quad on account of the phantom attenuation exceeding that of the pairs. However, the Star Quad cable is still preferred, as it provides about 5% more pair circuits than the total number of pair and phantom circuits available from a M.T. cable of similar gauge, pair mutual capacity and overall diameter, and the complication of phantom operation is not involved. In addition, an appreciably higher quadding cost is involved with Multiple Twin construction. From a cross-talk point of view, M.T. Quads without string insulation give about the same overall results as Star Quads with string insulation.

The Twin unit does not have its previously noted disadvantage in Switchboard Cables, owing to their dense construction, and is therefore widely used in this application. For certain purposes units containing three wires are used.

Stranding: The units are assembled in helically applied layers containing an increased number of units from the centre to the outside of the cable.

The centre may contain from 1 to 4 units, but the 2-unit centre is preferably avoided as it crushes badly. With a 1-centre the next layer contains 6 units, i.e., an increment of 5: in all other cases the increment is ideally 6 units per layer. However, small departures from perfect lay-ups are allowable in subscribers' cable in order to obtain a convenient total number of pairs.

It is usual to strand the layers alternately in opposite directions as this renders the cable mechanically neutral and has cross-talk advantages in that the adjacency of units in adjoining layers is then intermittent.

Owing to the helical application, the length of the quads may be as much as 2% greater than the cable length. The stranding lays must be short enough to confer sufficient flexibility on the cable, and the satisfaction of this requirement results in extra length of the order stated in the outer layers of the largest cables. Apart from the increased usage of material, there is, of course, a corresponding rise in resistance and mutual capacity.

Identification of Conductors: In Twin cables, red, blue and white insulating papers are used on successive pairs, with an orange marker pair in each layer, and a green pair in certain cases where the number of pairs per layer is not exactly divisible by three. To separate the layers an open lapping of paper is applied over each layer during stranding.

M.T. Quads commonly used an extension of the above scheme, whereby the two pairs of a quad were insulated with different coloured papers, and one wire of each pair had a black line printed on the paper. The colours of whipping cottons, etc., were also varied to facilitate identification. An earlier scheme used different coloured papers for the two wires of each pair, but this was found to be undesirable electrically as the two papers were likely to have different physical properties.

For Star Quads, paper of the natural shade is used, printed at intervals with I., II., III. or IIII. diagonal lines which, after lapping, appear as rings round the insulation. The spacing of the lines is such that all papers carry the same amount of ink: otherwise, variations in dielectric properties might occur, resulting in cross-talk. The quads in a layer have red and blue lines alternately, except that for an odd number of quads the last and second-last quads are both blue. White and black quad whippings are used in alternate layers; the first or marker quad, and the last or reference quad have an orange thread in addition.

The outer cotton coverings of the wires of Switchboard Cables carry one, two, three or four-colour combinations, chosen from eight primary colours. The colours of successive pairs follow an ingenious systematic scheme which, however, cannot be detailed in the space here available.

Special Precautions Observed in the Manufacture of Trunk Cables: These measures centre round the securing of low unbalances, and a number of the important factors, such as string insulation, uniform marking of the paper and correct twist selection have already been mentioned. High cross-talk couplings may also arise from the following:—

(1) Inequality in the stiffness or diameter of the two wires of a pair.

(2) Variable stiffness, thickness or width of the paper.

(3) Inequality in the application of the paper.

(4) Inequality of length of the two wires of a pair.

To reduce these irregularities the following precautions are observed:—

(1) The two wires of a pair are cut from the same coil of wire with the object of ensuring similar annealing and gauge.

(2) The papers applied to the four wires of a quad are cut from adjacent parts of the same roll, with special attention to the adjustment of the cutters.

(3) The four wires of a quad are insulated in succession through the same machine and hence the same die.

(4) The weights and run-off tensions of the spools loaded into the quadding machines are made as uniform as possible, and the wires are accurately located round the centre string.

The above, although not a complete account of the methods adopted, gives some idea of the complexity of the problem.

The Control of Mutual Capacity: This control may obviously be effected at the insulating stage; likewise during quadding, where the four wires are brought together through a sizing die. It is better, however, once satisfactory conditions have been established in these processes, to leave them as they are and make minor adjustments of mutual capacity at the stranding stage.

For this purpose, the cable during stranding goes through a die after each layer has been applied. The desired cable diameters are calculated from the area per pair appropriate to the gauge, mutual capacity and number of pairs involved. The correct areas per pair are determined mainly by experience, as the indefinite shape of the space occupied by each unit and other factors make theoretical investigation difficult. It is, however, possible to forecast the mutual capacity of new designs with fair accuracy from empirical data. Having fixed the diameter of the cable in this way, minor alterations of die sizes can be made, if necessary, on inspection of the test results of the first few lengths.

Sheathing: The use of paper insulation makes necessary careful drying, followed immediately by the application of a sheath impervious to moisture and of suitable mechanical properties. The size of the sheath is chosen to fit the stranded core snugly but not too tightly, in order to avoid crushing the core and thereby raising the mutual capacity.

Lead and its dilute alloys are universally adopted for sheathing owing to the ease with which moisture-proof flexible pipes may be extruded. Pure lead is mainly used and has sufficient mechanical strength to sustain the ordinary processes of drawing into ducts. Of the alloys, that containing about 1% antimony is the commonest, and compared with pure lead is more expensive for two principal reasons—a slightly higher first cost, and a lower extrusion rate. However, it has a higher strength and fatigue limit, and is therefore preferred where the cable may be subjected to persistent vibration, as for example on railway bridges or in aerial cable routes.

Lead resists corrosion well under average conditions, owing to the early formation of a protective film of basic carbonate, and it is not uncommon for cables to last 30 years or more. Under bad conditions, considerable trouble may be met, in particular from electrolytic action, which may arise from stray traction system currents, etc., or in certain cases from the nearby presence of metals lower in the electromotive series of the elements.

Armouring: When cable is laid direct in the ground or in river beds, etc., it is necessary to protect the otherwise plain lead sheath.

In the usual types of armouring, a layer of compound is applied first and covered by overlapping impregnated papers. This procedure is effective in retaining the compound film on the lead and affords a measure of corrosion protection.

A layer of jute strings is next added to form a bedding for the armouring itself and to avoid damage to the lead during application of the armouring, which for mechanical protection in normal areas consists of steel tapes. Where, in addition, severe tensile stresses are likely, as in subaqueous cables, galvanized steel wire armouring is adopted. An overall serving of jute and a coating of powdered limestone (to prevent sticking of turns on the drum) complete the cable. All materials are treated with bituminous compounds before or during armouring to preserve them.

Occasionally, protection against lead-boring insects is required, and is effectively provided by the application of a thin copper tape at an early stage in the armouring process.

3. Cable-Making Materials

The Manufacture of Annealed Copper Wire

Hot Rolling: For the manufacture of wire, copper is always supplied in the form of cast electrolytic wire bars, a typical bar measuring 4¼" square by 3' 4" long and weighing about 250 lbs. In preparation for rolling the bars are heated to 950°-1000° C. in a continuous type oil-fired furnace, whence they are conveyed one at a time by live rollers to the roughing rolls. There are three rolls arranged one above the other, of which the centre one is driven in the opposite direction to the other two: thus the bar can be fed into the rolls from either side without reversing the mill. Working is further facilitated by a power-operated tilting table, which brings the bar opposite the upper or lower set of grooves as required.

The profile of the grooves is such that the bar is rolled from a square to an oval section, and then back to square, during a number of passes, in order to work the metal uniformly.

Usually nine passes are given through the roughing rolls, and these serve to transform a 250 lbs. bar into a 1¼" square section 45' long.

Following further reduction in four passes through a set of intermediate rolls, the rod is delivered without re-heating at any stage to the finishing stand, which consists of a number of sets of rolls arranged side by side and operated at a surface speed of about 850 feet per minute. This is markedly faster than the earlier rolls, and the higher speed is, of course, necessary to handle expeditiously the now considerable length of the rod and to prevent its cooling below the hot-working temperature before rolling is completed. Time is saved here also by leading the rod into one or more of the later passes before the entire length has travelled through the first pass, the slack material between passes, distributing itself in open loops on long steel ramps situated either side of the rolls. Six finishing passes are generally given, to produce a rod 0.3" diameter and over 900 feet long, which is finally wound up on a coiling machine.

The entire rolling mill is driven by a 400 h.p. motor, and only about four minutes elapse from the time a bar leaves the furnace to the coiling of the rolled rod. The mill described is a comparatively small one; nevertheness, by rolling bars simultaneously in the three sections, 5 tons of 0.3" rod, equivalent to 45 bars, are rolled per hour.

A general view of the intermediate and finishing rolls is shown in Figure 2.

Cold Drawing: In order to produce wire having a high degree of surface finish and uniformity of diameter, the remaining stages in the reduction consist in drawing the rod cold through successively smaller dies.

It is necessary first, however, to pickle the rods in dilute sulphuric acid to remove the oxide skin which forms as the metal cools during and after rolling.

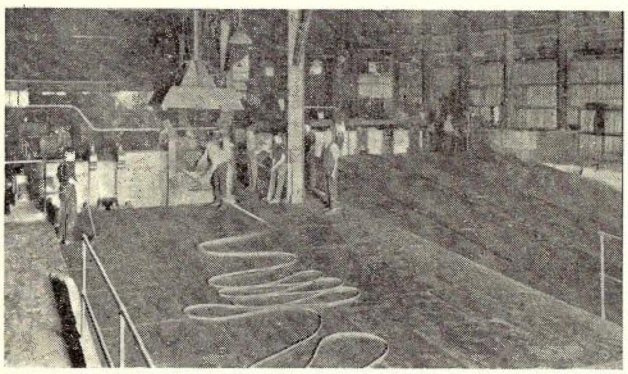

Fig. 2.—Intermediate and Finishing Rolls.

A nine-die heavy wire continuous drawing machine capable of reducing 0.3" rod to 0.064" diameter wire and delivering the latter at the rate of 2500 feet per minute is shown in Figure 3. A coil of rod is carried on a rotating swift at the rear of the machine, and is drawn through each die in turn by a separate draw-drum or capstan, passing finally from the last of these, through a die to the rotating block at the right-hand end of the machine. As the wire winds on to the bottom of the block, preceding turns are forced upwards and accumulate in loose coils on a spider of somewhat smaller diameter than the block, and mounted on top of it. A pneumatic hoist over the machine removes the spider when it is full, the wire is slipped off the spider and the turns then bed down to form a compact coil without tangles. Alternatively, the machine may be arranged to deliver wire from the block to a steel spool carried in a suitable winder.

The only stoppages normally necessary are for the purpose of unloading the swift, as a practically continuous rod supply is secured by welding a number of coils end to end; but if it is desired to change any of the dies, or if an irregularity such as breakage of the wire occurs, the machine must be freshly set up. This process consists in stringing the dies on the rod in their correct order, with the aid of a pointing device and a single drawing block mounted on a stand adjacent to the machine.

In operation, the dies are flooded with a lubricant consisting of wool grease, soluble oil, soap and water, which keeps the dies cool and free from copper dust, lengthens their life and improves the finish of the wire—objects which are further assisted by imparting mechanically a slight rocking motion to the die holders. The lubricant, at a constant temperature, is circulated continuously to all the drawing machines from a central pumping and filtering station.

As the wire is reduced in section it increases in length, and it is obviously necessary to drive the successive capstans at progressively higher speeds on this account, and to maintain the proper relationship between the die sizes and these speeds. The reduction in area used in practice averages about 25% in each die, and is equivalent to a similar increase in length of the wire. The wire is taken up at the output end of the machine at a speed closely equal to the surface speed of the block, but in the preceding sections each capstan is geared to run about 3% faster than the speed of the wire. By taking the wire round each capstan once or twice only, it is ensured that the capstan slip which this arrangement implies can and does occur, and in operation the wire leaves each capstan at a speed which just balances its rate of removal through the following die.

With this method of wire-drawing the stress in the wire at any point is substantially that imposed by one die reduction only, and there is consequently little risk of the wire breaking. Furthermore, the capstan slip represents a margin in which the machine can adjust itself automatically to slight differences in the rates of wear of the dies or capstan surfaces.

The wire from the heavy machine is reduced to sizes required for telephone cables on a medium drawing machine which has a stepped capstan on each spindle, the increasing diameters

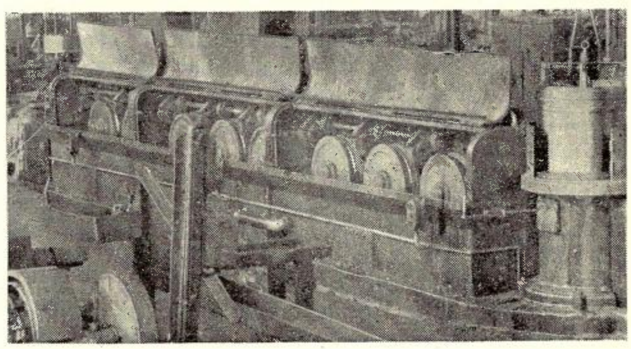

Fig. 3.—9-Die Continuous Wire-drawing Machine.

of the steps providing the required speed characteristics in this instance. Two, or at most four, spindles are then required, and the dies are mounted between them, giving a compact machine whose size is in keeping with the lighter die pulls required for the finer wires. This machine delivers the finished wire at about 3500 feet per minute.

Annealing: The cold-drawn wire is hard and springy as a result of the severe cold work done on it, and before being used in cables must be softened or annealed. At the same time, it is desired to retain the bright finish of the wire, and the realization of these objects involved heating the wire to about 550° C. for one hour in a controlled atmosphere. The coils or steel spools of wire are loaded into a steel basket, which is then placed on a special base and covered with a metal bell, water-sealed around the bottom. The base is equipped to circulate through the bell a reducing gas consisting of nitrogen and hydrogen, derived from the "cracking" of ammonia in a special apparatus, and the bell and its contents are heated by lowering over it a portable electric furnace. After heating, the furnace is removed and water is sprayed on the outside of the bell to cool the whole before the seals are broken. A number of stands is provided, served in turn by the one furnace.

Dies: Tungsten carbide and diamond dies are used in wire-drawing; the latter have the better wear resistance and are therefore selected for the finer sizes, owing to the large surface area per pound of wire in these gauges.

The inspection and maintenance of dies is an essential part of the factory's activities, since the dies are expensive and their condition is a main factor determining the uniformity of the wire.

When the allowable degree of wear has occurred, the dies are opened out to the next size on special polishing machines, using graded boron carbide or diamond dust (for diamond dies) as the abrasive.

Insulation and Sheathing Materials

Insulating Paper: The main physical requirements of cable insulating paper are exceptional tensile strength, to miminise breaks during or after manufacture, and uniformity of thickness and texture, for electrical reasons. The constituents should, chemically, be such that the paper will neither deteriorate with age nor have any corrosive action upon copper or lead.

The only readily available fibres which meet these requirements are manilla and well-washed chemical wood-pulp prepared in the first instance by an alkaline process. They may be used alone or in combination, but all-wood-pulp paper is preferred, because it combines physical properties practically equal to those of manilla with a much lower price than that material.

Very briefly described, the manufacture of paper consists in forming, from a dilute water suspension of the previously beaten fibres, a "web" of long interlaced fibres, either on a revolving cylindrical screen or on a moving flat screen; the extraction of much of the water, followed by the drying of the web on heated felt-covered drums; and the calendering of the paper between heated metal rollers. The paper is finally wound and slit to yield rolls about 2 feet diameter by 2 feet wide, in which form it is delivered to the cable-maker.

Paper String: This material consists of a narrow strip of paper compressed and twisted to yield a firm, uniform string. It is supplied ready for use, universal wound on cardboard tubes (i.e., in a manner similar to a cylindrical package of ordinary string).

Cotton: The short fibres obtained from the plantations are subjected at the cotton mills to various cleaning and carding processes before being spun into yarn. For wire lapping or braiding, a number of threads or "ends" is universal wound parallel to one another to give a ribbon of width suitable to the diameter of wire to be covered. Colour combinations are obtained by winding a number of ends of each colour, so that during lapping the familiar banded appearance will be produced.

Cotton is also used in the woven form for such purposes as switchboard cable core wrappers.

Flax: Its high tensile strength gives flax yarn a slight advantage over cotton as a quad whipping, since finer threads can be used, thereby reducing the bulk of the quads.

The yarn itself is prepared from the plant of the same name by a preliminary soaking in stagnant water to remove woody fibres, followed by processes similar to cotton spinning, etc.

Silk: A number of the fine threads from individual cocoons form the basic yarn, of which the required number of ends is parallel wound like cotton. In this form, silk is used under the cotton covering of the conductors of Braided Switchboard Cables.

Rayon: All man-made substitutes for silk are loosely termed "rayon," and in general consist of some form of regenerated cellulose. The process of manufacture is the same in principle for all classes, viz., extrusion of the material in the fluid state through fine nozzles into a hardening medium. Cellulose acetate rayon is, electrically, slightly superior to silk on account of its faster recovery from high humidity conditions, but all other types are inferior to a greater or less extent.

Inks and Dyes: Coloured or printed paper and dyed cotton are naturally required to have electrical and chemical characteristics not appreciably worse than the plain materials. The aniline dyes known as British Direct Dyes are satisfactory in these respects, and do not fade readily on exposure to heat (during cable drying) or light.

Sheathing Materials: Lead is purchased in the familiar form of pigs, each weighing 90 lbs., and is of high purity. The 1% alloy with antimony, conveniently prepared by diluting pure lead with a high antimony alloy, is also obtained in pig form.

Switchboard Cable Impregnating Compound: The standard mixture for this purpose is 8 parts of beeswax to one part of petroleum jelly, but shortage of the former material has resulted in various substitutes being used.

A compound now being adopted is a petroleum product best described as a hard petroleum jelly; it possesses the necessary insulating and moisture resistant properties, is chemically neutral, and, physically, has the desirable characteristics of plasticity and a slight stickiness.

Jute Yarn: The yarn is originally prepared from the jute plant by processes similar to those used for flax, and is supplied in large universal wound packages suitable for loading into the armouring machine. The packages are normally dried and impregnated at the cable factory before use.

Galvanized Steel Wire: The preferred quality is a soft steel having a tensile strength of about 25 tons per square inch. The wire, in a range of sizes extending from .064" to .276" diameter, is purchased in coils, and wound on to the armouring machine spools before use.

Steel Tape: The usual range of sizes of this material is from ½" to 2" wide and 0.020" to 0.060" thick, a mild steel having a tensile strength of 20-30 tons per square inch being specified. The tape, delivered in the form of flat pads, is wiped and lightly compounded during a rewinding process, which precedes its use in the armouring machine.

Impregnating and Preservative Compounds: The impregnation and protection of armouring materials is effected almost exclusively by bituminous compounds. A bitumen fluid at ordinary temperature is used for the pre-impregnation of jute and paper, which processes are carried out hot and under vacuum, and are followed by the removal of excess compound in a centrifuge.

For direct application during armouring, compounds of increased hardness as the outside of the cable is approached are used, with the object of striking a reasonable balance between a protective coating which will remain unbroken under all conditions of bending, and one which will not be unduly sticky to handle. All these compounds are solid at room temperature, and are therefore applied hot at temperatures well above their melting points. For the outer layers, air-blown bitumens have some advantages in that they are plastic over a wider range of temperatures than the equivalent straight compounds, but in spite of this do not have lower melting points.

To conclude this section of the paper, it need hardly be added that quite small defects in raw materials may render an expensive cable useless. The importance of using only high quality materials and of maintaining rigorous inspection procedures cannot therefore be over-estimated, though a description of the diverse tests adopted is beyond the scope of this outline.

4. General Features of Cable Making Machines

Supply and Take-Up Arrangements: In nearly all cable making machines the material is drawn off from the coils, spools or drums, and, after the desired operation has been performed, is delivered to a take-up spool or drum. The usual form of haul-off gear is called a capstan, after its marine prototype, and this term has already been mentioned in connection with the wire-drawing process. In that case, a certain amount of slip was deliberately allowed, but in the present instance the material is taken round the capstan a sufficient number of times practically to eliminate slip, at the same time permitting a considerable pull to be exerted on the machine side, if necessary, with a comparatively light tension on the take-up side. By this means a constant relation between the operation being performed in the machine and the rate of travel of the material is assured. The profile of capstans varies according to the particular application, from a self-fleeting wheel having a pronounced cast, to a slightly tapered design requiring a fleeting knife or ring to prevent the turns from working over to one side.

The take-up drive raises a problem in that the filling of the spool or drum requires that the latter must be progressively slowed down to maintain a constant linear speed of winding, and it is desirable that this adjustment should take place automatically and without seriously altering the tension applied to the material. Various methods are adopted to achieve this end, such as slipping belts, slipping clutches, manually controlled variable speed gears of hydraulic or mechanical type, and variable speed gears controlled by the tension of the material itself.

As it is usually necessary to secure neat and uniform winding of the material, an automatic traverse gear is standard equipment on the smaller machines, and is driven from the variable speed end of the take-up drive. In the winding of larger assemblies, such as stranded cores and lead-covered or armoured cables, there is no simple and adequate substitute for hand guiding-on.

Referring now to the operations performed within the machines, these consist in the main of lapping and twisting processes, and their underlying principles are summarized in the following paragraphs.

Lapping: Figure 4a shows a schematic of a paper-lapping head of the type used to insulate the individual wires of a cable. The wire is drawn through the hollow spindle of a revolving disc carrying a pad of paper, and a helical lapping applied. After passing through a sizing die, the lapped wire goes through the centre of a magazine plate carrying square pads of paper, and then to the usual capstan and take-up gear. The magazine is slotted so that it may be drawn to one side when it is desired to place a new pad on the disc.

A cotton lapping head is similar in principle, but the disc is replaced by a canister carrying the package of cotton and the die by a guide which holds the wire steady at the lapping point and which is also equipped with a small

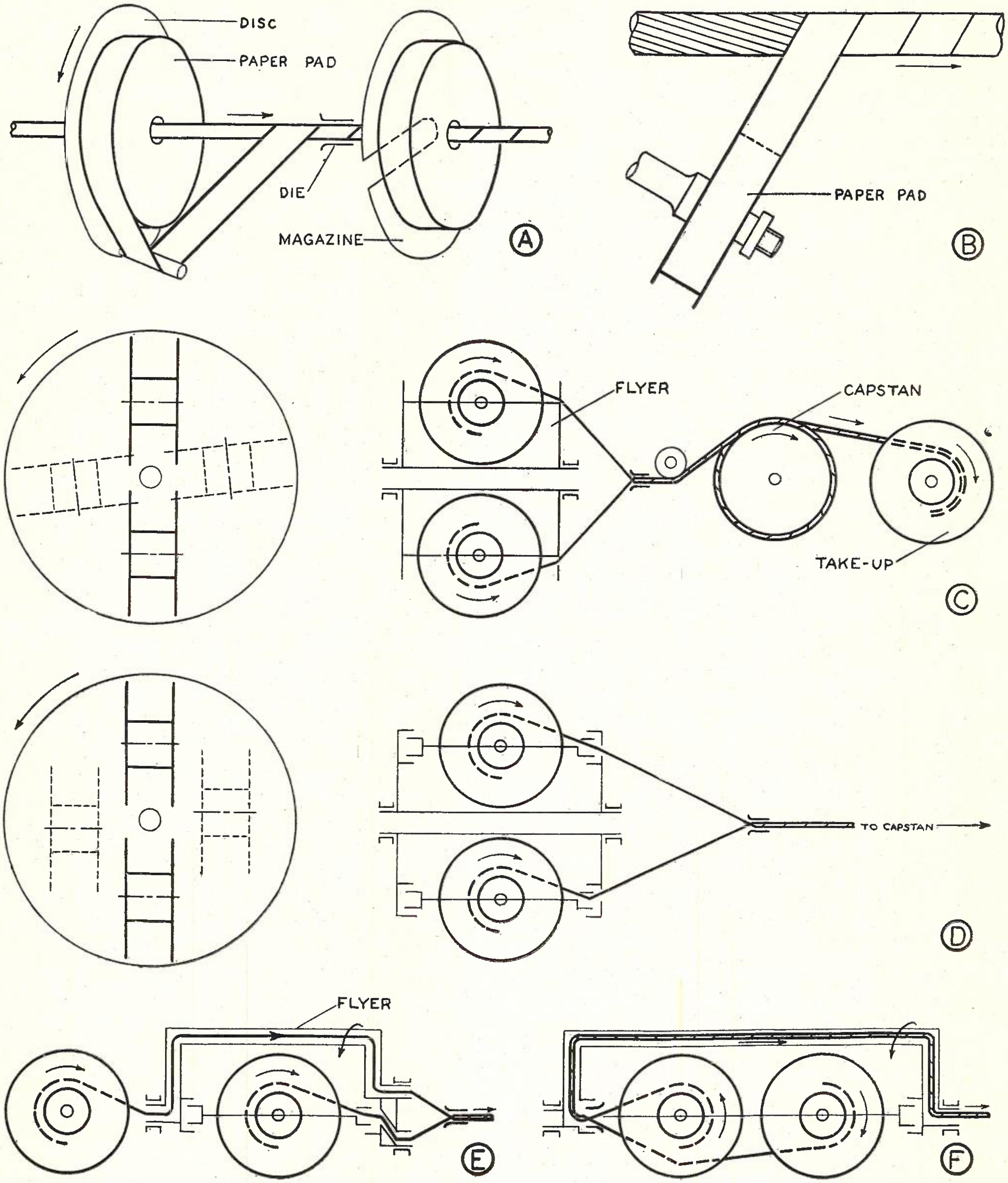

Fig. 4.—Principles of Lapping and Twisting Machines.

spring-loaded polishing plate; the magazine takes the form of a tube over which the centres of the spare packages are fitted.

From an operating standpoint, the main features of these heads are their balanced construction, allowing high speed operation, and the small inconvenience caused by accidental exhaustion of the magazine, since only a single wire need be cut to reload it.

In practice, heads are usually arranged with the wire moving vertically, as this economises floor space without raising the height unduly.

For the wrapping of stranded cores and the application of tape armouring, the pads of material are carried on heads mounted eccentrically with respect to the cable, as shown in Figure 4b. The centrifugal forces may be large, and limit the allowable speed, especially in the case of tape armouring machines—a restriction which is largely unavoidable. On stranders, the size and weight of the main sections are such that the speed is in any case fairly low.

With this type of head, a number of pad holders can be disposed round the cable so as to lap several papers, etc., simultaneously, without increasing the floor-space requirements, and the question of a magazine or its capacity does not arise.

Twisting: All twisting and stranding operations essentially involve the movement of the wires (or units) round the axis of the cable while the cable moves forward, but certain attendant conditions are subject to some variation, and the form of any particular machine depends on whether:—

(1) The spools move round the axis of twisting; or

(2) The spools are stationary with respect to the axis of twisting; and

(3) The individual wires are twisted with respect to their own axes; or

(4) The individual wires are not so twisted.

The various possibilities are best discussed by reference to diagrams (Figures 4c to 4f) which, for simplicity, show the twisting of two wires only in each case. This number can be increased in practice.

Figure 4c, for example, illustrates conditions (1) and (3), for it will be seen that the supply spools are fixed to a revolving flyer, and for a complete revolution of the flyer each wire will be effectively twisted once about its own axis. The positions of the spools when the flyer has made portion of a revolution are shown by dotted lines in order to clarify these points.

The main disadvantage of machines of this type for quadding or twinning is that the twisting of the wires alters the lay of the insulation, which is undesirable electrically. In stranding, however, the proportionate alteration of quad twist lengths does not affect the electrical characteristics adversely, and most stranding machines are constructed to this design; several flyers, large enough to hold the required numbers of spools, are used, and the main shaft of each flyer is made hollow so that the application of successive layers in the one machine is readily possible.

Figure 4d exemplifiies conditions (1) and (4), for in this case the spools are mounted in "floating" cradles which make one revolution about their own axes for each revolution of the flyer, and in the opposite direction. They thus assume a constant orientation to an outside observer, and twisting of the individual wires and their insulation does not occur. This scheme is applied to the quadding of trunk cables; and on the wire flyers of armouring machines, where torsion stresses in the wires are undesirable, as they would naturally make the cable prone to twist of itself.

In order to obtain higher operating speeds, the size and weight of the rotating parts of twisting machines have been reduced in certain cases by adopting the method shown in Figure 4e. Here the back spool is fixed, and the spool inside the flyer is mounted in a floating cradle, which remains a constant orientation by virtue of its own weight. The light rotating flyer carries the back wire round this spool, and the twisting occurs at the front end. The wires are not individually twisted, and this diagram therefore illustrates conditions (2) and (4).

The arrangement is readily extended to the quadding of subscribers' cable by retaining the back spool and mounting three spools behind one another in separate cradles inside the flyer. Each of the wires from the flyer spools passes through the hollow front journal of its spool cradle and outwards to the periphery of the flyer; the four wires are then brought together on the axis of the machine at the front end.

Figure 4f is somewhat similar to the preceding case, but here both supply spools are placed in a floating cradle within the flyer, and the wires are led into the flyer at the back end. A little consideration will show that this ingenious arrangement imparts two twists for each revolution of the flyer, thus doubling the output rate for a given lay and flyer speed when compared with any of the previous designs. It does not, however, avoid individual twisting of the wires, and therefore typifies conditions (2) and (3). The machine is sometimes used in the twisting of Subscribers' twin cable, and with more supply spools can be used to "bunch" a number of pairs or quads together. The bunched formation approximates a strand with the layers applied in same direction throughout.

Spools: To complete the account of the general features of cable-making machines, mention is made of the factory spools and drums. They are a vital part of the equipment, and manufacture is seriously hampered if for any reason an appreciable number of them is held up.

The spools which circulate between the insulating machines and quadders, and between the quadders and stranders, are generally made with strong, light saw-blade steel flanges, and are interchangeable with all others in their particular circuit. For trunk cable work, the quadder supply spools are divided into groups having a weight variation of 2 ounces or less. The spools in each group are marked with distinctive colours, and the four wires of a quad are, during insulation, reeled on to spools in the same group, in order to equalize as far as possible the centrifugal forces and tensions developed in the quadding stage.

The larger drums which circulate between the stranders and the drying ovens and lead presses usually employ a skeleton steel construction, primarily to facilitate the extraction of moisture during drying.

(To be continued).

THE N.S.W. NORTH COAST FLOODS—1945

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The North Coast corner of N.S.W. known as "The Northern Rivers" is subject to periodical flooding, but the flood of June 11-12th last made new records and caused some serious and unusual problems for the Postal Department. The principal rivers, commencing at the Queensland border, are the Tweed, the Richmond and the Clarence, and the respective principal towns are Murwillumbah, Lismore and Grafton. Although impeded by sandbars near their mouths, these rivers are navigable to coastal steamers for many miles, and meander through closely settled fertile river flats. It is arresting to see the masts and superstructure of a ship moving through these grazing fields as the ship plies its way to up-river wharves, that at Lismore being 75 miles from the mouth of the Richmond. Even in wet seasons these rivers generally confine themselves within their banks, but this flood had sufficient volume to rise feet over the river flats and extend to the hills. Like another big flood, it occurred in June, which is not in the normal wet season of the year. Steady soaking rains fell during the month preceding. Except that such weather was out of season, it attracted little attention.

Thus the Tweed River, late on the night of Sunday, 10th June, 1945, gave no indication of the major flood impending, but at 5 a.m. on Monday had risen 19 inches in the Murwillumbah Exchange and had completely covered the vehicles in the Post Office yard. Efforts by the staff averted damage to the switchboards, and the waters had left the building by 11 a.m., but returned the following night to lesser depth. Continuation of the telephone service, busy through the emergency, whilst knee deep in flood water, is something of which the exchange girls and technicians may well be proud. The pungent odour of the decaying silt remained for some days. The lot of the line staff outside was even more trying. As it took the floodwaters two days to recede from the Post Office yard, finding the right drum of cable for replacements, at one stage at least, literally meant diving for it, and the simple efficiency by which natural laws, in all the turmoil, filtered out the flotsam of oil, tar, creosote, sawdust and other debris and stuck it to clothing is best known by those whose duties invited them into those murky waters. Forty shops in the business area and much of the residential area were similarly covered, and the Department's cable system was mostly submerged. Happily, the flood waters did not generally reach telephone height and, partly on this account, Murwillumbah did not suffer the dislocation of subscribers' services which followed the deeper flooding at Lismore. However, faults put 330 of the 466 services and a trunk cable out of order. Near the ceiling of the Line Depot is a mark "1945 Flood Level," and in the difficult moments following the flood it meant that the staff was deprived of essential items of jointing material made unserviceable through submersion. Fortunately, Brisbane supplies were within easy distance and were promptly made available.

Murwillumbah's experience served to warn Lismore, where the Richmond River had not then risen dangerously. In the business community, varying opinions were reflected strangely between the customary Monday morning preening of stocks and the hurried lifting or shifting to places deemed above the flood level. At 9 a.m. the waters were below minor flood levels and it was said, even if the flood was equal to the "big flood," things that mattered would not get hurt. One thing that Lismore-ites now feel is that flood level is not a limit, but something like a sports record that stands only a matter of time. The 1945 flood is the biggest on record. The water was from 14 ins. to 30 ins. higher than the previous record, the variation being perhaps due to currents and the severe counter gale which rose at the peak of the flood. The Lismore Post Office and Telegraph Room floors are four to five feet above street level and the Telephone Exchange a floor higher. The Line Depot at North Lismore is at ground level. By 10 a.m. the flood waters had reached the Post Office yard and were rising a foot an hour. After motor vehicles and such equipment and stores as practicable had been moved to high ground, and a hurried check had been made of some of the cable pillars, all non-essential staff was sent home in anticipation of the morrow's task. By mid-day it was evident that the batteries in the Telegraph Battery Room would be submerged, and one o'clock was set down as the time to cut away the straps and lift the lowest cells to space

Fig. 1.—Post Office Corner, Lismore.

made available on the top racks. Access to that building was then through swirling waters four feet deep, a novel experience when familiar paths were expected. By dusk the rate of rise had decreased to three inches per hour, but it was not until midnight that a slight fall was noted. The long hours of that Monday night were not without their lighter moments. Despite efforts to lessen staffs, the total of telegraphists, telephonists, technicians and others who had remained on duty too long to get home, together with a few outsiders who had made any port, must have exceeded forty in the two buildings. They soon found that their food stocks were quite inadequate, and many will remember kindly those technicians, with fishing gear fashioned from stout conduit and an office paper basket, who netted pumpkins, which were served for the midnight supper, together with other objects of nutrition and amusement from the waters lapping the entrance to the New Exchange Building. Rain eased about this time, and the swish of the waters was punctuated by the collapse of plate glass shop windows under differences of pressure. Several collapsed together opposite the Post Office from the wash of a motor launch which was patrolling the main streets. Within an hour the storm passed, to be followed in ironic contrast by a starlit night and a sunny day. Throughout the darkness, fine work had been done by the Police and others, rescuing people from the lower portions of the town, many of whom had feet of water in their houses. Of Lismore's 15.000 population, half is estimated to have suffered and, in many cases, grievously. Most houses in Lismore are built of wood, Queensland style—on stumps, and this lessened the depth of flooding in them. The whole of the settled land surface of North Lismore, South Lismore and Lismore, excluding the narrow tongue of higher land reaching from East Lismore to the Police Station, also Girrard's Hill and East Lismore was covered at midnight.

The water was then 26 inches over the Post Office floor, and lapping the wiring under the tables in the Telegraph Room, from which all equipment had been lifted. At the Line Depot, North Lismore, the water was four feet deep, and the modern storeroom fittings and contents suffered considerably. The water had left the Post Office building by 10 a.m. on Tuesday, but portions of the wiring had suffered and were replaced. All trunk and telegraph equipment at the Post Office was workable for the following morning, but external line plant had suffered serious dislocation from the gale during the flood. These aerial interruptions were in themselves exceptional and were mostly due to the softening of the ground during the pre-flood period. The North Coast is heavily timbered, particularly south of the Richmond River, with slim spotted gums, ironbarks and other eucalypts having characteristically small root systems and commonly exceeding 100 feet in height. The steady rains had loosened the hold of these trees,

Fig. 2.—Keen Street, Lismore (Looking South).

and during the flood a wind of severity sufficient to snap many sound trunks uprooted individual trees over a wide area. Out of twenty-five aerial interruptions, such trees caused 21 and the flood waters directly the others. Three of the flood interruptions were caused by the failure of poles where roadworks had carried away, and one by the load of debris against pole and stay, but only minor routes were affected. The flood waters were, however, a major obstacle in the clearing of aerial faults, and much arduous walking was done by line staff giving temporary circuits where roads were untrafficable. Restoration was the more urgent, in that seldom have alternative routes so generally suffered. The interstate route was down in three places in the Grafton-Casino section, and the alternative route via the Pacific Highway through Woodburn was down in several places and less accessible by the later flooding of the coastal country along this route. South and West of Grafton arterial routes suffered. Also on the Casino-Tenterfield route, two miles were wrecked by falling trees. Happily, the principal circuits between Lismore and Brisbane were in order throughout. Certain minor routes suffered similarly, but service was restored, at least in an emergency manner, as soon as the obstacle of the flood waters permitted.

The flood caused a marked increase in certain classes of traffic. Local calls at Lismore on the Monday, as the floodwaters rose, were doubled. After the flood, as the whole of the business area had been submerged, Lismore was without many essential foodstuffs, building materials and merchandise. Bread and meat were brought from surrounding higher localities and distributed by the police, and the Air Force parachuted supplies to those marooned. These emergencies and the urgent traffic from Governmental and other representatives who came to Lismore to assist, together with a host of enquiries from friends even as far distant as Ireland, caused heavy congestion on available circuits. During this time the closest co-operation existed between the traffic and engineering staffs, the police and the local radio station. Electric power supplies were saved by a matter of inches at the height of the floodwaters, although some machines at the power house were unavailable through entry of water into cable ducts. Portions of the municipality were without water, electricity, gas or sewerage for a short period. The gas works were submerged and supply suffered considerably in the distribution network. The public was particularly tolerant and appreciative, and gratefully acknowledged the sympathy and understanding which prompted the immediate response of the several Government departments concerned.

As the flood waters in Lismore subsided, many subscribers' services showed heavy losses. On Tuesday morning a boat was obtained and an unforgettable trip made via the principal streets of Lismore and out to Wyrallah Road to pick up staff. Then, although 12 hours after peak flood, swift currents and feet of water remained over the greater part of Lismore. Of 1160 services connected, only 150 could be raised and insulation tests showed unusual variations between adjacent cable sections and pairs. The vital services' list which had been prepared for wartime emergencies was consulted and, with the aid of some three miles of Army rubber-covered wire rushed from Brisbane and strung, military fashion, on electric light poles and other supports, all such vital services were quickly restored. Some of these temporary circuits gave valuable service during the period when restoration of the normal cable channels was delayed by unforeseen tandem faults. With the fall of the waters came a coating of mildew on everything non-metallic, and low insulation resulted. It seemed that the sunshine following the flood would benefit restoration considerably at one stage, and as replacement of three larger cables proceeded, complete restoration appeared in sight. It was disconcerting, therefore, to find that the clearance of 600 pair, 500 pair and 400 pair faults did not noticeably increase the number of working lines. During the week after the flood, local staffs were increased by the arrival of an engineer and 16 jointers from Sydney, and 10 technicians from Sydney and Armidale. Despite the excellent and tireless services given by all staffs, progress was slow and the unforeseen work in the lesser cables repeatedly deferred the expected date of completion. The arrival of additional assistance presented some accommodation difficulties, and a good deal of inconvenience to those who had volunteered to assist in the emergency. As a substantial part of Lismore had been flooded, even dry bedding was scarce. Local engineers found the search for boarding accommodation and associated requirements such as butter rations, restoration of gas supplies and other household commodities quite an awkward addition to their engineering duties.

Unfortunately, such emergencies do not lend themselves to a detailed analysis of underlying causes, but a review indicates that the cable faults fall in to three general classifications. Firstly, there were the usual street cable faults —probably aggravated by the static head of the flood waters for many hours. Also, as about 150 telephones had suffered immersion, much trouble followed the entry of water via the small cables at the telephones. One business man with previous experience had his telephone in the ceiling, with access through the manhole. The flood triumphed. But most damaging was the entry of water, in many cases into large cables, via distribution pillars. Of the first class, it may be hoped that the flood's test of pressure and duration revealed faults which would normally have appeared at later dates. As some of these did not become evident until tandem faults in larger cables were cleared, replacement of much main and lateral cable was found necessary. The second class of trouble likewise involved much work, as the penetration of flood waters in many cases reached the lateral joints. These small cables, which were frequently under concrete or sealed in business premises, took much time per pair cleared. A surprising fact revealed by subsequent plotting of the rate of restoration of services from the daily tests made by the District Telephone Officer was that the number of services restored each day was almost constant, and was not influenced by clearances of large cable faults and increases of staff. This observation seems to emphasise the difficulties of the smaller cables. Efforts have been made to seal these small cables to prevent future similar trouble, but a cable impervious to the travel of water would minimise risks from damaged wiring and simplify new installations where flooding is probable.

The behaviour of the pillars under flood conditions merits particular attention, as flooding of business and near residential areas in some towns will remain a condition which the communities are apparently willing occasionally to risk. Flood waters rose over 28 pillars in Lismore, many being of the higher No. 2 type. Of these, five of the paper type and two silk pillars maintained insulation. Four of the five, significantly, although installed some months, were not in service. The fifth survived six feet of water and was comparatively badly dinted on the canister edge, but the rubber ring adhered, the break occurring at the flat surface of the ring. Two other silk pillars had workable lines, and at least one paper pillar had one cable tail clear. Some thousand cable pairs were thus affected, and in some cases the damage extended both ways into the large street cables. It is clear that something better than the fortuitous seal between canister and frame is essential if pillars are to remain below flood level. Generally, it was impracticable to determine the point of entry of the water, but undoubtedly the junction between the large rubber base ring and the bottom edge of the canister leaked in most cases. The present cheaply belled edge of the canister suffers a somewhat regular kind of dinting, apparently caused when the lineman places the canister between the hexagonal pillar cover and the building whilst working at the pillar. Some were slightly distorted and no longer circular. When the canisters are replaced such irregularities are moved and the rubber ring becomes an imperfect gasket. During a hurried inspection prior to the flood, some of these rings were renewed, but apparently without benefit.

Before the cables attached to a pillar can become faulty, two failures have to occur—one admitting water to the canister, and the other allowing this water to get into the cables. In one case, it was found that the water in the canister had entered the main cable of the pillar only, without affecting the subsidiary insulation. As, however, mere wetting of the pin strips renders the circuits unworkable, service during floods can only be guaranteed by keeping the water below the pin strips. Water entered the canisters by one or more of the following:—

(a) Minor dints in canister bottom edge.
(b) Slightly mis-shapen bottom edge.
(c) V gap at joint in canister.
(d) Fracture at seam of canister.
(e) Small brass washer at top of canister.
(f) Large holed brass washer at top.
(g) Rubber top washer.
(h) Sealing compound on rubber washers.
(i) Canister bedding at different levels on sloping surface of rubber ring.
(j) Leakage in folded seam of canister.

None of these irregularities was particularly evident, and all were the result of normal usage, and some were apparent only under pressure tests. The application of gas to the tails of certain pillars showed that the water could readily enter via the pin strips, and sometimes under the bottom edge of the bakelite. Generally, gas applied to one cable did not emerge from the pin-strips of the other. Efforts to seal the pin-strip holes by heating were unsuccessful.

Although careful maintenance and regular inspection may minimise trouble in a future flood, some improvements in design are desirable. Where convenient, the pillar could be installed above flood level on a short pole or a building. Pillars for use in flooded areas might be designed so that the bottom of the pin strip is three inches above the level of the large rubber ring and the cable tubes carried up to this level. Providing the canister is airtight, water may then enter through a faulty lower seal, and a head of six feet of water over the pillar would not cause sufficient rise within the pillar to wet the pins. The hole in the top of the canister is a weakness even with the latest type washers, and to avoid water entry as well as to ensure the success of the design proposed, this hole might be avoided by an inverted U-shaped piece of flat iron fitting over projections on two diametrically opposite lugs of the brass base casting, and having a small thumbscrew in its centre top to apply pressure to the top of the canister. Improvement in the bottom rubber seal would be an advantage, but such improvement seems likely to be a compromise between perfection and easy pillar access.

The towns of Coraki, Woodburn and Ballina in turn received the flood waters—happily without abnormal cable troubles. At Woodburn a motor launch was hired to expedite clearance of aerial faults, but with limited success. Here the waters reached the floor of the Exchange, which building is higher than most of the buildings in the township. Woodburn was thus suffering its second recent disaster. On April 7th a hurricane struck the locality and wrecked or unroofed many of the buildings. The Post Office residence was seriously damaged, but fortunately the roof over the Exchange and Post Office held. One church was demolished, and the two two-storeyed wooden hotels unroofed and distorted. Not one span of P.M.G. or power wire remained intact in the main street, and sheets of roofing iron were wrapped fantistically about cross-arms and trees. It might be added with satisfaction that the Department's construction apparently suffered no faults directly from this storm, and the damage—which was considerable

—was caused wholly by flying material from wrecked buildings.

On the Clarence, much flooding and most wind damage occurred. This river is the largest of the northern rivers, and a proposal for the generation of 75,000 K.W. is planned at a place known as the Gorge, as soon as a market for this power is available to off-set the initial capital cost of the dam wall. The principal towns of Grafton and South Grafton had little underground cable trouble, although the greater part of South Grafton was covered by water. At Grafton, following an equal record flood in 1928, a levee bank had been built, and this saved the town. Ulmarra was not abnormally affected, but Lawrence, the site of 2NR's transmitter, Maclean and the lower reaches suffered as a result both of flooding and wind. Three submarine cables across the Clarence were carried away. This big river is from 600-800 yards wide for the distance of 45 miles between Grafton and the coast at Yamba. At Copmanhurst, which is about 20 miles further upstream and was the limit of navigation before Grafton developed, the flooded river rose 69 feet. At Grafton the rise was 19 feet, and at the Harwood Ferry on the Pacific Highway between Maclean and the mouth the rise was seven feet. Two ferries, one of which probably took a P.M.G. submarine cable with it, were carried away. The laying of such cables on the upstream side of ferries is an advantage to be taken wherever practicable. The Department's cables at Maclean were affected, and many had to be replaced. None of the 15 submarine cables across the Tweed and Richmond Rivers failed, and, as stated, three of 14 across the Clarence. In addition to the one carried away by a ferry, another probably failed through weakened armouring, which in a recent fault had been found corroded. As an indication of the normal tranquillity of these rivers, small lead-covered cables remain in service for months, while the manufacture of replacement cable is in progress, and appear less susceptible to the action of the submarine borer beetle than damaged portions of armoured cables. Enormous quantities of silt were moved by the flood and deposited in low-lying localities. This silt was a much greater nuisance in repairs than the flood waters themselves, as it covered everything with inches, occasionally feet, of what can only be described as a natural grease.

Acknowledgment is made of the splendid work by all concerned. The engineering organisation of N.S.W. gave full and immediate assistance. Thanks are due to Queensland, particularly the Superintending Engineer and the Supervising Engineer Lines, who personally ensured immediate delivery of tons of material and tools, not quickly available from Sydney because of distance and railway dislocation. The efforts of the staffs from Sydney and Armidale, who carried out a major share of the restoration, is gratefully acknowledged. The task demanded dogged perseverance and the whole-hearted willingness of all to toil continuously through nights and week-ends, with the barest breaks for meals and sleep. Such eagerness is the bright picture left by the flood.

TELEPHONE TRAFFIC

K. B. Smith, B.Sc.

Introduction: The solution of traffic problems is frequently considered as essentially a mathematician's realm. So much so that when traffic is mentioned there are some who proceed to set down complex mathematical expressions, when the matter may require only fundamental logic combined with an appreciation of the principles of the concentration and distribution of telephone calls. Advanced Mathematics has been essential for determining some aspects of this subject, but the results are generally available in graphs or tables which are simple to use, and in other cases sufficient data can be obtained to give a solution with the application of only the usual mathematical operations. Some of the simple aspects of the composition of traffic are set out here to assist in a logical rather than a mathematical approach to traffic problems.

The Nature of Telephone Traffic: Telephone calls made from time to time by individual subscribers are brought together when they are handled in the Exchange or are transmitted over a trunk line and, when they are considered in this concentrated form, they are known as telephone traffic. Every day problems arise relating to the amount of equipment or the number of trunk lines needed to transmit this traffic, and it is a fundamental part of telephone engineering to find ways for concentrating the calls for eventual distribution as required, and to determine how much plant is needed to make the system efficient.

Calls are originated by a subscriber without any thought of the availability of exchange equipment. He makes a call according to his own desire, and without any outside control or consideration of the relationship to calls from other subscribers. To a person at the Exchange these calls appear in pure chance order, and it would be impossible to forecast when a call will come in on any particular line. The Exchange Observer would, however, realise that there are some definite controls by which he could anticipate the general incidence of the calls. The fact that calls would not be made from offices at night-time and that few calls would come from business houses on Saturday afternoons and Sundays would be known to him. By taking these obvious factors and others which might be thought of, some idea of the expected traffic could be forecast, and it may be necessary to make such estimates where entirely new conditions are to be met. For the general case, however, data has been collected over the years that telephone systems have been in use, which indicates the actual demands made on a telephone service in particular circumstances.

Certain regular cycles become apparent when traffic from similar classes of subscribers' service is considered. The cycles will differ for different classes of traffic. For instance, the relatively great number of calls will come from business houses in the morning and afternoon, but from suburban subscibers in the evening. Figures 1, 2 and 3 show records taken for one month, one day and one hour respectively. The cycles applying to these periods for the particular cases recorded are evident and the reasons can be easily deduced. On such data the general requirements of a system can be formulated, but much more information is needed to determine details of distribution and the quantity and type of equipment necessary.

The Traffic Unit: When the calls are concentrated on traffic routes, the total number of calls ceases to be the guiding factor in determining the needs of the system, as the duration of the calls must also be considered. If a number of calls occupy a route for a certain period of time and each call must wait for the completion of the preceding one before it can be connected, then the calls, irrespective of their number, could be carried by one circuit. This state of affairs exists in the case of a trunk route, where the calls originated independently are held waiting until a line is available. The telephonist distributes the calls so that as one finishes the next one is connected.

If the calls are connected to the route as they arrive at random without the help of the telephonist, it would be possible to have all calls in progress simultaneously for a short time. In this extreme case, the calls could be carried without loss only if the number of circuits available is equal to the number of calls. To avoid loss, it is therefore necessary to provide a number of circuits equal to the maximum number of simultaneous calls which could occur. In practice it is not economical to provide circuits on this liberal basis, and a small loss is tolerated, the number of circuits actually provided being much less than the maximum number of simultaneous calls possible.

When calls are in progress over a given route, traffic is said to flow, and circuits must be provided to handle the maximum traffic flow if no calls are to be lost. The unit of traffic flow refers to the flow at a particular instant, and the unit chosen to indicate the magnitude of traffic flow is called the traffic unit (T.U.). One traffic unit is the traffic flowing when there is one call in progress on a route. As instantaneous values are not suitable as a basis for the provision of switching plant because of economic considerations, the average traffic flow over a period is taken.

As an example, if the number of engaged circuits at a particular instant is 10, at that instant the traffic flow is 10 T.U. Then, if the observation is continued for a longer period and it is found that the number of simultaneously engaged circuits varies between 0 and 10, the traffic flow varies correspondingly between 0 and 10 T.U. Moreover, if the average number of circuits engaged simultaneously during the period is 5, then the average traffic flow during the period is 5 T.U.

It follows that the selection of the length of this period of observation requires careful consideration. Experience has shown that the most satisfactory period from which to obtain the average traffic flowing is one hour, and this period is always assumed unless other conditions are stated.

Calculation of T.U.: From the foregoing it will be seen that the traffic flow in one circuit continuously occupied for one hour will be one T.U. on the basis of average simultaneous connections, and also on the basis of occupied circuit time, which could be stated as one "circuit-hour." In some cases, traffic data is given for design purposes in a form which does not include simultaneous connections but which does allow the circuit occupied time to be determined. For instance, the data may be in the form of a nummer of calls and the average holding time per call. In this case, the method of calculating the traffic in T.U. is expressed by the formula:—

$$A = C \times T$$

where A = traffic in T.U.
C = number of calls during the period.
T = average holding time expressed as a fraction of the measuring period.

Great care should be exercised in the application of this formula, as the duration of the calls denoted by T must always be expressed as a fraction of the period of observation, otherwise the formula is not applicable.

There are three principal methods of arriving at the T.U. flowing, and an example will be given in the next paragraph to show that a similar result is reached by all three methods.

Considering a period of one hour, if there were a number of lines of which four were occupied continuously, and one for half an hour, then the traffic flow can be determined by the following methods:—

(a) The average number of simultaneous connections during the period under consideration (one hour). Assume that observations of the simultaneous connections were made at 3-minute intervals, i.e., 20 readings in the hour. On 10 occasions there would have been four simultaneous calls and on 10 occasions five simultaneous calls.

The total number of engaged circuits observed in 20 observations	$= (10 \times 4) + (10 \times 5) = 90$
The average number of simultaneous connections is therefore	$90/20 = 4.5$

which is the traffic flowing in Traffic Units. A similar result is obtained with any number of regular observations.

(b) The total occupied time of the circuits expressed in terms of the period under consideration, i.e., one hour $= (4 \times 1) + (1 \times \frac{1}{2}) = 4.5$ T.U.

(c) The number of calls originated during the period multiplied by the average duration of the calls expressed in terms of the period of observation, i.e., one hour. Assume that there were 4 calls of 1 hour duration and 1 call of $\frac{1}{2}$-hour duration:—

The number of calls originated	$= 4 + 1 = 5$
The average duration of the calls	$= 4\frac{1}{2}/5 = 0.9$ hours
The traffic flowing	$= 5 \times 0.9 = 4.5$ T.U.

A similar result is obtained with any number of calls, making up the same occupancy for each circuit.

For special classes of routes it may be necessary to select a period shorter than one hour for the observations. Take, for example, the case of a group of circuits which provide the "time" service to subscribers. It would be expected that on these circuits very sharp peaks of traffic would be experienced between 11.55 a.m. and 12.5 p.m., 12.55 p.m. and 1.5 p.m., and perhaps 4.55 p.m. and 5.5 p.m. Traffic flowing during these 10-minute periods would probably be many times greater than during the remainder of the hour.

Assume that over the 10-minute period there is an average of 30 simultaneous calls, i.e., 30 T.U. flowing, and during the remaining 50 minutes there is an average of 3 simultaneous calls, i.e., 3 T.U. flowing. The average number of simultaneous calls and therefore the T.U. flowing during the whole hour would be:—

$$30 \times 10/60 + 3 \times 50/60 = 7.5 \text{ T.U.}$$

If the provision of circuits is based on this figure, there would be a serious loss of traffic during the busy 10-minute periods when there is, on an average, 30 simultaneous calls. The circuits would therefore be provided to meet the busy 10-minute peaks, and the number of simultaneous calls would be averaged over the 10-minute busy period to obtain a basis for the number of circuits required.

Grade of Service: Because of the normal fluctuations in the amount of traffic carried by any group of circuits, the average number of simultaneous connections is always below the actual number of circuits which would be required to provide for the maximum number of simultaneous calls. In a typical case the average was 3 simultaneous calls, and the maximum number of calls at any one time was 7. If, however, 6 circuits only were available, then, for a brief period, a call made would have been lost. A typical traffic problem is to decide whether 6 or 7 circuits would be provided in this case. It depends on economics. As the calls are made in pure chance order, it would be possible for every subscriber to call at the same time, but the possibility is so unlikely that it would be uneconomical to provide for such a case. Mathematics would tell what is the chance of more than six calls occurring at the same time, and we could decide whether it is economical to provide for this loss. A train is not run to suit every passenger, a business does not provide a counter hand for every customer; someone must wait if there is a specially heavy demand, and it is a nice question to decide the extent the public will tolerate waiting and yet continue its custom. The telephone system gives a high grade of service when compared with most other trading concerns. As we shall see later, it is designed so that during the busiest hour of the day there will be a loss at any one switching point of not more than 1 call in 500 attempted calls. This is hardly noticeable.

In considering the provision of lines or junctions on any given route, it is only necessary to take into account the busiest period. Obviously, if that is catered for, then at all less busy times calls will be put through with less loss, if any at all.

The Busy Hour: The average over one hour when the incidence of traffic is greatest is selected as being indicative of reasonably stable conditions, and this is called the busy hour. Some consideration needs to be given to the determination of a characteristic hour for our purpose.

From Fig. 1, which shows the day-to-day variation in traffic over a period of a month, we see that the traffic value for the days between Monday and Saturday is fairly stable. The Saturday afternoon and Sunday traffic is a great deal lower than during the other days of the week. Traffic records made between Monday and Friday and also on Saturday morning would therefore be representative of the average daily conditions in the Exchange.

The daily variation in traffic shown in Fig. 2 represents any day between Monday and Friday, and is fairly typical of a City Exchange. There are two traffic peaks during the day, one before noon and a lower one of longer duration during the afternoon. Fluctuations such as these may be expected to occur during any normal week day. Traffic records made during the busiest

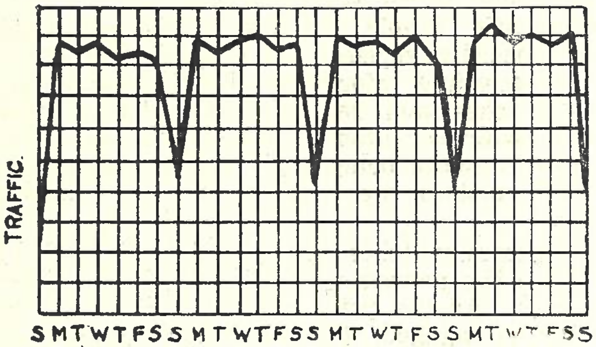


Fig. 1.—Fluctuations in Traffic During the Course of a Month.

successive 60 minutes, which on the curve would be approximately between 9.30 and 10.30 a.m., should indicate the maximum traffic for which equipment needs to be provided, and would be selected as the busy hour. At Christmas and Easter, etc., excessively high peaks might be expected, but as these occur on relatively few days in the year, they are not taken into account for the busy hour. They must be neglected, or receive special treatment.

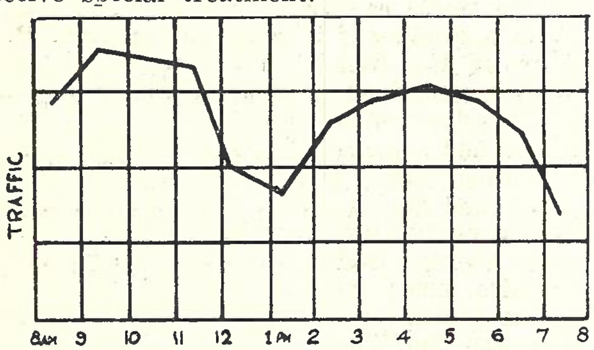


Fig. 2.—Fluctuations in Traffic During the Course of a Week Day.

During the busy hour, the traffic is reasonably constant; this is shown in Fig. 3.

Considering the various traffic routes in an exchange, the busy hour does not occur in the same 60-minute period on all routes in the exchange. In the case of junction traffic in particular, the busy hour occurs at considerably different times, depending on the type of exchange (i.e., city or suburban) at which the far ends of the junctions terminate. Due to this variation, it is necessary to measure the traffic in all groups of trunks at **their** busy hour, and not at the busy hour indicated for the whole exchange. It may be expected from this that some of the intermediate switching stages in the exchange would not show the pronounced peaks in traffic that incoming switches do, and this has been found to be so in practice.

When the traffic flowing over a single large group of circuits is switched to a number of independent smaller groups, the busy hour traffic flowing in the single large group is always less than the sum of the busy hour traffic in the smaller groups which it feeds; the converse also applies. The difference is due to the non-coincidence of traffic peaks, and depends on the number of smaller groups and the average traffic flowing over them. With an average of 10 T.U. or more in each of the smaller groups, the % difference is approximately equal to the number of groups into which the large group is switched.

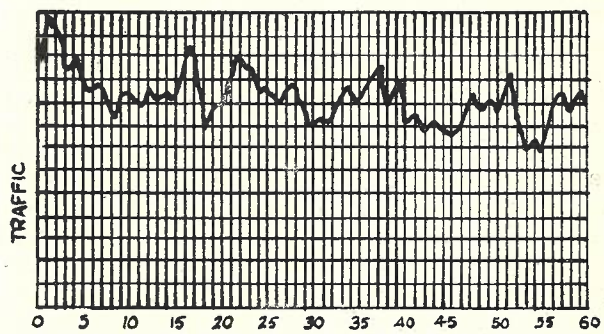


Fig. 3.—Fluctuations in Traffic During the Course of a Busy Hour.

The traffic records are usually made in three consecutive half-hour periods during the busiest $1\frac{1}{2}$ hours of the day. This gives two busy hour readings, with a common half-hour at the end of the first hour and the beginning of the second hour. The average of each of the two-hour periods over three consecutive days is determined, and the highest average is taken as the busy hour traffic.

The following methods of measuring traffic are in common use:—

Pen Recorder Method: As the traffic flowing in the busy hour is equal to the total time during which the circuits are occupied, expressed in hours, the traffic flowing in a group of circuits could be measured by arranging a pen to record on a chart whenever a circuit in the group is in use. This type of recorder indicates the passage of a call by drawing a line on a strip of paper travelling at a known uniform speed past the pens, one of which is provided for each circuit. The length of each of the short lines thus obtained would be a measure of the duration of each of the calls. Therefore, by totalling all these lengths and converting the total to hours, an accurate measure of the traffic flowing in the group of circuits would be obtained.

This method would be very laborious and very costly, however, where large groups of circuits are involved, and is only used where special information is required, e.g., the distribution of calls and the individual holding times.

Manual Traffic Records: In a second method of measurement the traffic is measured by observing when each individual circuit is engaged (for example, a switch "off normal"). At certain fixed intervals during the busy hour, the total number of switches which are engaged in the group under observation is noted. This data gives the total occupied time or the number of simultaneous calls. The accuracy of the results obtained will depend on the frequency of these observations, which is controlled by the size of the group being observed and the staff making the observations. In practice, it is found that observations taken at from 30 seconds to three-minute intervals are satisfactory, more frequent observations being impracticable because of the time taken in counting the engaged switches. If the period between observations is increased above three minutes, the chance of missing a call completely between successive counts becomes too high, and the readings are unreliable.

As an example, the following table shows the records made from 120 readings taken at half-minute intervals. It will be realised that when a switch is recorded as engaged it is assumed it has been engaged for the half-minute interval since the former reading.

5 switches engaged on 12 readings
= 6 minutes' engaged time.
4 switches engaged on 37 readings
= 18.5 minutes' engaged time.
3 switches engaged on 28 readings
= 14 minutes' engaged time.
2 switches engaged on 25 readings
= 12.5 minutes' engaged time.
1 switch engaged on 18 readings
= 9 minutes' engaged time.

120 readings = 60 minutes' engaged time.

From this we obtain the total time during which switches are occupied during the hour:—

$5 \times 6 + 4 \times 18.5 + 3 \times 14 + 2 \times 12.5 + 1 \times 9 = 180$ mins. = 3 hrs.

The traffic equals 3 T.U.

Another method of obtaining the traffic is by calculating the average number of simultaneous calls. There were:—

5 simultaneous connections on 12 occasions
$= 5 \times 12 = 60$ engaged tests.
4 simultaneous connections on 37 occasions
$= 4 \times 37 = 148$ engaged tests.
3 simultaneous connections on 28 occasions
$= 3 \times 28 = 84$ engaged tests.
2 simultaneous connections on 25 occasions
$= 2 \times 25 = 50$ engaged tests.
1 simultaneous connection on 18 occasions
$= 1 \times 18 = 18$ engaged tests.

Therefore the total number of engaged tests .... = 360
And the total number of readings = 120
Therefore the average number of simultaneous connections over all readings .... = 3

Or there was an average of 3 switches engaged simultaneously throughout, which again gives 3 Traffic Units as the traffic flowing.

Automatic Traffic Recorder: The automatic traffic recorder replaces the observers and the person recording information, by uniselector access switches and registers respectively. The access switches automatically search over the group of circuits being read, and record on one or more meters the total number of switches engaged.

The access switches test a special lead brought out from the private wire of each switch in the exchange. As the private is earthed when the switch is engaged, the recorder registers an engaged circuit every time an earth is found by an access uniselector. The access uniselectors are stepped over the indicating leads so that each circuit is tested once every 30 seconds. Faster testing can be arranged if required up to a maximum of one test every 12 seconds.

The access uniselectors are connected automatically in turn to the meters allotted to the groups of switches on which the traffic is being measured. In the smaller exchanges, the whole of the traffic can be read simultaneously at each rank of switches. Meters can also be allotted to record the traffic carried by the individual outlets from a grading if it is desired to prove the efficiency of the design. The number of test cycles is recorded on a separate meter on the traffic recorder control panel.

Suppose 360 engaged tests and 120 test cycles were recorded during a period of one hour, then the total time during which circuits were occupied would be 180 minutes, i.e., 3 hours. Therefore, the average traffic flowing in the group is 3 T.U.; also, since each circuit was tested 120 times, the average number of simultaneous connections was 360/120 = 3 T.U.

Trunking: When the traffic records are completed in an exchange, and details for all groups and between all ranks of switches are available, the information is examined, and representative busy-hour traffic determined for each rank of switches.

These figures show the flow of traffic originated by the subscribers connected to the exchange and the subdivision of the traffic over the various routes to which the subscribers have access. From the results, a critical examination of the methods of trunking in an exchange can be made to ascertain whether an improved service is possible with the plant already installed. A departure from previously efficient arrangements may have been caused, for example, by the successive connection of new and busy subscribers' lines to one part of the exchange equipment instead of distributing them evenly. As the traffic flow from new services cannot be accurately estimated, a periodical review of the dispersion of the originating traffic is necessary.

Secondly, the analysis of the traffic records gives the basic data required to ascertain the number of switches required in each switching stage in the exchange, to ensure that the proportion of calls lost due to the economic aspects of plant provision will be within the allowable limits.

Thirdly, the projection of the basic traffic data by the application of appropriate growth factors is used for the estimated future requirements, so that long-range plans for network development may be formulated.

In considering the trunking of an exchange, that is, the method of connecting the successive ranks of switches, the problem is to take the traffic originated by the subscribers' lines from the apparatus individual to the particular line (the uniselector) to the common apparatus available to all subscribers (the group selector equipment), then through the various switching stages in such a way that the maximum availability of the common equipment is obtained. This, in turn, leads to the condition of highest traffic-handling efficiency.

The means of achieving this result in recently installed exchanges is by the use of subscribers' uniselectors, each switch having access to 23 trunks to the first switching stage, followed by group selectors each having access to 20 outlets on each level, or D.S.R's, having access to 10 outlets on each level, and lastly, to 200-line final selectors, having their bank multiple connected to the subscribers' lines.

The problem of exchange trunking in practice comprises firstly, the application of basic traffic data to Traffic Tables, which indicate the number of switches required to handle a given traffic flow under the conditions obtaining at each switching stage; and secondly, the engineering design factor, in which, when the switch quantities have been determined, the methods of cabling and interconnecting between the various selector bank multiples and the following ranks of switches are planned. The following paragraphs are devoted to these principal factors, the application of the published Traffic Tables and the points to be kept in mind when preparing the details of the outlet gradings from selector levels.

Traffic Capacity Tables and Their Use: The tables in the Engineering Instructions referred to are divided into three main groups, with additional tables for special purposes. They are:—

Table A, for application when there is full availability.

Table B, for limited availability with smoothed traffic.

Table C, for limited availability with pure chance traffic.

Full availability is the condition when each switch has access to every trunk in the group of outlets. The number of trunks satisfying this condition is obviously limited by the number of contacts on a switch level and, if all the traffic can be carried by the 23 trunks from the bank of a uniselector, then at this point there will be full availability and Table A will be applied. If the traffic outgoing from a bimotional switch is being considered, then, in the case of a 20-point level if the total trunks required do not exceed 20, Table A is used. It is not often that these conditions apply, but they are met in R.A.X. or P.A.B.X. units. Apart from the direct application to a particular case, a lot of valuable information is obtained from the figures in the tables. For instance, when the traffic is small, the number of trunks required may be several times the number of traffic units. When the traffic is high, the number of trunks may be very little higher than the number of traffic units. Stated in another way, we arrive at an important axiom that large groups of lines are more efficient than small groups. When there are 100 trunks in a group, the average occupancy of each trunk will be about 75%, representing a flow of 0.75 T.U. per line, but there is very little increase in the average traffic-carrying capacity for additional trunks. For a ten-line group of trunks with a standard grade of service, the traffic averages only about 0.35 T.U. per line, and for a 20-line group about 0.5 T.U. per line. It is important, therefore, to make groups as large as possible up to approximately 100 trunks. The figures quoted assume that the 10, 20 or 100 outlets form a completely independent group.

The cost of switches increases with the number of outlets, and it is a balance between the efficiency of the group and the cost of switches which has led, in practice, to the restriction of switch levels to 10, 20 or 23 contacts. Searching time is a further reason for this restriction. Means have been devised for improving the efficiency of small groups of trunks outgoing from switch levels. The traffic is concentrated by the use of secondary or mixing switches and other means which give some of the advantages of a big group. In some cases the carrying capacity may even be doubled, but it will never exceed the efficiency of the same number of trunks arranged for full availability. Table A will, therefore, give the minimum trunks or switches it is possible to use, and is not applicable where the number of trunks required exceeds the number of contacts in the level of the switch to be used. When full availability conditions apply, the outlets on any level are obtained by a complete multiple of the bank contacts of that level, the trunks being numbered in the order of search, for allocation to the subsequent rank of switches.

Tables B and C are both used for conditions of limited availability, i.e., when the number of trunks required exceeds the number of bank contacts on a particular selector level. This condition occurs frequently as, with group selector switches having 20 outlets per level, most routes need more than 20 trunks. The outlets are then "graded" to provide the required number. Tables B or C are applied to switch computations, according to the form of the traffic carried at the switching stage in question. The terms used are "smoothed traffic" and "pure chance traffic."

As the subscribers are free to originate calls at will, the time of origin of each call depends upon chance, and the variations in the instantaneous traffic flow from the average during the busy hour may be quite appreciable. This is the type of traffic most frequently met, and it is called pure chance traffic. In computing switch quantities from basic traffic data for this class of traffic, Table C is used.

Under some conditions where the concentration of traffic is high and means for the proper mixing of traffic from several sources, such as subscribers' lines and various junction groups are present, or several separate groups of subscribers' lines, a degree of smoothing is obtainable, and Table B is used. This requires slightly fewer trunks for a given traffic flow than does pure chance traffic. Generally, Table B can be applied to find the number of outlets from 1st group selectors only. Even then, specific conditions must obtain. These are:—

(1) The primary trunking should consist of 23-point homing uniselectors with graded outlets, or primary line finders with partial secondary working.

(2) The number of 1st selectors should exceed 70; and

(3) The local and incoming automatic junction selectors combined should total more than 70, and should comprise more than 50% of the total number of first selectors (which include incoming manual junctions, etc.).

If all these conditions do not apply, it is necessary to use Table C. Other tables are used for special purposes, such as the determination of junctions between manual and automatic exchanges.

The thorough mixing of traffic is most important where it originates from several sources. The time at which the busy hour occurs will almost certainly vary in these different sources, and mixing will limit the traffic peaks. This is arranged by allotting incoming junction selectors for each route over shelf positions on all the selector racks. It has been found in practice that, in combining traffic from a number of routes in this manner, the combined busy hour traffic may be as much as 20% below the aggregate of the separate busy hours. This depends upon the number of routes, and the average traffic carried by each route.

Conversely, when a given amount of traffic incoming to a rank of switches from one route divides into a number of different routes from the various bank levels, the busy hour traffic load on each route does not exactly coincide. If the outgoing traffic is measured in separate groups, it will be found that the total traffic so obtained will exceed that measured as incoming to the switches. As an example, the traffic incoming to third group selectors in a main exchange was measured as 175 T.U. Seven levels were in use for trunks to the respective fourth selector groups, and the measured traffic to each group was 34, 36, 36, 30, 30, 16 and 8, a total of 190 T.U. This represents an increment of approximately 8%. From these considerations, it will be seen that an arithmetic check of the traffic incoming to and outgoing from a group of switches, when measured separately on each route involved, need not necessarily balance.

Gradings: It has been mentioned previously that, because of economies, switches with limited outlets are used, and therefore give limited availability. The relative inefficiency of small groups has, however, been greatly improved by various means of combining the trunk outlets, and this has greatly assisted the economies of the limited outlet switch. Although with non-homing switches there are means of combining the outlets to increase the availability, in general these are not as convenient as the means for combining outlets from homing type switches. In practice, the method employed is to "grade" the outlets of homing type switches. This is a system of connecting level multiples together so that a group of switches is given access to individual trunks on the early choices but, in the later choices, shares access to trunks with other groups. It follows that this will increase the load on the trunks connected to the later choices, and increase the overall traffic carrying capacity of the group of trunks.

The following example shows the saving to be achieved by grading. Suppose a group of 10 outlet switches originates 60.5 T.U. Ten trunks serving a group of switches on a full availability basis will carry 3.43 T.U. To carry 60.5 T.U., 18 full availability groups would be required, that is, 180 trunks. If this traffic is carried by a single graded group of trunks, only 138 trunks are required and, by the use of a graded group, the cost of 42 switches can be avoided.

The gradings are divided into grading groups, which are groups of switches having their banks commoned by bank multiple and tie cables. As will be seen later, a grading group is the smallest unit in the formation of a grading.

As an example, take the case of six racks designated A, B, C, D, E and F, each fitted with four shelves of 20 banks, the switches having 10 levels of 20 outlets each on level 1. Assume the traffic flow from this level is 60 T.U. and it is desired to determine the most suitable grading.

From Table C/20 the number of trunks required for the standard grade of service (1/500) is 100. The next step is to decide upon the number of grading groups. The ideal figure is calculated from the formula:—

$g = n \times 2/a$ where g = the number of grading groups.
n = the number of trunks.
and a = the availability.

Substituting, $g = 100 \times 2/20 = 10$.

As each of the grading groups must be served from an equal number of selector banks, a practical difficulty arises in this case because the number of banks (24) is not equally divisible by 10. The next suitable number of groups above 10 is therefore taken, i.e., 12, and this will require the selector banks to be multipled in pairs in order to enable a 12-group grading to be installed. It is now necessary to decide the formation of 12-group grading for 100 trunks.

There is a large number of possible methods of commoning the outlets from the groups to provide for 100 outgoing trunks, but it has been found that the most efficient arrangement is obtained when there is a smooth progression of choices from individuals through partial commons to full commons. The best arrangement of these commons has been tabulated in convenient form in the A.P.O. Telephone Engineering Instructions, Sections TO801 to TO868. For the example being considered, the arrangement is as follows:—

First 4 choices as individuals;
The next 3 choices as pairs;
The next 4 choices as 3's;
The next 3 choices as 4's;
The next 3 choices as 6's;
The next 3 choices as commons.

The actual method of arranging the connections is shown in Fig. 4, which is a typical grading chart as used in 2000 type exchanges. Other features of the chart are discussed later.

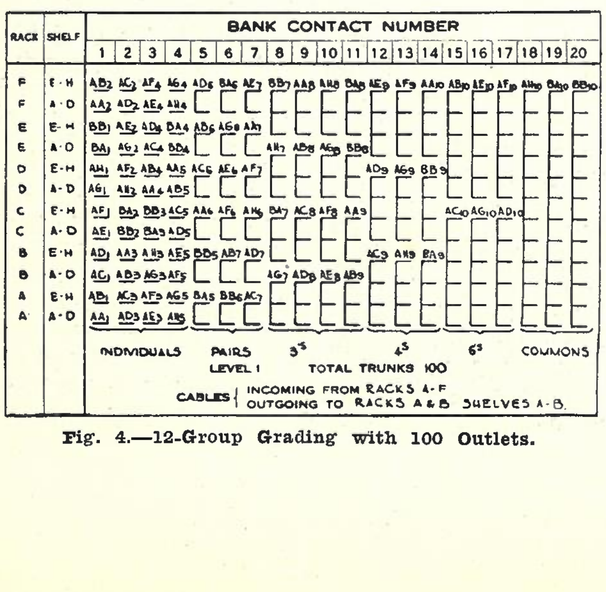


Fig. 4.—12-Group Grading with 100 Outlets.

Gradings With an Odd Number of Groups: It will be noted that, in the tables showing the formation of gradings, no odd group gradings are included, because with these it is usually impossible to obtain a smooth progression from individuals to commons without making the grading unsymmetrical. Unsymmetrical gradings are inefficient and are only used when they cannot be avoided. It should be noted, however, that 15-group gradings are quite satisfactory, because 15 has more factors than other small odd numbers.

Limitations to Size of Gradings: It may appear that there is no limitation to the size of gradings, for it is obvious from the traffic tables that, as the number of trunks outgoing from a grading is increased, so the efficiency of the group of trunks is increased. Theoretically, gradings could be of any size, and we could trunk between ranks of switches by means of single gradings. In practice, however, several factors limit the size of a grading.

Firstly, it has been found from experience that the tracing of calls between ranks of switches becomes difficult if the number of trunks outgoing from a grading exceed the capacity of three racks. This limits the number of trunks to 240 in the case of 2000 type 10/20 group selectors.

Secondly, in pre-2000 type equipment, to reduce the number of tie circuits between trunk boards, the maximum number of trunks from a grading should always be limited to 120, the capacity of half a trunk board.

The third factor limiting the maximum size of a grading is the occurrence of cross-talk between two connections made on adjacent contacts on the same or adjacent levels. The cross-talk is proportional to the number of contacts joined together, and will obviously be greatest on a connection made over a late choice, that is, one of the commons of the grading. To limit the cross-talk, the maximum number of contacts which can be multipled together has been fixed for various types of switches. These are set out in the Telephone Engineering Instructions, Section TO120. Briefly, the limits are:—

Selector banks, 2400 contacts in multiple, but reduced to 1250 when an adjacent level has between 1250 and 2400 contacts in multiple.

Uniselector bank contacts, maximum number of contacts in multiple, 2000.

In practice, it will usually be found that the grading is limited by the call-tracing limitation to a value which gives satisfactory cross-talk characteristics.

Trunk Distributing Frame: The grading is carried out on a trunk distributing frame installed close to the rank of switches from which the traffic originates. For each bank level to be graded, a number of cables each carrying 20 circuits is provided to the T.D.F. Each cable is terminated on a horizontal terminal strip. The number of cables required depends on the number of grading groups determined for the grading. In the example shown in Fig. 4, there are 12 cables from the level under consideration, one for each grading group. The grading is installed by connecting the horizontal strips by vertical wires. The switch jacks for the following rank of switches are cabled to one side of terminal strips mounted vertically on the left-hand side of the T.D.F., viewed from the front. On these strips the switch wiring appears in rack and shelf order, the growth being from the bottom to the top of the frame. The outlets from the grading are connected by means of jumper wires from the horizontal terminal strips to the terminals wired to the switches. At this point the dispersion of the outgoing trunks from the grading over the various shelves of following switches is arranged.

Allocation of Trunks to Selectors or Junctions: Having formed the grading, the next step is to allot the outgoing trunks to selectors in the next rank or to the junctions to another exchange. There are two principal factors to be considered. Firstly, the need to ensure equality of traffic loading on the shelves of switches in the following rank which, in turn, causes equality in the selector bank multiples and grading groups comprising the outlets from that rank. To obtain this result, the individual choices which are heavily loaded are distributed uniformly over the selector racks in the next stage, after which the pairs, 3's, 4's, etc., are treated similarly until all the trunks are allotted.

Secondly, the widest possible dispersion of trunks outgoing from each grading group over the selector shelves of the succeeding rank is necessary to assist in smoothing the effect of peaks of traffic occurring in any particular grading group. Under these conditions, trunks serving consecutive choices in a grading group do not appear on the same shelf in the succeeding rank. Reference to Fig. 4 will indicate the details of the allocation of the 100 trunks to the switches in the next rank, which are shown as being distributed over one and a half racks of selectors designated A, A-H and B, A-B.

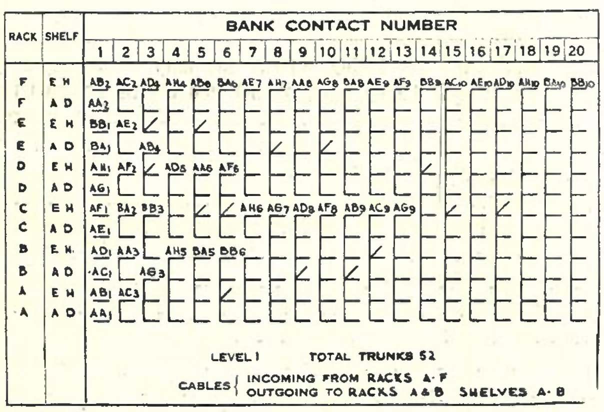


Fig. 5.—12-Group Grading with 52 Outlets Derived from Fig. 4.

In allocating outlets from a grading to junction groups, the same principles apply, even though the selectors are located in another exchange. When the junctions between the exchanges occupy two different cables, they are allotted to the alternative routes in such a way that a proportion of individual choices and commons is carried in each cable to balance the traffic load in case of failure.

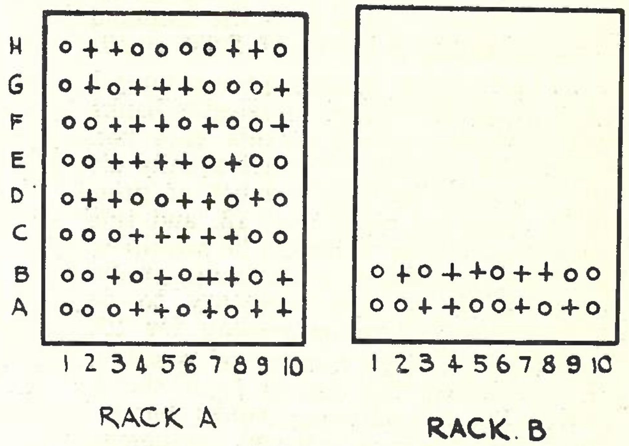


Fig. 6.

O Indicates switches installed vertically based on grading in Fig. 5.

+ Indicates switches to be added subsequently based on grading in Fig. 4.

In designing the grading and the method of trunking between ranks of switches, it will be seen that the allocation of 100 trunks to carry 60.5 T.U., when completed, required the use of 100 selectors distributed over 120 banks on racks A and B in the succeeding rank. The development of an exchange involves alterations and extensions according to the growth of subscribers' lines and traffic. For reasons of economy, as well as to obtain satisfactory design features, it is the practice to instal racks and banks estimated to cover a period of five years' development, and to instal the switches estimated for a period of two years distributed over these racks. This policy permits ease of extension without major alterations between the two and five year dates. The method of design followed is to base the trunking details on the estimated five-year requirements, and then reduce the quantities of trunks and switches to the two-year figure. Taking the example given in Fig. 4 as the five-year capacity, and assuming that the estimated two-year traffic is 30 T.U., the number of trunks would be 52 instead of 100. This number of trunks would need a six-group grading, but the 12 group arrangement is installed initially, and the 52 trunks obtained form the five-year grading reduced from 100 to 52. The result is shown in Fig 5. The allocation of switches on the selector racks of the following rank is shown in Fig. 6.

The method of increasing the trunks from 52 to 100 over the estimated period of three years is a simple matter, the work involving only the alteration to the grading and the fitting of switches in the allotted shelf positions.

There are many theoretical and practical problems relating to Telephone Traffic and the trunking of exchanges which cannot be covered in this article, the purpose of which is to serve only as an introduction to the subject. Much of the detail contained in the A.P.O. Telephone Engineering Instructions has accordingly been omitted from the foregoing. For a text book containing a more complete study, reference may be made to "Traffic and Trunking Principles in Automatic Telephony," by G. S. Berkeley.

THE APPLICATION OF PROCESS WIRING CHARTS TO SWITCHBOARD CONSTRUCTION

S. Mulhall

Wiring diagrams, for the purpose of connecting various pieces of electrical equipment, have been in use ever since telephones and associated apparatus were first produced commercially. Familiarity has made their use comparatively simple for experienced workers; but to the inexperienced, the average wiring diagram destroys at sight that basic confidence so necessary to attack a big wiring job. Routed schematic diagrams with dissociated contacts were a vast improvement in many ways, though still not satisfactory for manufacturing purposes with inexperienced workers.

The need for some improved method of setting out the necessary wiring connections was brought to the fore when the manufacture of the new steel-framed C.B. P.B.X. was being considered. The mass production of this switchboard in the Melbourne Workshops called for much original work, and the wiring arrangement was one of the special sections where this applied. The completed unit was described in Vol. 5, No. 2, of this Journal. A few statistics will be of interest in considering the problem of arranging the wiring methods.

In the main forms in the chassis, $\frac{1}{2}$ mile of twisted pair and $^1/_3$ mile of single wire are used, cut up into 441 pairs and 547 single wires, with 2858 ends to connect to 2450 points. The relay equipment is mounted on jacked-in bases. In a cord circuit relay set catering for 4 cord circuits on one base, there are relay springs, relay winding terminals, U-plug points, condenser and resistor terminals, totalling 350 points, connected by 221 wires. An exchange line relay set (3 circuits) similarly has 174 points connected by 114 wires. There are 4 cord circuit relay sets per board, 5 exchange line relay sets, and a telephonist and miscellaneous relay set. In a complete switchboard there are upwards of 4720 points connected by 2783 individual wires, with 5566 separate wire ends to be stripped for terminations.

Wiring diagrams for the foregoing circuits are formidable, but it was realised that, if they could be broken up, or, to use a more convenient term, "exploded," their complexity would practically disappear. Going further, by presenting the task as a sequence of entirely independent operations, each complete in itself, the monotony and depressing effect of a slowly-moving job, as well as the incidence of errors, could be greatly reduced.

As a result, a system of charts was evolved to cover the requirements of "explosion" and, although a grade of labour with commonsense and manipulative dexterity is essential, these charts markedly reduce the necessity of technical knowledge, previous experience, or an unduly long period of training. The step by step process of building one operation on another makes them particularly suitable for production line purposes in a mass production scheme.

Some of the factors considered in the preparation of these process wiring charts were:

(a) They should be readable from a position which would not hamper the movements of the operator's hands or tools;

(b) They should convey as much information as possible pictorially;

(c) Chart markings should be readily associated with corresponding points or markings on the relay set or forming board;

(d) Confusing cross-overs should be avoided;

(e) Charts should be orderly and symmetrical to enable the operator to keep check on progress and to facilitate overall check;

(f) Each chart should not have so much on it to make it look difficult, but not so little as to increase unduly the number of charts;

(g) This balance of amount depicted should create the effect of a quickly-moving job, and reduce the upsets of absenteeism on a long production line;

(h) The sequence of charts should provide that an early operation does not obstruct or hinder a later one.

This article is concerned with a description of the main features of these charts as applied to wiring of relay sets, and to the building up and termination of switchboard forms, as well as some of the methods of making the job suitable for inexperienced labour.

The first chart for relay sets was concerned with the mounting of relays on the bases. Bases were set up in a cradle, wiring side up, with ample clearance underneath to enable placing and holding the relay in position while it was being secured with fixing screws. The chart Fig. 1 shows the wiring side, presenting a full

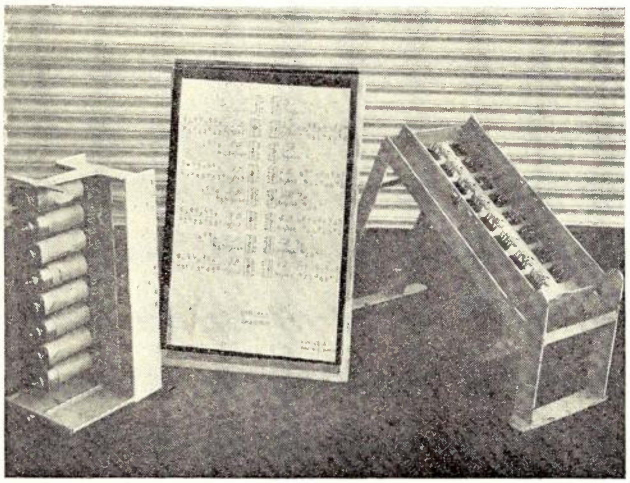


Fig. 1.—Relay Set Assembly.

assembly with all spring tags and coil terminals, each relay being marked with serial and item numbers, and a code number (Contract Item No.), thus providing three means of identification. The order of mounting the relays is important, since the first group must not obstruct later groups. Whether left or right side constitutes the first group depends on the operator being naturally left- or right-handed.

The Assembly Inspection officer, with long experience of testing, used a chart showing the relay side of the base, when checking correct assembly and relay springsets; but relied on a schematic circuit when checking insulation from frame and between windings, and winding continuity and resistance.

At the wiring stages the relay sets were placed, wiring side up, in a cradle adjustable for slope and height to suit the operator. At each

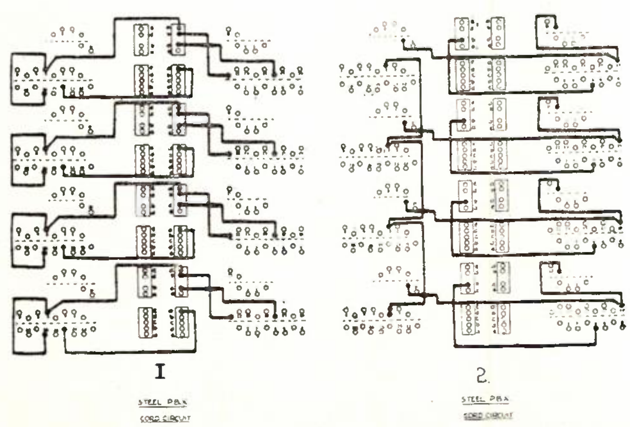


Fig. 2.—Relay Set Wiring Charts, Showing Wires Stitched on Charts.

stage, two charts, fixed back to back in a suitable holder, were used. The charts showed as small circles, in correct relative positions, the full array of spring tags and relay winding terminals as seen on the relay set, but on a slightly larger scale than actual size (see Fig. 2). At a distance, lines are apt to be confusing at crossovers, so wires, in the colour to be used, were stitched on to the charts. The exact route to run the wire was not necessarily shown (to avoid overcrowding on the chart), but preliminary instruction and practice were given in the accepted methods of approach to, and termination on, the various terminals. As each wire was terminated, it was soldered to firmly anchor it and to avoid "dry joints," the only exception to this rule being when another wire was to be terminated on the same tag at a later stage; this was indicated by a red spot against the appropriate terminal on the chart. Four relay

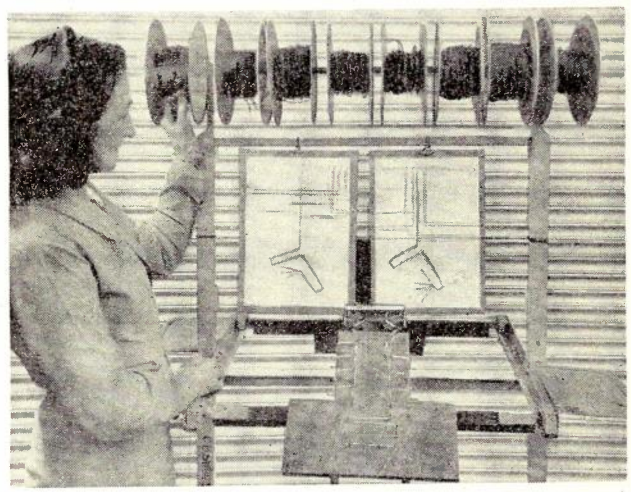


Fig. 3.—Relay Set U-Plug Form Construction.

set wiring charts, two of which are shown in Fig. 2, were planned to have approximately an equal number of terminations on each chart, so that each stage would take the same time to perform and thus enable an even flow of relay sets along the production line.

By this method, all the basic point-to-point wiring on the relay set was done in four stages, the operator at each stage doing two charts. As U-plugs and condenser boxes were not in position, there were no obstructions to hamper the operator. In this type of relay set (3000 type), U-plugs and condenser boxes mask off 75% of the relay coil terminals and spring tags (see Fig. 6) and are difficult to wire. To facilitate movement of the U-plugs to expose wiring and terminals for maintenance purposes, some form of "goose neck" was called for. A "goose neck" is most conveniently provided in a laced form. This idea fitted in very nicely with the planned "explosion" of charts and operations, as a wiring form for U-plug and condenser boxes could be made away from the relay set proper. Forming boards, with a "quick release" bracket to hold the U-plug, were made, and a series of charts designed for the building up of the forms. The general set-up is shown in Fig. 3.

The charts and forming boards were built up on the fact that on the relay base there are two main tracks for the wires, each track, left and right, having nine possible leads off. This may be seen in Fig. 4, which shows the different cord circuit relay set forms. The "goose necks"

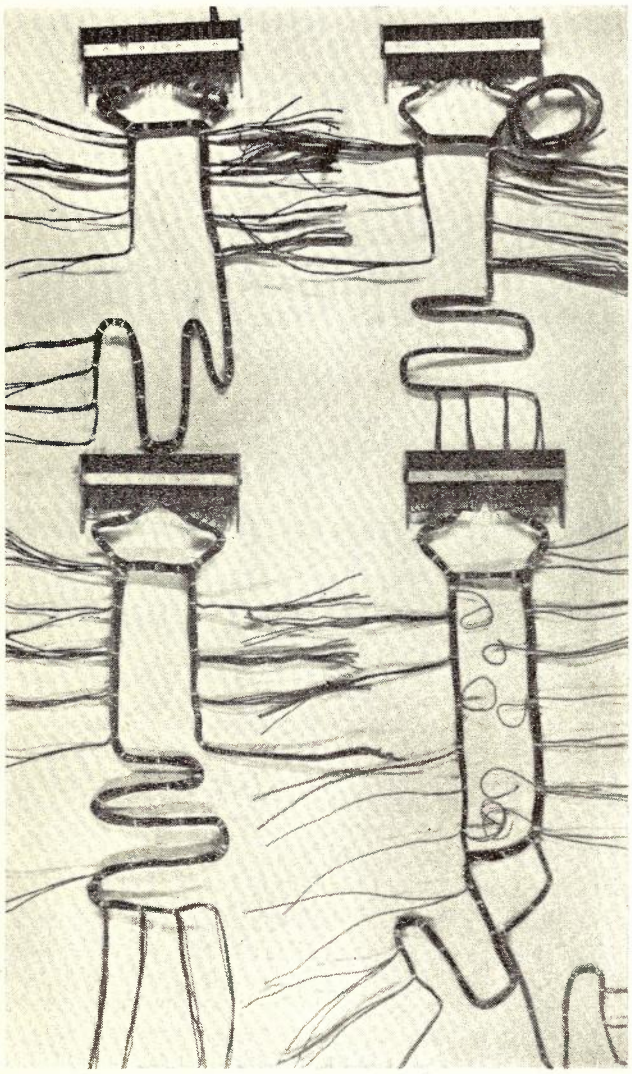


Fig. 4.—Relay Set U-Plug Forms.

to the U-plugs are self-evident, and the wires coiled inwards are leads to relay coil terminals. Only one cross-over between the two legs was permitted, and was designed to be directly under the U-plug to gain full advantage of the "goose neck." Here again the charts did not set out to show the exact wiring tracks to be followed, but only to which "lead off" the wire was to be run and the colour to be used. The conventional numbering of U-plugs was disregarded. Wires were terminated, one at a time, on the U-plug springs, and run around the "goose neck" pegs to the "lead off" designated on the chart, it being obvious that a wire from the left side of plug had to make use of the cross-over to get to a right-hand "lead off." Colour code was applied at the lead off end, but had no significance at the U-plug end. Colour code was used at both ends of wires leading to the condensers. The goose necks serving the condenser boxes are shown as tails at the lower end of completed forms in Fig. 4.

When all wires were laid on the forming board the U-plug terminations were soldered and the form laced up; quick release features on the forming boards enable the form and

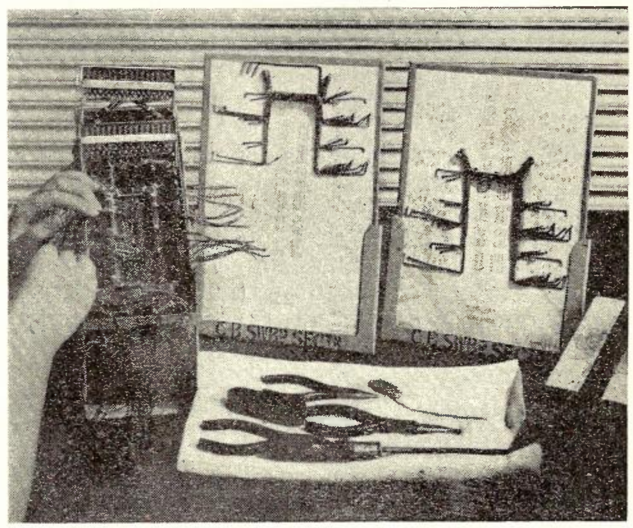


Fig. 5.—Relay Set—Termination of U-Plug Forms.

plug to be lifted off as a completed unit. Two such forms were built for each cord circuit relay set, and one for each exchange line relay set. Taken back to the wiring line as required, they were tied in place and terminated as shown on terminating charts. These charts (Fig. 5) had forms stitched on, with "lead off" wires in correct colours leading to points on which they were to be terminated. Fig. 5 also shows how advantage was taken of "goose necks" to move the U-plug out of position, enabling unobstructed termination of wires. The relative positions of forms on the charts indicate upper and lower termination groups; condenser tails have been cut off on the chart as serving no purpose at this stage.

When all terminating on relay set terminals and springs was finished, the condenser tails were led through holes in condenser boxes and terminated on condensers, which were fitted back into the box which was then attached to the relay base with hinge pin and lock screw. This operation and chart are shown in Fig. 6.

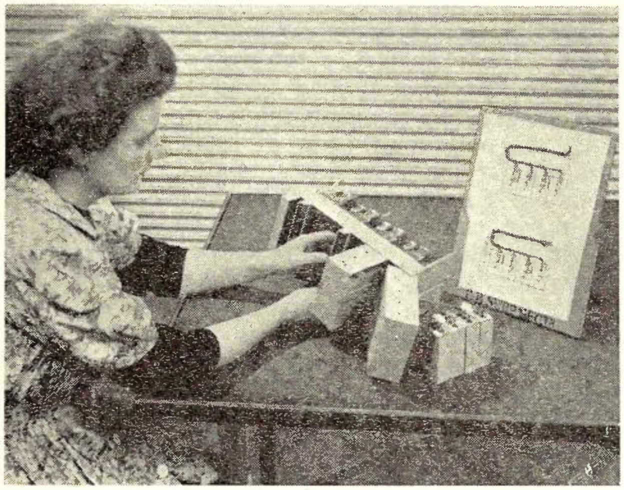


Fig. 6.—Relay Set—Fitting and Terminating on Condensers.

Cord Circuit relay sets were handled in 8 stages, 4 stages basic wiring, 2 stages making forms, upper and lower U-plugs, 1 terminating form and 1 terminating and fitting condensers, using in all 19 charts. Exchange line relay sets were treated in 5 stages and required 12 charts.

The operators readily grasped the import of the charts, and had no trouble in translating charts to relay sets. The system is, to a great extent, self-checking. Errors in termination at early stages show up later when subsequent operators come to terminate a wire on a tag on which there is already a wire.

Forming boards, in one plane, have been in use for a long time. They usually have a series of holes through which the ends of individual wires are pushed to hold them in place until they can be laced together in a form. Often there is some bending to shape to fit into the switchboard, and termination of wires is made on the equipment in situ. Since all of the work is confined to two places, forming board and switchboard, with one operator at each, there is a tendency for the job to drag. This type of forming board is, therefore, not suitable for large-scale production which calls for a continuous wiring process.

The physical characteristics of the steel-framed P.B.X. made it convenient to split the chassis wiring into two separate forms, the few wires common to both forms being junctioned on spare tags on the terminal blocks. The chassis form catered for the jack field, fuse panel terminal block and U-jacks for exchange line relay sets, while the keyboard form took care of keyshelf, supervisory lamps, cord rails and U-jacks for cord circuit relay sets. Forming boards were designed so that all the wires for a particular circuit could be "laid on" as a continuous run around appropriate pegs, until all circuits of that type were completed. For instance, from 18 exchange line jacks to 5 exchange line relay sets required 7 wires per circuit; therefore, 3 pairs and 1 single wire were run simultaneously and without break until all wires were laid on; then cuts in the wire loops were made at appropriate points, leaving 18 separate circuits with 7 wires per circuit.

The forming boards set up on quadruped shafts were free to rotate, to enable the operator to turn the board as the wires were run on, rather than have the operator walk around the board. In Fig. 7, illustrating the

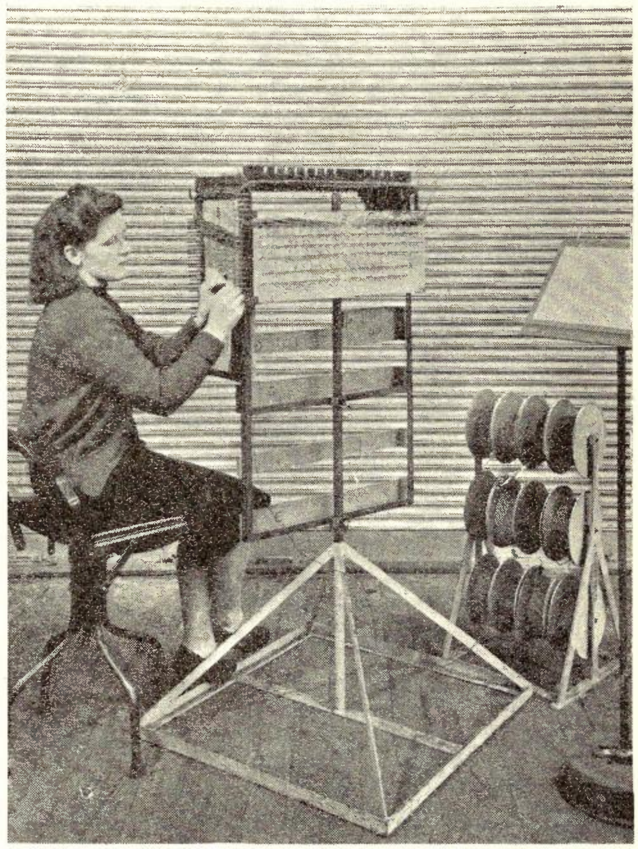


Fig. 7.—Forming Board Chassis Form.

chassis form board and chart set-up, rows of hooks for jack field wiring are seen on panel A; but hooks on the panels OP, C and E are on the reverse side, necessitating a 180° rotation of the forming board when wiring. Similarly, a 90° rotation is made when wiring from panel A to panel B, and nearly 270° when wiring from fuse panel (out of sight at far right) to left side of panel A.

There is an adjustable collar to regulate the height to suit individual operators, and suitable thumb-screws to lock the form board when lacing the completed form. The only use of holes occurs on that part of the forming board corresponding to the fuse panel, and only then, because comparatively few wires of a non-repetitive character are involved. The charts are mounted on a stand, and are arranged in sequence and provided with eyelets so that as each one is finished with, it is folded over to the rear. When chart No. 7 is completed and folded over, the head of the chart holder is rotated through 180°, and Chart No. 8, which was back to back with No. 7, is presented.

The charts for the chassis form were made with either inked or pencil lines to represent a run of one or more wires, charts and forming boards being marked with corresponding letters. The tracks to be followed by the wires were not depicted, and short, practical demonstrations were given to the operator in relating the chart to the form board. Here again the wiring was separated out into a number of stages, each one being shown on a separate chart. The first six charts for the chassis form concerned the power and miscellaneous wiring. Two of these charts, No. 5 and No. 7, are shown in Fig. 8. A is the jack field, OP the telephonist and misc. relay set, F the fuse panel and R the resistance spools. The toothed strip at top of the forming board (Fig. 7) marks the subsidiary forms leading off to resistance spool groups at the top of the switchboard.

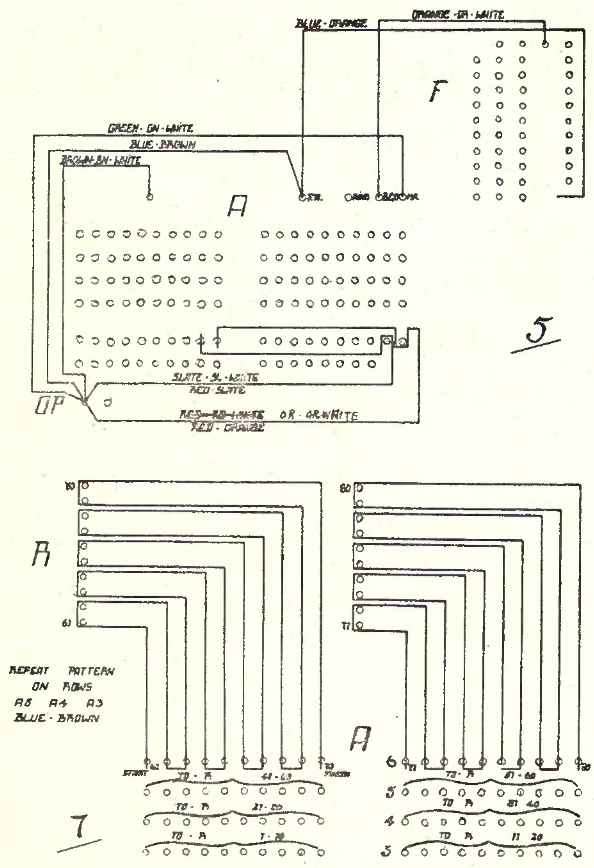


Fig. 8.—Chassis Form Wiring Charts.

Continuous wiring is shown on Chart 7, Fig. 8, from jack field to resistance spools. It will be noted from the charts that the wiring is started in the top row on jackfield, so that successive layers of wire would lie neatly in the main form. When the top row is finished, the wires having been slipped on to hooks on the jack field panel, the hanging loops are folded up to clear the next lower row of hooks for the next run. When the form is completed, a wood strip is screwed on, to lock wires in position, and cuts are made at necessary points, leaving pairs of varying lengths. This difference in length made them individuals, and was the key to the order of termination. Every single wire and one wire of each pair is buzzed to prove correct location. This proving out of every wire is justified on the grounds that the whole success of the charting scheme for terminations depends on correct locating of wires, and is carried out by experienced operators, using the same set of charts as is used for wiring. The form is then laced, and ends stripped for termination before being taken off the forming board.

The problem of terminations on lamp and jack strips and U-jacks, free of the restrictions imposed by the switchboard chassis, was met by the construction of a special jig. Jack field stiles are mounted in place in the switchboard, and the terminating jigs affixed to the stiles. Stiles are then released from the switchboard, but are held in their relative positions by the jigs. The jig and stile assembly is taken out of the switchboard to have the form mounted. The subsidiary jack field forms are folded outwards, then lamp and jack strips are fixed to the stiles, row by row, as terminating proceeds. The general set-up is shown in Fig. 9. All the required jack field terminations are made before the lower section of the jig is attached. An additional pair of legs is also fixed so that the jig will stand up on the bench, presenting the U-jacks at a convenient height for termination. Tails at top of jig are the subsidiary forms to resistance spool groups. Fuse panel wiring is hanging loose at the left side. The terminal block is not terminated at this stage, and only appears in Fig. 9 to show its relative position.

The jig and form already terminated on equipment are lifted bodily into the chassis and the stiles refixed. The form is tied in place, the main weight being taken by a cross member at the top of the chassis. The jig is released, the relay set shelf put in position, and the U-jacks already terminated secured. The fuse panel, terminal block and resistance spools (already mounted on rods and commoned) are fixed in position and terminated. Lines are used on the resistance spool group at top of the relative chart, and bare wires show the commoning of studs on the fuse panel to make + and — busbars, while coloured wires are stitched on the chart to show connections to power switches, fuse, pilot lamps, terminal block and fuse panel. All the items on this chart are terminated after the form is in the chassis, because they can be easily reached from the outside, and, if necessary, three operators can work simultaneously.

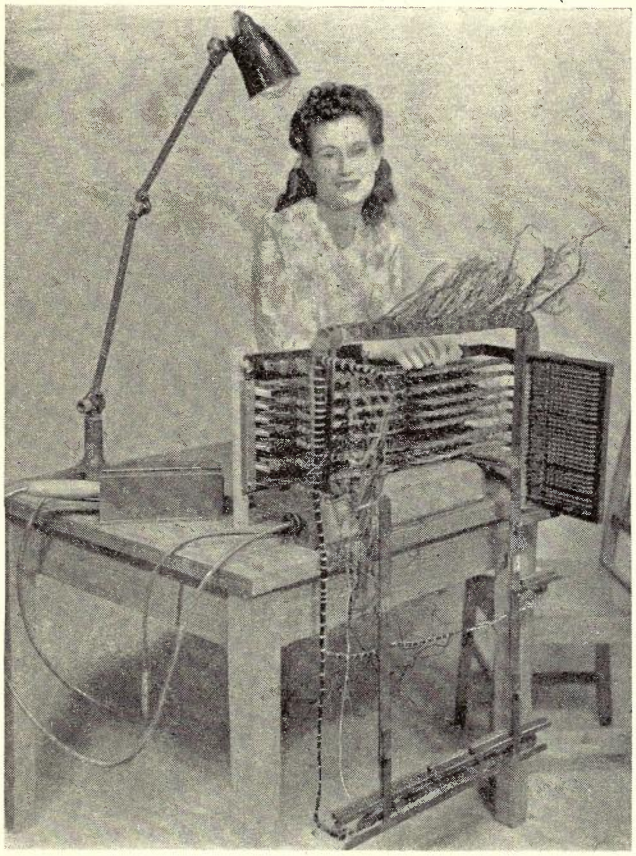


Fig. 9.—Chassis Form Terminating Jig.

For the keyshelf form, another forming board was made up as in Fig 10, and a "build as you go" feature was introduced to facilitate the continuous wiring process. At the right-hand side of the board five rows of teeth are seen. The first row is fixed on a slope to regulate the length of subsidiary forms to the double key plates, and compensate for the diminishing thickness of the main form as the subsidiary forms are led off. There are two three-position keys on each keyplate—key ring front, key speak, key ring rear, key dial and hold. For wiring purposes they were treated as four separate springsets. Hence the use of the other four rows of teeth. One row was fixed, and, after all wires pertaining to it were run, the next strip was slipped into position in the top and bottom channel sections and pushed up against the first, thus locking in all wires. The other strips were fixed in turn. The wires were looped around hooks on a distance rail at the rear, and in conjunction with the toothed sections, made possible the continuous wiring. It was necessary to use a locking strip to hold the wires when cuts were made for testing. When the form was laced, four separate groups of wires were left leading out of each subsidiary keyplate form, thereby reducing the number of colours necessary for terminating coding, as the same colours could be used in each group.

At the U-jack end (out of sight in Fig. 10), where four circuits, distributed over two 32-point U-jacks, had to be catered for, the wires were led around hooks and distance rails in a continuous run. In this form, however, an insulation tubing was fixed in position so that half of the wires were run above and half below a short length of tubing. These tubes were laced into the form, and, by means of a long screw, provided an easy method of securing the forms to relay set shelves.

The general chart set-up is also shown in Fig. 10, and, because two charts are on view at once, a window was cut in the sloping desk, and a disc placed at rear. Figures 1 to 21 on the disc made a ready indicator for the operator to mark the chart in use. The charts are provided with eyelets to run on the wire loops, in much the same way as the leaves of a book.

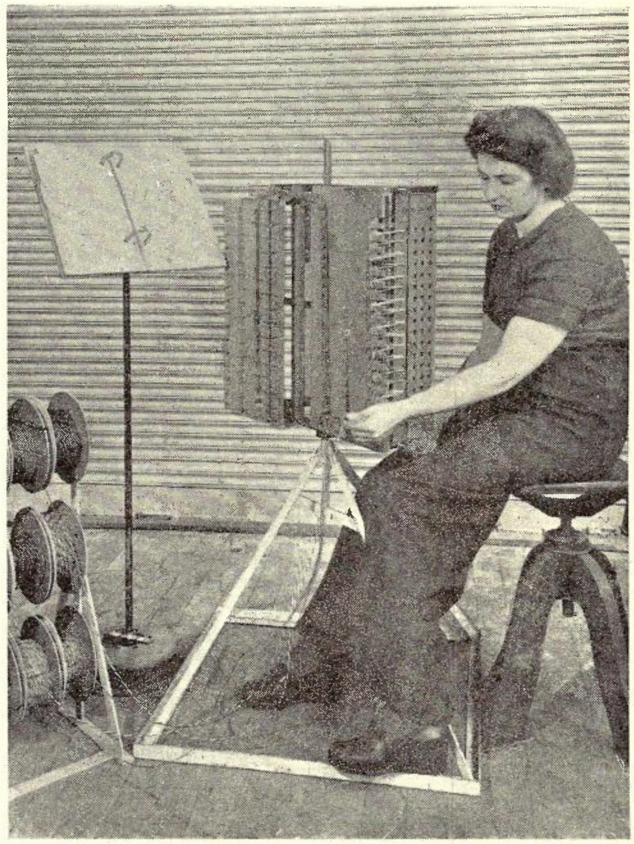


Fig. 10.—Keyshelf Form Forming Board.

In the wiring charts for the keyshelf forming board, the same patterns are frequently repeated, and it is obvious that, if the designation of the strip on the chart could be changed, one chart could be used three or more times. This idea was seized upon, and a novel twist given to a very old idea. The patterns were drawn on charts in which suitable windows had been cut. Two charts were secured back to back, with a rotating disc between them. By rotating the disc, the designations opposite the windows changed in unison. One window gave the chart or sequence number, another gave the colours of wires to be run, and the third window gave the designation of the strip to which wires were to be run.

The keyshelf form was laced and stripped on the forming board. The locking strips were released, and the form transferred to a jig (Fig.

Fig. 11.—Keyshelf Form Terminating Jig.

11), on which 32-point U-jacks had already been mounted. The keyshelf end of the form was folded over to the left to allow the operator to work in comfort when terminating the U-jacks. The appropriate chart shows actual wires, and marks their terminations.

Cord rails were added one at a time, and terminated to the appropriate chart. The keyshelf was placed in the jig and held by thumbscrews. The form was secured by plastic tubing covered steel saddles and clips. The key springs were terminated row by row and not key by key. For instance, the wire for the bottom right-hand key spring would be picked out, terminated, and soldered on all keys before the wires for the next row of springs would be terminated.

The fully terminated keyshelf unit was released from the jig, turned right side up, and the U-jacks and cord rails "handled" into the chassis from the front. Cord rails were fixed in position, the U-jacks screwed down, and the form secured to the shelf by screws through insulation tubes already laced into the form.

The wiring of the switchboard was completed by running the coupling and ring common feeds to the terminal block to junction with wires in the chassis form, inserting lamps, lamp caps, designations, etc., jacking in relay sets, and applying the usual overall insulation and working tests.

Throughout the job, the only use for a buzzer was in closely checking the main form before lacing, and although frequent checking at intermediate stages had been planned, the operators absorbed the relation of charts to relay sets, forming boards and terminations so quickly and thoroughly that the checks were abandoned very soon after the job commenced. The wiring errors occurred mainly in the relay set section when terminating the U-plug form; but over a group of 480 relay sets, they did not exceed 0.4% of wires terminated. Most of the faults in relay sets were caused by blobs and splashes of solder and straying, clipped-off ends of wire. Frequently, in pushing aside spring tags to terminate other wires, tags were left contacting their neighbours and were not picked up until

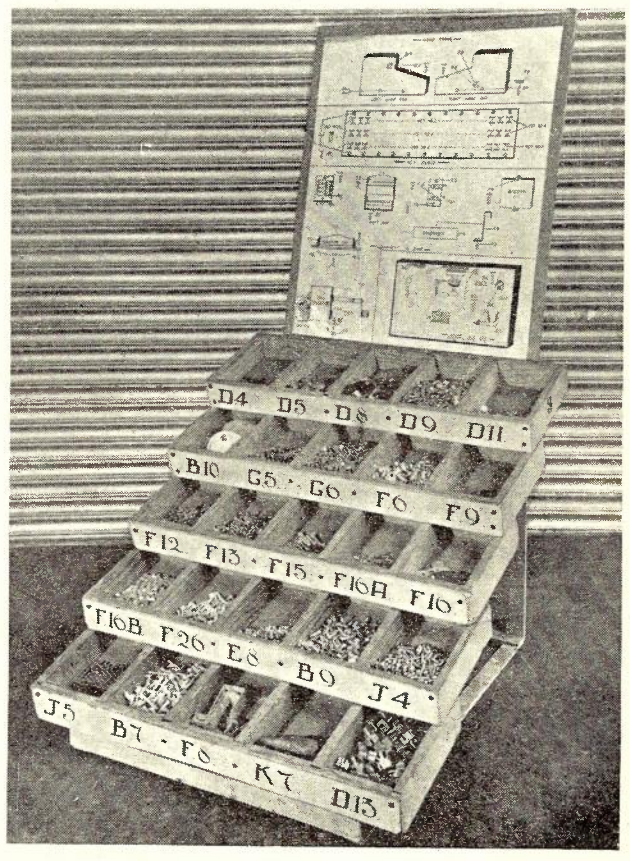


Fig. 12.—Chart and Bins for Assembly.

put on the test stand and checked for working on minimum permissible voltage (37 V.). Dry joints in soldering occurred mainly on relay coil terminals.

Similar charts have been applied to assembly work as shown in Fig. 12, in which the items have been drawn on the chart (a pictorial representation), together with the item code number for screws, nuts, etc. Other charts (not illustrated) have been constructed, with the screws, nuts and other small items stitched on to the chart. Either system serves the purpose, but the actual sample is preferable because the operator can, by comparison, readily pick out wrong screws, etc., which may have fallen into the bins. The bins are a necessary accompaniment of the chart.

The system of process wiring charts has been developed beyond the experimental stage, having been applied to four comparatively large jobs with complete success. No doubt further improvements will be made. Care and forethought are required in planning them to suit the job, and the time occupied in making them up is amply repaid by the results. Once the wire runs are set out or terminations plotted on paper, colour code clashes are made obvious, and rectified before a wire is run. The aid of a buzzer for identification purposes can almost be eliminated from termination operations. Results are to be judged not only by the fact that a few experienced "key men" can control and direct the efforts of many with less experience, but also that the output of experienced workers can be considerably increased.

THE STORY OF THE OVERLAND TELEGRAPH LINE

A. R. Cameron

PART II.

Appointment of Mr. Patterson

In a letter from John Carr, Commissioner, to R. C. Patterson, Esq., Assistant Engineer and Resident Engineer of Railways, Mr. Patterson was appointed in charge of a party about to proceed to the Northern Territory for the purpose of constructing that portion of the Telegraph intended to be erected between the north end of Section E, latitude 19½°, and the point where the Darwent and Dalwood party ceased operations. The terms of payment were that he should receive a lump sum of £300 in addition to his ordinary salary and also have the opportunity of earning one or other of the following bonuses. If communication was established by wire between the north end of Section E and Port Darwin by 31st December, 1871, £1500; by the 15th January, 1872, £1000; 1st February, 1872, £600; and 1st March, 1872, £300.

It has been stated that rumours of the bonuses to be paid to Mr. Patterson were current at the time, and it was not uncommon to hear a workman shout to his mate "Hurry up, Jack! If this job isn't finished in '72, Patterson's bonus will look pretty blue."

Mr. Patterson left Melbourne by the S.S. "Omeo" in August, 1871, accompanied by a fleet of vessels (the "Himalaya," "Golden Fleece," "Laju" and "Antipodes"), taking 170 horses and 500 bullocks, together with plant and stores.

Arrival at Darwin: In his initial report after landing at Darwin, Mr. Patterson, under date 18th September, 1871, reported having despatched Mr. Burton with the advance construction party for Section No. 4 from Southport on Friday, 8th September. Burton was accompanied by Mr. Stephen King, jnr., who was to keep in advance to select the route to be followed by the line of telegraph, and effect a junction with the central section. Mr. Patterson arranged for Mr. King to meet Captain Sweet with the "Gulnare" at the head of the navigation of the Roper River, and load up with rations for the advanced section. Mr. Burton, in anticipation of the Roper being selected as the main depot, had sent all teams on to the Katherine. In the absence of these teams the loading was spread over the teams arriving with Mr. Patterson.

Many of the bullocks landed at Darwin by the "Omeo" were in weak condition. Wire and stores were sent to Southport by the "Gulnare" in order to lessen the load of the teams. Stores by the "Laju" when it arrived were also sent around to Southport by the "Gulnare." The "Antipodes" arrived from Newcastle on the 6th September with only half a day's water supply left. It appears that the tanks were not properly filled and some were quite empty. Many of the bullocks died after unloading. The condition of the stock delayed the despatch of the construction party to No. 3 Section. This delay caused a corresponding loss of time in starting those for sections Nos. 2 and 1.

On September 13th the "Golden Fleece" and "Himalaya" arrived. Great difficulty was experienced in landing stock from the vessels—with the exception of the loan of some boats, no assistance from the ships was rendered. The crew of the "Himalaya" mutinied the morning after the arrival, taking with them one of the boats. The other boat with the crew from the ship was occupied for some hours in looking after the deserters. Much valuable time was lost. On the 16th September all the water in the wells in the neighborhood of Palmerston entirely failed and the stock had to be watered nine miles away.

Patterson goes on to report:—

"It is a matter of great regret to me that I am not in a position to report very favorably of my prospects; I have been here 25 days, and have only been able to start one of the four working parties owing to the late despatch of the vessels from Sydney and Newcastle . . . . I have been paralysed by the late arrival of the stock, owing to circumstances over which I have had no control.

"I have only been able to take a few tons of coal out of the 'Antipodes.' As her lay days expire today I have been compelled to sell the remainder of the coal to the Captain.

"In conclusion, I would draw your attention to the fact that the average length of each of the four sections into which I have divided the work is 110 miles, exclusive of the wiring yet to be done upon the portion already poled, and that taking the most hopeful view of my position and assuming that I shall be able to start all four sections from Southport, I shall then have from three to five weeks of this year left by the time the different parties arrive at the beginning of their respective lengths, or in other words, in order to establish communication by the end of the year I shall have to clear the line and erect the wire at the rate of from 15 to 24 miles per day."

Writing from Palmerston on the 24th October, 1871, Mr. Patterson reported the arrival of the "Laju" (the last of the chartered vessels) on the 21st September. He also reported continued mortality amongst the bullocks, notwithstanding the fact that they had been placed on good feed and water.

He mentioned Messrs. Bedford, Hack, Geo. Bayfield, Giles and Dean as being all men of great experience with stock, and being in charge. Five hundred bullocks were shipped for Darwin, 80 from Victoria and 420 from New South Wales. Out of this number, 110 died, 21 were too weak to travel or be driven, 13 were lost, making a total of 144 bullocks lost to the expedition, or 29% of the number shipped.

Deaths amongst horses amounted to 10%. A large number of horses was very light and quite unfit for the work. Messrs. Bayfield and Hack were engaged for three weeks in breaking a number of the horses into harness. Some were very wild and could not be handled save by roping and throwing them, others were confirmed jibs, and altogether they were a source of great trouble and delay.

Disposition of Northern Parties

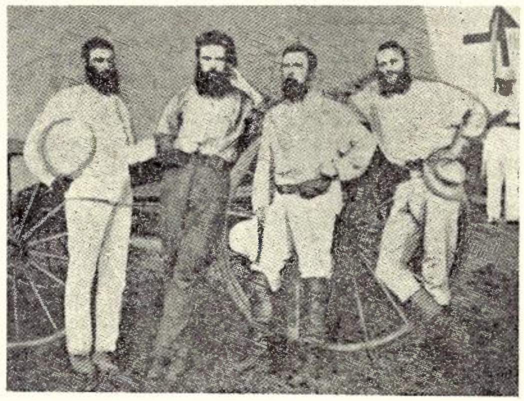
Parties were despatched as follow: Advance Construction Party for Southern Section No. 4, Southport, 8th September (Mr. Burton); the Construction Party for third Section, under Mr. McLachlan (Senior Surveyor of the Northern Territory staff), Southport, 30th September; the Construction Party for No. 2 Section, under Mr. Rutt, Southport, 7th October.

No. 1 Section was left in abeyance owing to the want of transport power, and Mr. Patterson decided to push on with the three most southerly sections and complete No. 1 when sufficient teams were released from the other sections.

On the 4th October, Burton having arrived at the Katherine, Mr. Patterson received the following telegram from him:—

"On the journey one bullock dray was left at Mt. Carr, being broken down and useless; nearly the whole of the new plant has required repairing repeatedly, including the breaking of two axles and one wheel, which rendered the waggon useless; also one waggon hind wheels and axle, one hind wheel and one front wheel of bullock waggon and three poles broken, nine pairs of wheels so bad compelled to cut and shut tyres, twelve bullocks unfit for work, three dead, three horses dead and 25% bullocks knocked up."

Burton picked up further rations and waggons at the Katherine, but after travelling 160 miles at the rate of seven miles per day, he had little chance of reaching the beginning of his section before the end of the year, at which time his rations would have been consumed. This determined Patterson to reluctantly abandon the Southern Section, No. 4 instead of Section No. 1, and Burton was started on Section No. 3.



Principals in the Construction of the Line:
Messrs. A. G. Little, R. C. Patterson, C. Todd, A. J. Mitchell.

In order to endeavour to get communication through the first three sections soon after the end of the year and bridge the gap (Section 4) by horse express, Burton left Katherine on October 5 with his advance party trying for water. They sank 55 ft. in two different places without success. In the meantime the "Gulnare" was despatched to the Roper with full cargo of rations and material.

Stranding of "Gulnare"

On the 9th October the Chief Officer of the "Gulnare" returned to Palmerston with the information that the schooner had struck and stranded on a reef off the west end of North Vernon Island. Captain Sweet wrote at the same time asking for the "Bengal" to be sent to his assistance. The "Bengal" was sent by the Government Resident.

Burton sent Surveyor Packard with a party of men to the head of the navigation of the Roper to meet the schooner, and they were provisioned to the 2nd November only. As the "Gulnare" was stranded, Patterson got in touch with Burton with regard to sending a man after

Packard. Burton advised that out of the three men with him, two were ill, and there was no horse available. Patterson then telegraphed direct to Mr. Brock, the only man who could go, representing it as a matter upon the issue of which were dependent the lives of Mr. Packard's party. In a reply, Brock consented to go.

Brock started on foot and alone, to traverse 25 miles of heavy sand, having to carry his rations, arms and water, and travel until he caught the teams. In the meantime Burton reported:—

"Great difficulty and suffering in crossing the 25 miles from the Katherine to the King. Nothing for the cattle to eat but dried porcupine grasses. This they would not touch."

Burton was greatly concerned in regard to the want of stock to carry him through. Nearly all the horses and bullocks were knocked up owing to the difficulty in getting good feed and water. The carting of the water up to the present time since leaving the Katherine had equalled that of the line material.

Alteration in Plan of Operations

Patterson goes on to report:—

"I cannot conceal the fact that I now entertain the very gravest apprehensions as to Mr. Burton's success in reaching the starting point of his work with anything like the amount of line material he should have. He has already been compelled to drop over 30 miles of wire. I am not justified in anticipating any better fortune for the parties following Mr. Burton. This tract of desert sand, without either water or grass, has to be crossed by all the teams, and I must expect similar losses with every party. Under the circumstances, I thought it advisable to stop Mr. Burton at the beginning of Section 2 and let him start his work there."

He further states:—

"Could I ensure the wiring being temporarily suspended over three sections before the end of January, 1872, I would have adhered to the original idea, as the gap would easily have been bridged by horse express; but now, as I was compelled to increase the gap to a great length, probably 240 miles, the horse express service would have involved the employment of several relays of men and horses and the establishment of several post stations, to all of which I should have had to cart rations. Considering the small party and rations I should have at the end of the farthest section and the limited transport power at my disposal, which was already taxed beyond its strength, and the fact that the express service would have been established in the middle of the wet season, when travelling would have been very uncertain, I came to the conclusion that I should be best serving the interests of the Government by constructing the line in a substantial manner at once, thus avoiding increased cost both of labour and material which would have been incurred by going over the line the second time to strengthen and complete it after it had been open for traffic.

"I was strengthened in this conclusion by the knowledge that the object which was to have been gained by, in the first instance, simply suspending the wire 'on trees on or near the direct line wherever I could, and any other places, planting only 10 poles to the mile' (vide instructions) was now unattainable by any effort, and that by adopting this course I should have been simply adding largely to the cost of the work and delaying its final completion without obtaining any compensating advantage."

Chartering of "Bengal"

The "Bengal" rescued the "Gulnare" and returned to Darwin. She was then chartered to take the place of the "Gulnare" and to proceed to the head of the navigation of the Roper River. The charter was at the rate of £400 per month. The "Bengal" took the cutter "Larakeeyah" aboard to be used between Normanton and the Roper.

Difficulties of Third Section Party

On the 20th October Patterson received a telegram from the Katherine River announcing the arrival there of Mr. McLachlan. Nothing could be more discouraging than this report, as the following extract from the telegram will show:—

"I arrived here today, having left my horse-drays twenty-six miles back camped on the Stow—the horses spelling until they are able to proceed. Nearly all my horses knocked up . . . . I have left one horse behind at the Duffield, knocked up, and I am afraid I shall soon have to leave a good many more. With regard to the bullocks, six have died and five left behind knocked up. I have left one bullock-dray behind and divided the wire amongst the other teams. The wheels of all the new drays are coming to pieces; I shall, therefore, have to remain here several days to make repairs . . . . Under present circumstances, I should only mislead you if I said I expected to reach my section with all my loading."

This confirmed Mr. Patterson's resolution to start Burton on the second section and abandon the two southern sections, but as all endeavours to get information of this to Mr. Burton failed, the No. 3 section was proceeded with.

Mr. Patterson points out that success was never possible with Port Darwin as the base of operations, but had the Roper been made the main base, in all probability he would have been able to complete the line before the end of the year. He states that the performance of stock in South Australia in conveying loading for the interior sections was no criterion of the capabilities of stock brought around to Darwin by sea, with passages varying from 21 to 31 days and with but a limited supply of water, which supply was in two of the ships exhausted before their arrival in port. The bullocks conveying loading from Port Augusta to the central sections had the advantage of making a fair start, with such an abundance of feed and water that they, in many instances, arrived at their destinations in better condition than when they started. At Darwin, however, stock arrived after a trying passage through the tropics so enfeebled that they died by the score after they were landed.

Every chance was given to the stock to recoup their strength and 90% of those that died were never yoked. Nevertheless, the horses were landed in admirable condition, but many of them were extremely light and others confirmed jibs, and nearly 20% were so unmanageable that they had to be broken in to harness.

Patterson's Request for Reinforcements

Writing from Palmerston on the 25th October, 1871, Mr. Patterson reported that in order to complete the line before the end of 1872 he would require at the head of the navigation of the Roper River either 30 teams of bullocks or horses, counting 10 bullocks or five horses to the team. Without these reinforcements it would, in the event of a long wet season, be necessary to recall the construction parties to the Roper.

On the 26th October, 1871, Mr. Patterson was concerned regarding the safety of Mr. Burton's party, travelling to Section 3, and he therefore determined to send an express message to arrest his progress. Mr. McLachlan was despatched.

On the 31st October, writing from Southport, Mr. Patterson reported leaving Darwin on the 30th October. He urged the necessity for sending instant reinforcements of stocks and plant to the Roper. He intimated that he would not withdraw the Construction Parties to the Roper unless absolutely necessary. He required sufficient staples for lightning conductors to do 400 miles of line, and also binding wire and soldering fluid sufficient for 150 miles; also requested a fresh supply of clothing, boots, rope, mosquito nets and medical requirements, powder and shot, wines and spirits for medical purposes.

Arrival of "Investigator" at Port Darwin

On the 3rd November the "Investigator," with Capt. Halpin, also Mr. Little, the stationmaster, arrived at Palmerston. Patterson therefore returned to Darwin to investigate the charter of the "Investigator." However, he did not charter her, as the cost to send her to Normanton would have been £4000, or to Adelaide £8000, and Mr. Patterson considered that the Government would not have upheld him in this expenditure.

Mr. Patterson then set out on horse-back to catch the express waggon, and reported that there would be no news from him for some months. He pointed out that he was satisfied that he had fulfilled his duties throughout, and done the best that was possible under the circumstances for the interests of South Australia. Should the Government think otherwise, he would only be happy to retire from a post from which no apparent honor could be gained and in which he had already suffered so much anxiety and care that nothing in the future could repay him for it.

Mr. Little's Report Re Completion of Cable at Darwin

Mr. Little, writing from Gilberton on the 15th December, reported the successful completion of the cable on the 20th November, and the receipt of a telegram from Patterson, at Katherine, to the effect that Burton was detained 10 miles north of the Roper for want of water. King had made repeated trips south and south-east searching for it, but without success. Water was only obtainable by sinking, and therefore it had been determined to follow the most direct route for the line and sink wells. At this time the men were working in shifts night and day.

McLachlan with the second party was at Katherine having much trouble with jibbing horses. Packard's party, attempting to reach Roper Landing to meet the "Bengal," was attacked by natives three times and driven back. Two horses were speared. Any accident delaying the arrival of the "Bengal" would be disastrous. John Bowman, bullock driver, of Newcastle, died from sunstroke on the 4th November.

Difficulties Retarding Construction of Line by Burton's Party

Reporting from Birdum Creek, December 8, 1871, Mr. Patterson states:—

"Advanced construction party, under Burton, stuck up at 300 miles from Port Darwin, unable to proceed from want of water. Repeated explorations to the south-east, east by south, and south-west have been made for water without success. Two wells have been sunk for water at twenty miles apart; water obtained in one at thirty-five feet and in other at sixty-five. Other wells have been sunk further south, without slightest success. One was sunk at sixty feet and then abandoned on account of hard nature of the rock; and, at twenty miles from well No. 2 repeated attempts have been made to get water by sinking, without success—eighteen feet hard sinking, silicious sandstone struck; this has been penetrated through for six feet, and the shaft being then abandoned. The whole of Burton's men are engaged in sinking wells—working at shafts night and day, and rapidly getting knocked up. McLachlan reached well No. 3 two days since, and has commenced construction of line there. Rutt would start poling from the King about a week since. Should Burton be another week without success in getting water he will start poling line here and do what he can until rations come down, when he will push through to the Daly and Newcastle Waters. Ross's route has been taken for the telegraph. Birdum Creek, the supposed Strangways River of Ross, which contained abundant supply of water when Ross came through in May, has been travelled for seventy miles and found to be thoroughly dry. The country is, otherwise, favorable for construction of telegraphs and infinitely better than the Strangways, and a saving of over forty miles is effected by adopting Birdum Creek route. As soon as Burton can get water and can get clear of flats, with a fair start, he will proceed poling the line at ten poles to the mile, and only using such trees as will be of permanent service to the line. I have been induced to make this change owing to accounts Mr. Burt brought me from southern sections, to the effect that Woods would pole north of Section "E" to meeting, at the rate of ten poles to the mile. I am now on my way back to McLachlan and Rutt's section, after which I will proceed to Roper Landing, where expect to arrive by 10th January."

Progress of Construction Party "E"

In the meantime the position in regard to the progress being made by Mr. Harvey on the extension of Section "E" northward is disclosed in the following report from Mr. Harvey, written from Attack Creek, 1st January, 1872:—

"Knuckey, Mills and Bagot arrived on Section "E" three weeks ago. They started north on 19th December to explore route. Knuckey goes on to Burton's party on Daly Waters; Mills returned here 30th instant and reports that he examined both sides of Ashburton Range, thinks west side best for telegraph; Burt holds same opinion. Knuckey sent on here 17 men from southern sections; 11 have arrived, remainder daily expected. To avoid risk of short rations I sent Mr. Foster to Adelaide in charge of a party of five, with bullocks. dray and horse. Burt, Ewart and blackfellow Tommy returned here on 24th instant; they met Patterson, Burton, MacLachlan, King and others. From this creek northwards the natives are numerous and apt to molest small parties. On 30th August, Jno. Millner, who was assisting his brother to take stock to Port Darwin, was murdered by a native; murderer escaped after being shot in the breast. I use every precaution to avoid collision. Main camp arrived here 15th instant from Tennant's Creek. Much better sites for station here. Line is surveyed up to camp; about 16 miles of Section "F" are poled and cleared; about 12 miles poles are cut and being carted. Much rain has fallen lately, making cartage heavy. Some more rain may entirely stop cartage. Burt reports that he had rain most of the way from Daly Waters; as he came south rains became less frequent."

Patterson's Arrival at the Roper

The following extracts from Mr. Patterson's report from Maria Island, off Roper River, on 26th January, 1872, deal with the position on the northern section during the period, 3rd November, 1871, to 26th January, 1872:—

"I left Darwin for the interior on the 30th November, after making arrangements with Mr. Little, stationmaster, to superintend the loading of the 'Bengal' for the Roper, and transference of the crew of the 'Gulnare' to the service of the expedition.

"I picked up supplementary ration teams in charge of Hack on the 6th November. On the 7th arrived at Depot No. 1 of the late contractors. Broke shackle and instructed Field Operator to get in touch with Darwin, but owing to the atmospheric condition, 45 hours elapsed before I could get a simple message through to Port Darwin. It was disconcerting to learn that the 'Bengal' was not expected to sail for the Roper before the 15th or 17th November, and also that the flour in the 'Gulnare' was so much damaged as to be unfit for use and so was the wire. Instructed Little to buy 10 tons of flour from the 'Bengal.'

"Arrived at No. 2 Depot of late contractors on 10th November, 126 miles from Port Darwin. Had to wait 24 hours to get a message through, the Field Operator stating the cause was due to the disturbed state of the atmosphere. I spoke to Katherine, but a little later signals failed from both stations.

"The men of the expedition are inadequately armed, and although I recommended arming every second man, the Chief Secretary decided to arm every fourth man. This caused grave dissatisfaction amongst the men.

"On the 16th November I overtook Rutt's teams (Section 1) camped on the Edith, 175 miles from Port Darwin. They had been spelling there since 11th November owing to condition of teams.

"Arrived at Katherine the same evening (202 miles from Darwin). Spoke to Little, who stated the 'Bengal' would not be ready for sea for some days. Mr. McLachlan's party (Section 2) was a short distance in advance of the Katherine, stuck in heavy sand and unable to get on.

"Burton (Section 3) reported that he was in difficulties south of the Elsey for want of water. Burton struck water in Birdum Creek, and at that point at which he commenced (280 miles from Darwin) he had obtained water at 35 feet.

"Remained at Katherine until the departure of the 'Bengal,' which sailed on the 21st November; thus 35 days were lost through the stranding of the 'Gulnare.'

"On the 25th November I overtook McLachlan's teams at Gum Flat Billabongs, 42 miles from the Katherine, 244 miles from Port Darwin, and instructed McLachlan to start the erection of the line at Well No. 1, 280 miles from Darwin.

"Overtook Burton on the 2nd December, and found his party engaged in sinking Well No. 3, 40 miles south of Well No. 2. The men were working night and day, and rapidly getting knocked up with such severe work in the hot climate. Well No. 2 was abandoned at the depth of 60 feet. The second well proved more successful, a small supply being obtained at a depth of 65 feet. During the sinking of No. 2 well water had to be carted 20 miles. Four attempts made to get water at No. 3 Well without success.

"Before I left Mr. Burton's camp, explorations for water had been made for 90 miles south of No. 1 Well and up to within five miles of Daly Waters. Judging from the absence of water over such an extent of country it was supposed that the Daly Waters had dried up, and Mr. King therefore felt that it would be running too great a risk to push on to Daly Waters in case on his arrival there he should not find water and so be unable to get back. On Mr. King's return with the exploring party, water was found in Birdum Creek, nine miles south of the camp, at intended Well No. 3. There was about a week's supply, two or three water holes having been partially filled from a thunder storm the day before."

"On the 7th December I left Burton and retraced my steps to visit the other two parties a second time. I had not gone 10 miles before I met Mr. Burt, who had come over from the southern sections in search of Mr. Ross. I at once decided to send Mr. Burt back with telegraphic despatches informing you of the state of the work. Mr. Burt reported Mr. Millner's arrival with sheep and horses at the Roper, and also the murder of Mr. J. Millner at Attack Creek by the natives.

"On the 9th December reached No. 1 Well. Party at work poling the line. Ration allowance to men had been reduced to make stores last until 20th January.

"12th December, I arrived at the first crossing of the Roper Creek, 230 miles from Port Darwin, and found Mr. Rutt and party, who had started poling the line a week before. Alarmed at the non-arrival of Hack's teams, I returned to the Katherine. I met these teams five miles south of the Katherine, having experienced heavy rains from the Adelaide River to the Katherine and having great difficulty in getting through. Took 51 days for Hack to travel from Southport to the Katherine. Hack most valuable and capable officer.

"I went to the Katherine to speak with the Government Resident, but line out of order. Next morning succeeded in getting a message through to the Government Resident. Government Resident wanted to know if I could establish a horse express to Section 2, as the Company were considering the desirability of putting on a steamer to run from Port Darwin to Normanton. Informed the Government Resident that the establishment of an effective horse express during the wet season was impossible. Only a short message, but took two hours in transmitting. After spending a whole day I did not receive any answer, nor could any further signals be obtained from Port Darwin.

"23rd December, started for the Roper Landing.

"24th December, express waggon bogged for four hours in flooded country. In the afternoon I came upon Mr. Millner and his party with their sheep, camped at Red Lilly Swamp. Mr. Millner's bullock drays had been bogged often, and it took over a fortnight to go five miles. I bought 1000 sheep from Millner, also 16 horses.

"26th December, resumed journey to the Landing, my party consisting of three others and myself. Both saddle and pack horses were repeatedly bogged. I passed Rutt's teams. Most of the teams were bogged and drivers were in like predicament. Arrived at the head of the navigation of the Roper on the 30th December and found that Messrs. Burton and McLachlan's teams had arrived seven or eight days before.

"I waited until 1st January, at which date there were only two days' provisions left in the camp and no sign of the 'Bengal.' I therefore improvised a boat out of the body of a horse waggon, and with a volunteer crew comprised of two bullock drivers, a stockman and the storekeeper, set forth in search of the 'Bengal,' which I found after two days' sailing, rather more than half-way down to the mouth. We despatched two boats with provisions for the men at the Landing, and I remained on board the 'Bengal.' Now the 4th January, and it has been raining continuously since the 12th December.

"13th January, one of the boats returned to the 'Bengal' and the other boat returned on the 15th inst. The river had risen over twenty feet, and the boats could only manage to get to the Landing by rowing close to the banks from tree to tree, and holding on at every possible point. Meantime, the men at the Landing were living on jirked beef and water, having been obliged to kill bullocks as their supplies were exhausted on the 3rd January.

"No. 1 teams had not arrived at the Landing by the 13th, although due on the 2nd. These teams would be exhausted of rations. Decided to despatch Mr. King with rations, but he advises that the country could not be passed owing to flood. I attempted to get to the Landing in the cutter, 'Dolphin,' but, despite fair breeze and the efforts of five oarsmen, the boat gradually dropped astern, the flood proving too strong for her.

"Mr. Little arrived from Normanton in the "Larrskeeyah' on the 14th January with correspondence relating to the expedition. On the 15th I left the 'Bengal' in the pinnace, laden with rations for the Landing, where I arrived on the 17th. Mr. King had left the day before with pack horses for the relief of the transport party of Section No. 1. The river has been flooded for a distance of five or six miles back. The men in the camp were extremely apprehensive for their safety. The camp was 35 feet above the usual level of the river, and Mr. King considered it quite beyond the reach of the highest flood.

"Found a good spot for a jetty on the Hodgson River, half a mile above the junction of the Roper, and arranged for the construction of the jetty. Returned to the 'Bengal' on the 18th. Left for Maria Island in the cutter 'Dolphin' on the 19th January for the purpose of meeting the 'Omeo.'"

From Maria Island, off Roper River, whilst awaiting the arrival of Mr. Todd, Mr. Patterson in a final report dated 26th January, 1872, states:—

"I put forward no excuses, as I stated in a former report, for my want of success, because such excuses would only infer self-accusation, and from such upbraidings I am entirely free. The ill-luck that has attended the expedition, like most things else, admits of a reasonable theory, and that theory is simple enough.

"The expedition has not suffered from misfortune so much as mistakes. Under any circumstances there might have been adverse influences and undoubted obstacles to contend with, but in this case these things have been aggravated by the incomparably greater obstacles thrown in the way by the adoption of a course to which I was utterly opposed. I am suffering from the imputation of disasters which were inevitable under the circumstances, but which would undoubtedly have been averted or rather never have taken place had I been left unfettered in my action and been allowed to carry out your original idea of making the Roper the sole or main base of operations . . . ."

Todd's Arrival at the Roper River

In February, 1872, Todd arrived at the Roper River with the steamers "Omeo" and "Young Australian" carrying reinforcements and supplies for Patterson's party. These vessels, together with the "Bengal," which had arrived from Darwin, were taken up river 80 miles from the mouth to a spot known as "the landing." It was necessary for Todd to furnish guarantees to the captains of the ships, protecting the owners of the vessels from loss which might eventuate from the hazardous journey. Todd found that Patterson's party had endured considerable hardships, and at the time of his arrival was nearly destitute of provisions.

He also learnt that the work of the northern section, where Rutt's party had taken over from the contractor at the King River, was steadily progressing at the rate of about 3½ miles a week. Rutt was to construct the line from the King to a position 280 miles south of Darwin. McLachlan's party was working from the 280-mile to Daly Waters, about 365 miles from Darwin. This party was proceeding at approximately the same rate as Rutt. Much time was lost by parties in exploring for water, and in some cases shafts to a depth of over 60 ft. were sunk. Only on one occasion were they successful in striking water. Shortly after these attempts to find water the "wet" season set in, and much of the country was rendered impassable for the teams. Todd immediately despatched teams from the

Roper with provisions, and made arrangements to establish a horse express service to convey messages over the gap in the line. The teams despatched from the Roper had great difficulty in getting through, and, as the interior parties were running short of supplies, rations were transferred to pack horses, and a party of eight men with 50 pack horses started off ahead. The rains were so heavy that even this party had great difficulty in getting through.

It was not expected that even with the most favourable circumstances that the line would be completed before the end of June or July, but the express service under Mr. King was to be established as early as possible.

After making the above arrangements, Todd visited Darwin in the "Young Australian" and returned to the Roper landing. From here he travelled inland to inspect the work of the line parties.

Todd arrived at Daly Waters on 22nd June, 1872. From there he sent a message to the Agent-General in London informing him of the state of the work and the establishment of the Estafette, which was in operation between Tennant's Creek and Daly Waters. After a few messages had been received from London the cable between Port Darwin and Java broke down and communication on this section was not restored until October 30th, 1872. At this time the land line was completed in every respect from Port Augusta to Tennant's Creek and poled as far as Attack Creek, 40 miles further north. Wire for this section had to be carted from the Roper. On the north side communication was complete between Port Darwin and Daly Waters. Four construction parties then concentrated on the joining of the line, but the cutting of a clear track a chain wide through at least 500 miles of forest and scrub country was a huge task.

However, during the final completion, communication with Adelaide on the one side and Port Darwin on the other was maintained by field operators. The gap was gradually closed, and finally the two ends of the wire were joined on August 22; then communication was established right through between Adelaide and Port Darwin, a distance of nearly 2000 miles. Thus the great work, notwithstanding all disasters and mishaps, was successfully accomplished within two years.

When the lines were joined, Todd was at Central Mt. Sturt (Mt. Stuart), and in the evening was inundated with kindly worded messages of congratulations from friends in all parts of the colony. He reports that it was a bitterly cold night with a strong south-east wind, and seated on the ground with only a pocket relay instrument, he received one after another of friendly recognitions from those who took an active interest in the work. He worked at the instrument until he was nearly frozen and completely knocked up with fatigue and excitement. Three cheers were given by the party before they finally retired for the night.

Cost of Construction

The original cost of the work amounted to £338,600, which included the construction of substantial stone buildings at the Peake, Charlotte Waters, Alice Springs and Barrow Creek; temporary huts of three rooms at Tennant's Creek, Powell Creek and Yam Creek; substantial log huts of six rooms at Daly Waters and Katherine; and a large stone building to accommodate both staffs at Darwin.

THE DESIGN AND CONSTRUCTION OF UNDERGROUND CONDUITS FOR TELEPHONE CABLES

A. N. Hoggart, B.Sc.

PART VI. — CONDUIT LAYING

General: In the first article of this series (Vol. 4, No. 6) the qualities of a good conduit run were reviewed, and it is well to keep these particularly in mind while considering methods of laying conduits, as careful attention to this phase of conduit construction is essential in order that a properly constructed route may result. In particular, the requirements as to straightness, smoothness, grading and strength are important. In the first place, and before commencing laying, it should be ensured that the bottom of the trench has been correctly graded and tamped firmly as described in Part III. (Vol. 5, No. 2). Apart from particular features applying to the laying of each type of conduit, the following general principles are important:—

(1) Before commencing laying, the conduits should be laid out along the side of the trench, so as to be conveniently available to the conduit layers.

(2) To ensure a straight run, a line, attached to stakes, should be run along the centre of the trench and the conduits adjusted to this line. (In some cases, particularly with multiple ducts, it may be more convenient to place the line at one side of the run.)

(3) The bores of the ducts, also the spigots and sockets, should be kept clear of dirt, stones, etc., during and after the laying process. The ends of the ducts should be kept closed, except when conduit laying is actually in progress, by placing a board suitably supported across the mouth of the ducts, or alternatively by using wooden duct plugs.

(4) All conduits should be forced well into position so that adjacent conduits butt together closely. Joints should, as far as practicable, be water-tight.

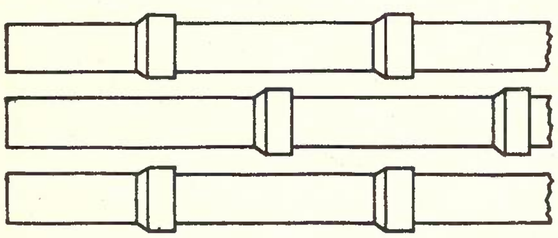


Fig. 37.—Staggering of Joints in Multi-Duct Run.

(5) When using several single pipes to form a multi-way run, the joints should be staggered as in Fig. 37. For this purpose short pipes are used on alternative ways at the commencing end. The same procedure applies when using two or more multi-duct conduits, e.g., two four-ways to form an eight-way nest. Staggering of joints in general saves space and provides more room for jointing.

(6) Where conduits or pipes, other than square butt jointed types, are laid in two or more layers, soil should be filled in to two or three inches above the conduits in the first layer, well tamped and levelled off before the next layer is laid.

(7) Before filling in, the grade of the conduits should be checked by means of boning rods to ensure that the correct fall is provided from end to end, and where necessary, adjustments made. If the trench is correctly trimmed, no difficulty should be experienced.

(8) Conduits should be correctly aligned at all joints. Fig. 38 shows how faulty aligning reduces the space available for cabling, besides leaving an edge which may damage the cable during pulling-in operations.

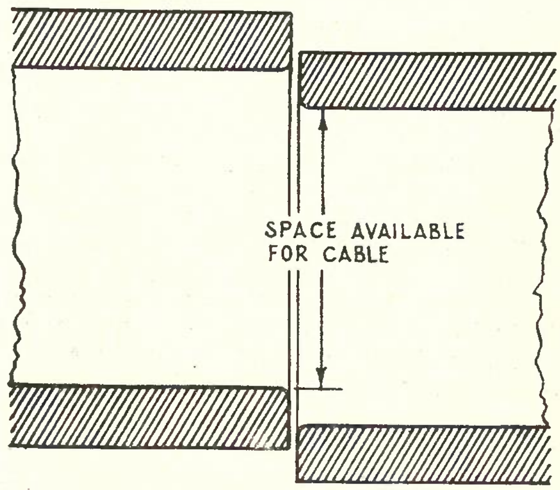


Fig. 38.—Effect of Faulty Alignment of Conduits.

(9) In the case of conduits fitting with collars, some administrations require that the bed of the trench should be hollowed out to receive the collar, so that the barrel of the conduits rests on the firm bed of the trench and the weight of the conduits is not taken by the collar. This, however, tends to make the conduit laying slow, and experience has shown that, provided special care is exercised in filling-in, this precaution may be omitted. After the conduits are laid, fine loose earth should be filled down each side of the ducts to about half their height; this should then be well tamped with a narrow piece of wood so that the soil will work into the space under the barrel (see Fig. 39). Loose soil should then be filled in to a couple of inches above the conduits and again well tamped. The spigot of the first conduit, to be laid in a sec-

tion, should be supported by a piece of wood so that it will lie parallel with the bottom of the trench.

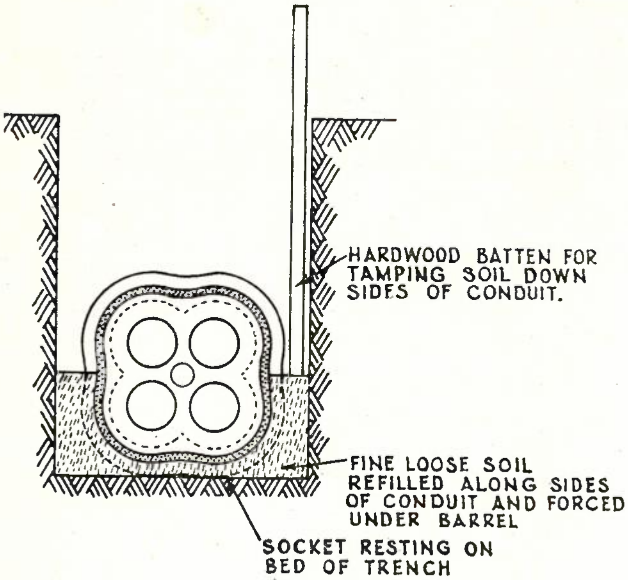


Fig. 39.—Filling-in Round Spigot and Socket Type Conduit.

(10) Generally, conduits are laid with sockets facing away from the point of commencement of the work irrespective of whether they face downhill or uphill. However, it is easier to lay conduits with sockets facing uphill, and in cases of steep grades it will probably be advisable to lay with sockets pointing uphill, necessitating changing direction of laying in different sections.

(11) When laying in unstable ground or where there is a risk of subsidence due to operation of other bodies or other causes, it may be advisable to provide a concrete foundation (reinforced, if necessary) to support the conduits. The concrete should be 3 inches or more in thickness and should extend 2 inches either side of the conduits. Except in the case of butt-jointed conduits, 2 or 3 inches of fine soil should be laid over the concrete to form a bed for the conduits.

(12) Where, owing to the necessity for laying conduits below the minimum depth or where other hazards which may result in damage exist, it may be worthwhile providing concrete protection over the conduits. This should be 2 to 3 inches thick, and should extend 2 or 3 inches beyond the conduits.

In the following paragraphs, particular features in the laying of different types of conduits will be described. A description of the various types was given in Part II. (Vol. 5, No. 1).

Single Earthenware Pipes (Drain Pipes): Cement mortar is used for jointing. The mortar is made by mixing intimately together one part cement to two parts clean sand (by volume) and adding sufficient water to make the mixture wet, care being taken to avoid making the mixture sloppy. The mortar is worked well into the space between the spigot and socket, and finished off with a trowel. Care is necessary to ensure that the space is completely filled and that no mortar is left inside the pipe. As these conduits are not self-aligning, a mandrel should be used when jointing, the mandrel being placed as shown in Fig. 40.

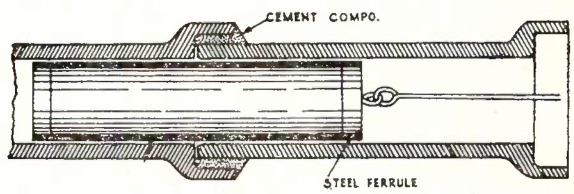


Fig. 40.—Laying E.W. (Drain) Pipe, Showing Method of Using Mandrel.

The mandrel should be $\frac{1}{8}$ in. to $^3/_{16}$ in. smaller in diameter than the duct. On completion of each length, a mandrel should be pulled through to test the length. A rubber or leather washer attached to the test mandrel can be used to clean out the length. Curves in the duct run should be avoided, but where essential can be arranged by using pipes slightly curved in the burning process, or by offsetting at the joints. In any case, curves should conform to limits set out in Part I. (Vol. 4, No. 6).

Earthenware Butt-Jointed Square Conduits: As these conduits are not provided with collars and are not self-aligning, it is necessary to provide a firm foundation on which they are laid. Except where conduits are laid on very firm ground or rock where there is no possibility of movement, a concrete bed 3 inches thick and extending 2 inches either side of the conduits is first laid in the trench and finished reasonably flat. A layer of cement grouting $\frac{1}{2}$ to $\frac{3}{4}$ inch thick is laid over the concrete before it dries, and levelled off to the correct grade for the conduits. In order to provide additional strength in bad ground the concrete may be reinforced with steel rods or rolled T sections.

The conduits are bedded into position on the grouting. The joints are covered with a calico strip $4\frac{1}{2}$ inches wide, lapping evenly over the two adjacent conduits, the ends of the strip being required to overlap at least 3 inches. The calico strip is first made waterproof by soaking in tar, bitumen or other similar compound, and is required to prevent the cement mortar entering the conduits. Each joint is then covered at the sides and top with a layer of cement mortar at least 1 inch thick and extending at least 2 inches on each side of the calico strip. The sides of the joints can be formed conveniently by using moulds made from galvanised iron sheet; these should be well greased with fat or soft soap to prevent the mortar adhering. Fig. 41 shows the method of laying and jointing butt-jointed conduits.

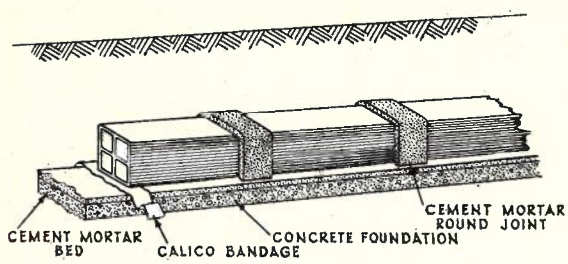


Fig. 41.—Laying of Butt Jointed Conduits.

Where more than one layer of ducts is to be laid the joints should be staggered and a ½-inch layer of cement mortar provided between the layers to ensure even bedding. The cement mortar at the sides of the joint of the upper conduits should be continued down past the lower layer of conduits (see Fig. 42).

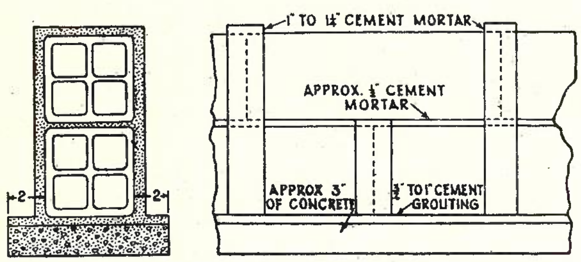


Fig. 42.—Laying Butt Jointed Conduits in Two Layers.

To prevent any subsequent movement forcing the conduits out of alignment, concrete is filled in to half-way up the sides of the ducts, or in the case of multiple layers to half-way up the sides of the top duct. The concrete should be at least 2 inches thick. In good ground where disturbance of the ground is unlikely, the concreting of the sides of the conduits may be omitted, but in this case the mortar round the joints should be at least 1½ inches thick, and the conduits must be well bedded into the cement grouting in the bottom of the trench. In any case, filling in should not commence until at least six hours have elapsed, so as to allow the concrete to set.

To ensure correct alignment, it is necessary to use mandrels while laying. Each mandrel is 12 inches long by 3 $^{3}/_{16}$ inches square (for 3¼ inch square conduits). The mandrels are used in two ducts in the case of two, three or four duct conduits, and three ducts in the case of six duct conduits, the ducts used being as widely dispersed as practicable. When the first conduit is laid, mandrels are inserted in it and the next conduit laid and jointed, each mandrel being across the joint until half is in each conduit. As each additional conduit is laid, additional mandrels are joined on by means of links of iron wire or chain until there are 12 mandrels in each chain. The space between adjacent mandrels should be 12 inches so that each mandrel effectively covers a joint. This method ensures that correct alignment is maintained until the concrete has taken its initial set. On completion of each length, each duct should be tested by drawing through a mandrel 12 inches long by 3⅛ inches square, with a leather or rubber washer 3¼ inches square at one end. The mandrels used for both laying and test should be of hardwood with hard steel shoes at each end. Mandrels are subject to hard wear and should be discarded when they have worn to $^{1}/_{16}$ in. less than the specified dimensions.

The concrete used should be quality B, i.e., by measurement—cement, 1 part; clean sand, 3 parts; crushed stone, 5 parts.

Earthenware Self-Aligning Conduits: Although the design of these conduits considerably simplifies the laying operation, particularly by virtue of the self-aligning feature which is intended to automatically ensure the correct alignment of the duct, there is nevertheless need for special care in handling and laying. The bitumastic linings are very easily damaged, being brittle in cool weather and soft in very hot weather; damaged linings mitigate against the making of a good joint. Self-aligning conduits should be stacked so that the weight is taken by the barrel and not by the socket and spigot end lining.

With this type of conduit the levelling and ramming of the bottom of the trench is most important, as the ducts are in general laid directly in the trench. A firm trench bottom is therefore essential to prevent strains being communicated to the joint, with possibility of the joint coming apart.

In jointing E.W. self-aligning conduits, the object is to weld together the bitumastic linings of adjacent conduits, so that the resultant joint is as strong and as watertight as possible. Two methods have been used for making the joint. In the first, the spigot and socket linings are coated with a molten mixture applied hot, which sets to form a firm joint. The mixture should be liberally applied and preferably hot enough to soften the bitumastic lining, thereby forming a welded joint. The procedure is for the conduit layer to apply the compound to the socket end of the last conduit laid, and simultaneously an assistant treats the spigot end of the conduit being laid; this is then lowered into the trench, aligned with the adjacent conduit and driven into position. A final application of compound is made to the exposed surface of the joint.

The compound usually consists of the following: Resin, 4 parts by measure; oil, 1 part (sump oil is suitable); coal tar, 1 part. The mixture is heated until molten and thoroughly mixed.

In the second method the bitumastic linings are heated until the compound begins to melt and the joint made as before. Blow lamps may be used for heating, but it is found than an air acetylene torch with a fish-tail burner gives better results as the flame is not so fierce or so concentrated. Two torches should be used so that the spigot and socket can be heated simultaneously. When the joint is made, the torch is again applied to the exposed surface of the linings and the joint finished off with a trowel.

Special care is necessary to ensure that the spigot and socket are clear of dirt, etc., as a good joint cannot be made if the spigot and socket are not clean. It is important that as each joint is made, the spigot is forced well into the corresponding socket, so that the linings meet closely throughout. To drive the conduit home a piece of wood is placed inside the socket of the conduit being laid and tapped with a hammer or mallet. The blows should not be too heavy, so as to avoid damaging the conduit. If, after releasing the pressure, it is found that the joint opens, it is probably due to the bed of the trench being uneven. The ducts should then be removed and the bottom of the trench flattened. Slight offsets can be given at the joints to introduce a curve in the route, but these must be kept small, otherwise a satisfactory joint cannot be made.

Single duct conduits can be readily handled into the trench by one man, but in the case of four- and six-way conduits two men are usually necessary. These conduits can be handled conveniently by inserting a length (about 4 ft. 6 in.) of 1-inch water pipe through one of the small-bore holes in the conduit. During laying, one end of the pipe is inserted into the corresponding hole of the last pipe laid, thereby facilitating the bringing of the two conduits together in correct alignment.

An alternative method is to use the device illustrated in Fig. 43. The two pipes fit into diagonally opposite ducts of the conduit and when laying also act as mandrels, thereby ensuring correct alignment. The external diameter of the pipes should be $\frac{1}{8}$ in. to $^{3}/_{16}$ in. less than the bore of the duct, and should be 3 ft. to 3 ft. 6 in. in length.

Upon completion of each length, the ducts should be tested by pulling through a round mandrel $\frac{1}{8}$ in. to $^{3}/_{16}$ in. less in diameter than the bore of the ducts. Generally with well manufactured conduits and good workmanship in laying, the self-aligning feature will ensure correct alignment.

It is frequently possible to obtain from the manufacturers modified types of conduits, which will facilitate the work, e.g.:

Short conduits, 12 or 18 inches long, for use at ends of sections to permit of staggering of joints and finishing off to correct length; also for forming slight curves in the route.

Double Spigot conduits, 12, 18 or 24 inches long, for finishing off a run, spigot ends being preferred to socket ends for entry into manholes.

Double Socket conduits, used to enable a run to be commenced in the middle and laid both ways, which may be necessary in some exceptional circumstances.

Concrete Pipes.—These pipes, which are six feet in length, are now generally supplied with rubber ring joints, but two other types of joint have been fairly generally used in the past, viz.:

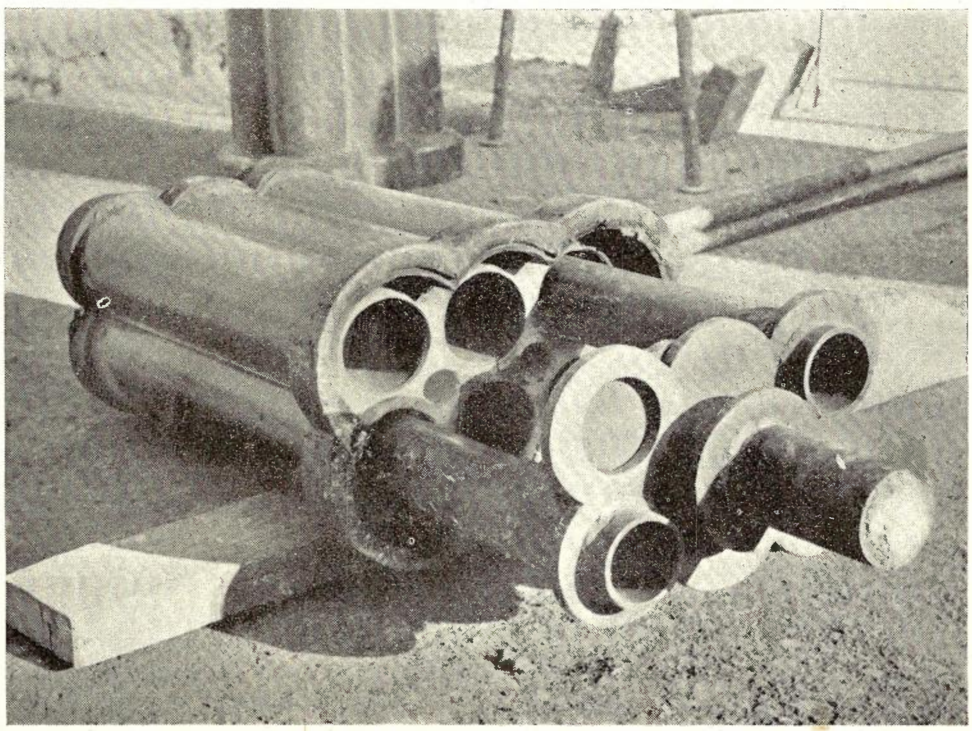


Fig. 43a.—Mandrel for Laying E.W. Self-Aligning Conduits.

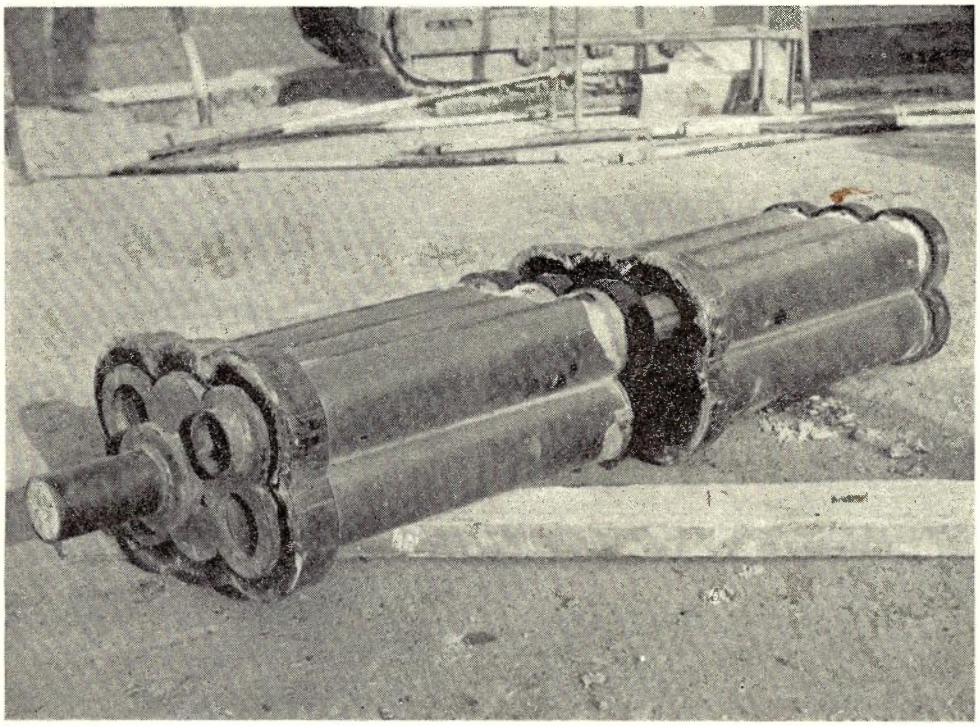


Fig. 43b.—Use of Mandrel for Laying E.W.S.A. Conduits.

(i) Cement mortar joints, which are substantially the same as the joints in earthenware drain pipes, and a similar laying procedure applies.

(ii) Bitumastic self-aligning joints similar to those on earthenware self-aligning conduits, and which are laid in a similar manner.

In the case of pipes with rubber ring joints the joint is formed by a rubber jointing ring compressed between the spigot and socket of adjacent pipes and no other jointing material being necessary. With a little experience, rubber ring jointed conduits can be laid at a very fast rate, although a certain amount of care is necessary. The trench is prepared in the usual manner, and the first pipe placed in position and carefully lined for direction and grade. A rubber ring is then stretched over the spigot of the next pipe, close to the end. The ring should be square on the pipe and should be free from twists. The spigot is then placed against the socket of the previous pipe laid, so that the rubber ring is touching the socket evenly all round (see "A" Fig. 44). The pipe is then pushed home using, if necessary, a bar levering against a block of wood held across the socket of the pipe. It may also be necessary to drive a stout peg into the ground behind the spigot of the first pipe to hold it firm when the next few pipes are being laid.

When the pipe is pushed home the rubber ring should roll into the position indicated at "B," Fig. 44. The depth of the socket and the thickness of the ring are so chosen that when the pipe is being pushed home the rubber ring rolls through a fraction more than half a turn. The stresses in the rubber then tend to complete the turn, i.e., to force the two pipes together; a strong joint therefore results. If the rubber ring is not placed close to the spigot end of the pipe, it may not roll more than a half turn, and a firm joint will not result. If the spigot is not square with the socket, or the ring is not placed on squarely, the ring may enter the socket first on one side, and thus the rubber rolls forward insufficiently on the other side. The resultant twist in the ring tends to cause the joint to push apart, and the joint would not be watertight. As each pipe is laid, a little loose earth is thrown in and tamped down along the sides of the pipe to prevent any lateral movement. When about five pipes have been laid they should be given a final push together, and with the pressure on, loose soil should be filled and rammed in layers around the pipes and joints. At the same time the earth round the previous five pipes should be given a further ramming.

Slight curves in the duct run can be made by offsetting the pipes slightly, the flexibility of the joint permitting this; but it is advisable to lay the pipes straight and move them out of line after they have been driven home. The degree of offset should not exceed the limits quoted in Part I. (Vol. 4, No. 6). It is important that the spigots, sockets and the rubber rings be clean to ensure a satisfactory joint. In wet weather some difficulty may be experienced in laying the pipe, particularly if the spigot is wet and the socket dry, or vice versa. If both are wet or both dry, the rings will roll into position without skidding.

The rubber ring joint very effectively ensures correct alignment of the pipes, and a mandrel test is generally not necessary. It is important, however, that the interior of the pipe be clean and free from dirt, stones, etc.

Wrought Iron Pipes: Before wrought iron pipes are laid they should be examined to ensure that the bores are clean and any burrs on the inside edges removed. All joints should be screwed up to the maximum extent possible, using "footprints" or pipe wrenches; otherwise a gap may be left in the coupling between the two adjacent pipes, which in turn may injure the cable when pulling in. The application of red lead to the joints is desirable, as it assists in making watertight joints, and retards corrosion.

Iron pipes are frequently used for crossing culverts, drains, bridges, etc., where other forms of conduit are not suitable. The arrangement for supporting the pipes in these cases will depend on the conditions applying, and as a rule each installation will be individually designed. It is important, however, when fitting iron pipes on bridges, etc., which at present or in the future may be associated with electric railways or tramways, to ensure that the iron pipes are insulated from the steelwork of the bridge. This is necessary, otherwise severe electrolytic corrosion trouble will be experienced on the cables.

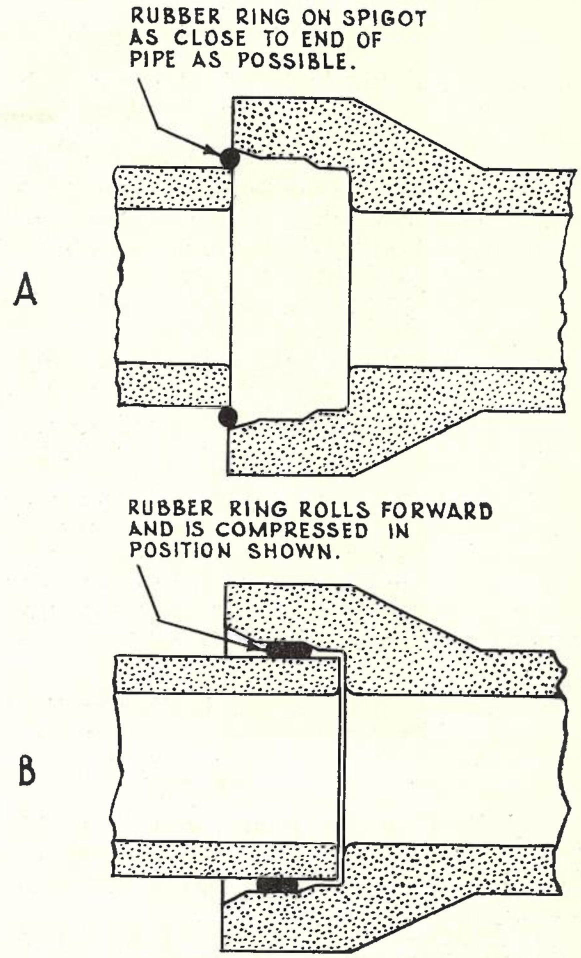


Fig. 44.—Laying of Concrete Rubber Ring Jointed Conduits. "A" shows position of ring before conduit is pushed into position. "B" shows completed joint.

THE LOCATION OF FAULTS IN LOADED CABLES

O. J. Connolly, B.Sc.

In connection with the installation of loading coils on junction and trunk cables, the need has arisen for a simple method of locating the position of faults or discontinuities which may be present. Such irregularities, which cannot be detected by D.C. measurements, may be caused by a faulty loading coil or by the omission of a loading coil at one of the loading points. As loading pot tails often contain more pairs than the number of coils in the loading pot, and the surplus pairs are usually connected through from tail to tail, a mistake in identifying these pairs would lead to the second type of fault mentioned above. The accuracy required in locating a fault of this kind is only such as to indicate the loading pot at which the fault occurs.

Discontinuities in a telephone line such as those mentioned above cause maxima and minima in the impedance curve of the cable pair when the impedance is plotted as a function of frequency. The maxima appear at frequencies at which the wave reflected from the discontinuity is in phase opposition to the transmitted wave at the point of measurement. The minima appear at frequencies at which the two waves are in phase agreement; thus the frequency interval between two adjacent impedance peaks is a measure of the difference in phase change between those frequencies in going to the fault and back to the point of measurement. If the velocity of propagation is constant, then the distance to the fault from the point of measurement is given by the formula

$$d = \frac{V}{2\,(f_2 - f_1)}$$

where V is the velocity of propagation and f_1 and f_2 are the frequencies at which adjacent peaks of impedance were observed. (Typical values of V are as follow: Aerial wires, 180,000 miles/sec.; unloaded cable pairs, 123,000 miles/sec.; loaded cables, 88mH at 6000ft. spacings, 14,000 miles/sec.) This formula can be used in locating discontinuities in aerial wires such as sections of intermediate cable, etc. The formula cannot be applied with much success to non-loaded cables, as, due to the high rate of increase of attenuation with frequency in these cables, faults more than a few miles from the point of measurement do not give definite peaks of impedance, and in the case of faults near to the point of measurement, only one impedance peak may be obtained.

Due to the lower attenuation per mile of loaded cables and the small increase of attenuation with frequency below the cut-off frequency, irregularities can be located over a wide range of distance beyond the point of measurement. The formula given above can be applied with reasonable accuracy where the frequencies of the impedance peaks are below 2000 C/s. For higher frequencies of measurements, a formula which takes account of the variation of velocity of propagation of a loaded cable with frequency is required.

The phase change "a" per loading section of loaded cable at frequency f_1 is given by

$$\cos a = 1 - 2 \left(\frac{f_1}{f_c}\right)^2$$

where f_c is the cut-off frequency of the cable.

In applying this formula, measurements of impedance are made on the faulty pair, which is terminated in its characteristic impedance (the 1000-cycle value) at the far end, to avoid irregularities due to reflection at this point. A curve of impedance versus frequency, or of the resistance component of the impedance, is then plotted in order to determine the frequencies at which maxima and minima occur. It is not essential to carry out actual measurements of impedance. If a voltmeter of 4000 ohms impedance or higher (such as a rectifier meter) is bridged across the junction between the oscillator and the cable pair, maxima and minima of impedance will be indicated by corresponding maxima and minima of deflections of the voltmeter scale.

If f_1 and f_2 are the frequencies, determined as described above, at which two successive maxima or minima occur, then a_1 and a_2 can be determined from the formula given above.

The phase changes per loading section in going to the fault and back are respectively $2a_1$ and $2a_2$. As the difference in phase between the two reflected waves at the point of measurement is 360°, the number of loading sections from the point of measurement to the fault is

$$\frac{360^\circ}{2\,(a_2 - a_1)}$$

where a_1 and a_2 are expressed in degrees.

In order to test the accuracy of this formula, a loaded cable was set up by looping together pairs in a short length of cable and inserting 88mH loading coils at approximately 6000 ft. intervals. By this means a loaded cable pair was formed, consisting of four full sections, with half-section terminations. Measurements of mutual capacity of the cable pair in each loading section gave a mean value of 0.082 mfds. per loading section. The calculated cut-off frequency of the cable was 3730 C/s.

Attenuation and impedance measurements were made on this loaded cable pair over a range of frequencies up to the cut-off frequency. These measurements were made under the five possible conditions, namely, with all coils in circuit and with each coil cut out in turn.

Fig. 1 shows details of the attenuation measurements.

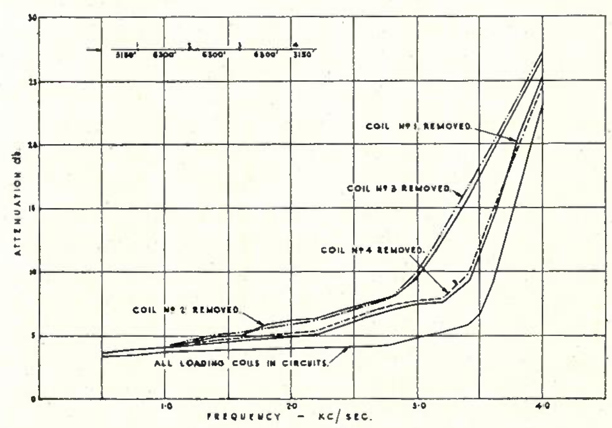


Fig. 1.

The impedance curves are shown in Fig. 2.

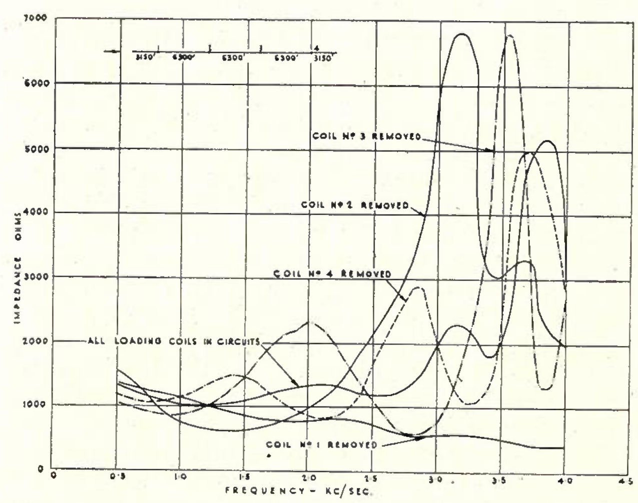


Fig. 2.

The removal of the first coil gives an impedance curve which has no definite maxima or minima. The curve for the condition in which coil No. 2 is removed has only one definite maximum point at 3.2 kC/s. The other curves, however, each have at least two maxima and minima and are suitable for testing the formula for locating the irregularity.

Results of calculations made from the latter curves are shown in the following table:—

No. of coil omitted	Frequencies at which successive maxima or minima were obtained, C/s.		a_1	a_2	Calculated distance to fault in loading sections	Actual distance to fault in loading sections
3	1000	2800	31.0°	97.5°	2.7	2.5
3	2000	3500	64.8°	143.1°	2.3	2.5
4	1400	2850	44.0°	99.3°	3.2	3.5
4	2100	3250	68.5°	121.4°	3.4	3.5

These measurements show that irregularities in loaded cables can be located with reasonable accuracy by the method which has been described.

This method of locating irregularities has been applied successfully in a number of cases. Faults have been located in loaded cables consisting of up to 10 loading sections. Faults located included faulty loading coils, an intermittently high resistance joint, and the omission of a loading coil at one of the loading points.

Experience with the method has shown that special attention is necessary to the following points:—

(i) The cable pair under test should be terminated in its nominal characteristic impedance. A check measurement of impedance should be made to ensure that no serious reflection takes place when a good pair is terminated in this impedance. If necessary, the impedance curve of the faulty pair can be corrected for any irregularity noted in the curve of the "good" pair. This correction is made by subtracting the ordinates of the curve of the good pair from those of the faulty pair. The corrected impedance curve is then used in determining the frequencies at which the impedance peaks occur.

(ii) The cut-off frequency of the cable should be known with reasonable accuracy. If the mean mutual capacity per mile of the type of cable which is being used is not known, or it is suspected that the actual mutual capacity varies considerably from the mean value, an impedance measurement should be made of a good pair left open circuit at the far end. The correct value for the cut-off frequency can then be obtained by applying a succession of trial values in the formula for locating the irregularity.

(iii) Where the impedance measurements indicate that the fault is close to the point of measurement, as in the case of curves (d) and (e) of Fig. 2, a further measurement should be made at the far end of the cable in order to obtain suitable maxima or minima for purposes of calculation. Alternatively, a good pair could be looped with the faulty pair at the far end, thus placing the fault further from the point of measurement. This method can be applied to faults up to an attenuation length of from 5db to 10db, depending on the nature of the fault. If the impedance peaks are not sufficiently defined, a test should be made from the far end of the cable, or the cable should be opened at an intermediate point to allow of a test at a point closer to the fault.

APPENDIX

Example of calculation of distance to fault:

$f_1 = 2100$ C/s.

$f_2 = 3250$ C/s.

$f_c = 3730$ C/s.

$$\text{then } \cos a_1 = 1 - 2\left(\frac{2100}{3730}\right)^2 = 1 - .635 = .365.$$

and $a_1 = 68.5°$,

$$\cos a_2 = 1 - 2\left(\frac{3250}{3730}\right)^2 = 1 - 1.520 = -.520$$

and $a_2 = 180° - 58.6° = 121.4°$,

$$\text{Then } N = \frac{360°}{2(a_2 - a_1)} = \frac{360}{105.8} = 3.4.$$

where N is the number of loading sections to fault.

THE UNIVERSAL TELEPHONE TYPE 300

A. W. McPherson.

During the last 10-15 years many interesting developments have occurred in the design of telephone instruments. These developments followed the desire of subscribers generally for greater comfort when using a telephone, and of engineers for greater efficiency in the transmission of the human voice.

Such advancements in telephone design have resulted in the replacement of pedestal type telephones by instruments of the handset pattern, of which the 332 type shown in Fig. 1 received in Australia in 1939, was then the latest British model. The magneto telephone in this series is known as the 334 type with built-in Alnico generator, and was developed following certain suggestions from this Administration.

Fig. 1.—Automatic Table Telephone, No. 332 A.T.

The shape of the instrument shown in Fig. 1 made it suitable for table use only, and the need for a specially designed wall telephone was still apparent. Associated with the development of an instrument for this purpose was the consideration of a Universal Handset Telephone to meet the following requirements:—

(1) Modern appearance.
(2) Provision for wall or table mounting.
(3) Maximum transmission efficiency and side tone control.
(4) Simplicity and ready interchangeability of component parts.
(5) Economy in manufacture and ease of maintenance.
(6) Standardisation of circuits.

A universal telephone has now been developed, and the features incorporated therein form the subject of this article. The design caters for separate phenol formaldehyde moulded cases for wall and table telephones, and each is available for C.B., Automatic and Magneto working. There are thus six distinct telephones of the universal type, viz., AT, AW, CBT, CBW, MT, MW, and to distinguish these from earlier handsets, the identification number 300 has been allotted to them. Typical completed instruments are shown in Fig. 2. Whilst the general appearance of the table telephone is similar to that of the 332 type, the construction and lay-out of the component parts is such that greater facilities for interchangeability are offered by the 300 type. The wall sets present a neat and modern appearance, and should prove popular with subscribers who desire a wall-mounted instrument.

The following apparatus is common to each of the six Universal telephones:—

Base Plate.
Switchbracket Assembly.
Plunger Assemblies.
Terminal Block.
Magneto Bell.

Fig. 2a.—Automatic Table Telephone, No. 300 A.T.

Fig. 2b.—C.B. Table Telephone, No. 300 C.B.T.

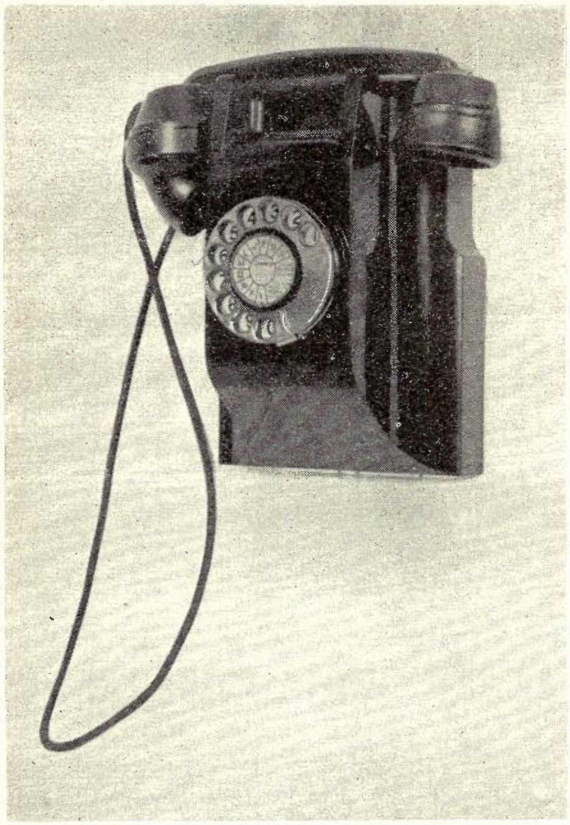


Fig. 2c.—Automatic Wall Telephone, No. 300 A.W.

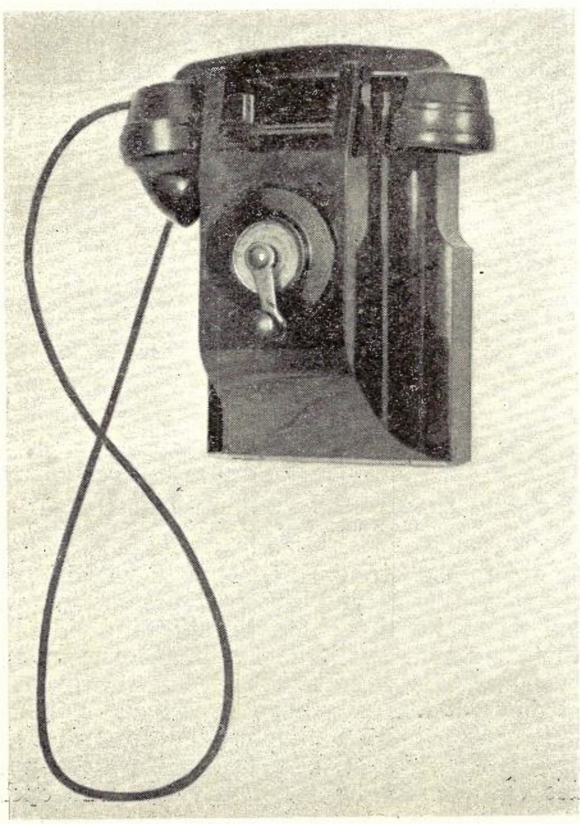


Fig. 2d.—Magneto Wall Telephone, No. 300 M.W.

Condenser Clip.
Spring Assembly.
Handset No. 184.
Cord 3306 for Handset 184.

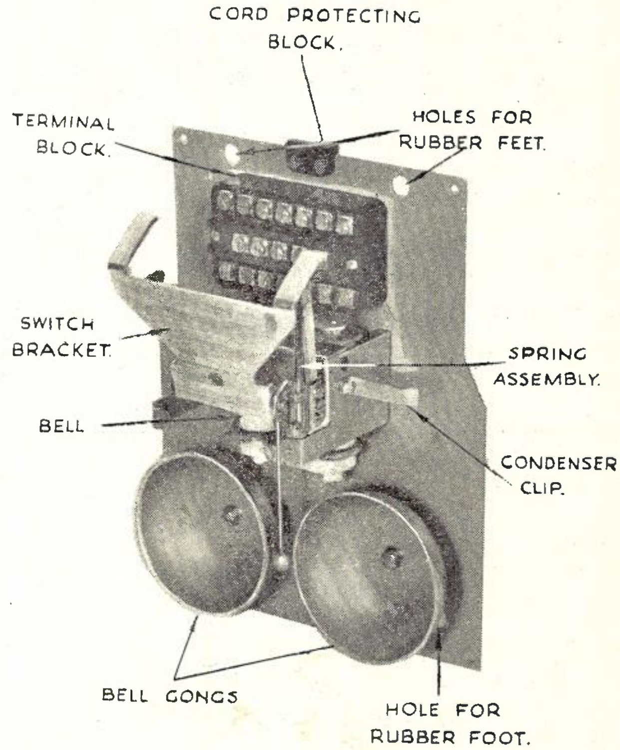


Fig. 3.—Base Plate with Common Component Parts Mounted.

Fig. 3 shows a base plate with all of the above component parts mounted, with the exception of the plunger assemblies, which are associated with the wall or table case. For the sake of simplicity of illustration the handset and cord have also been omitted. The assembly of an automatic table telephone requires the following additional equipment:—

Table Case.
Dial No. 10.
Dial Retaining Plate.
Dial Cord—8 in.
Condenser.
Induction Coil.
Rubber Feet.
Line Cord.
External Terminal Block.

The complete assembly ready for screwing the base plate to the case is shown in Fig. 4. The securing of four captive screws attached to the base plate completes the telephone. The assembly of a C.B. table telephone is identical except that a dial dummy is used in lieu of the dial, and the dial cord is not required. The necessary strapping is accomplished by means of special links on the terminal block.

The assembly of the automatic wall telephone requires the same components as for a table

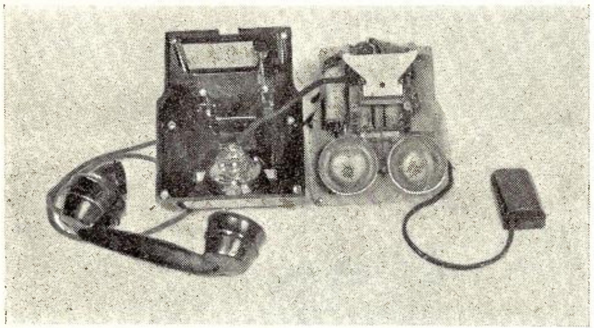


Fig. 4.—Complete Assembly of Telephone No. 300 A.T. Ready for Fixing Base Plate to Case.

set, less the line cord, external terminal block, rubber feet and table case. A 15-inch dial cord is necessary to enable the telephone to be opened sufficiently for maintenance. The common base plate containing the components is secured to a

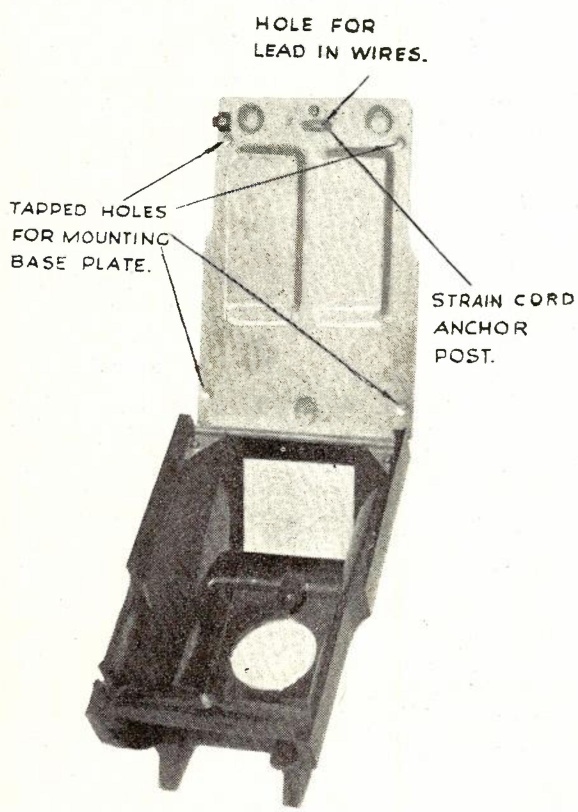


Fig. 5.—Wall Case Moulding and Back Plate Before Component Parts are Fitted.

back plate by means of four screws, and the back plate in turn is hinged to the wall case moulding. Fig. 5 shows the back plate and moulding ready to receive the components, and Fig. 6 is a view of the complete telephone before the hinged portion is closed. It will be noted that the moving arm of the switchbracket assembly is mounted in a position at right angles

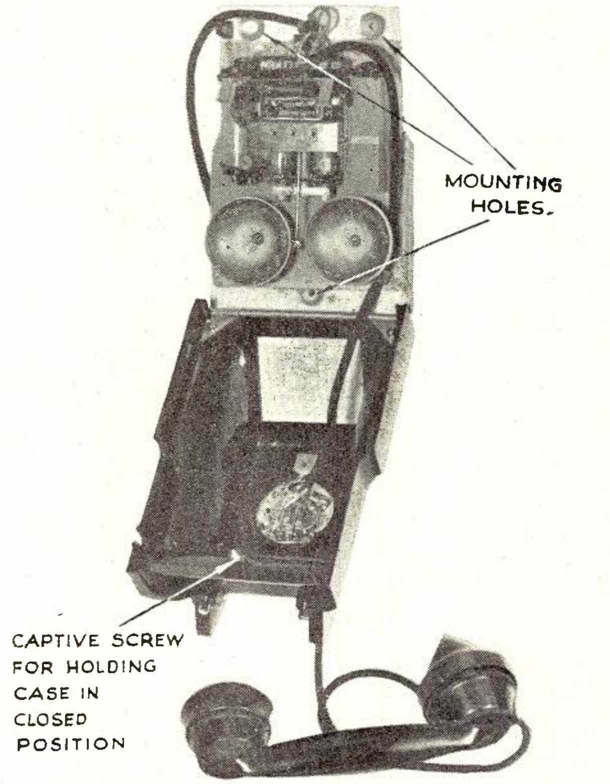


Fig. 6.—Telephone 300 A.W. View of Complete Assembly Before Case is Closed.

to that occupied when fitted to a table telephone. This is necessary because of the different relationship of the base plate with respect to the plunger assemblies. The method of assembling the switchbracket in the two positions is shown in Fig 7.

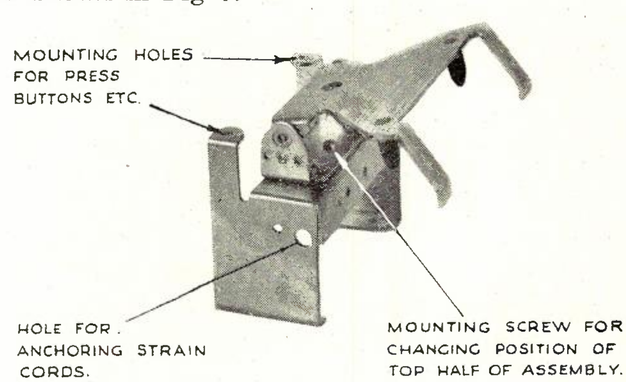


Fig. 7a.—Switch-bracket Assembled for Use on Table Telephones.

One common circuit diagram shown in Fig. 8 is used for C.B. and automatic table or wall telephones, and the characteristics individual to each instrument are indicated in the accompanying notes. The circuit is basically the same as that for the 332 telephone described in Vol. 2, No. 2, October, 1938, the only difference being that a B.P.O. No. 27 induction coil, which supersedes the No. 22 coil, is now used. The operation of each is identical, but the No. 27 coil has different values of resistance and turns for the windings, and was developed to provide higher efficiency and slightly different side-tone characteristics to the No. 22 coil with which it is interchangeable.

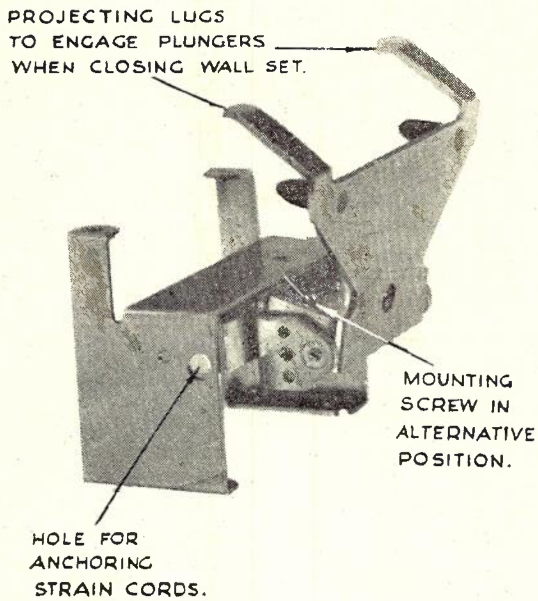


Fig. 7b.—Switch-bracket Assembled for Use on Wall Telephones.

The assembly of the magneto telephones is similar to that of the C.B. and automatic instruments, except that a built-in generator is provided in the position normally occupied by the dial or dial dummy. Flexible cords 8 in. and 15 in. in length respectively for the table and wall telephones provide the means of connection

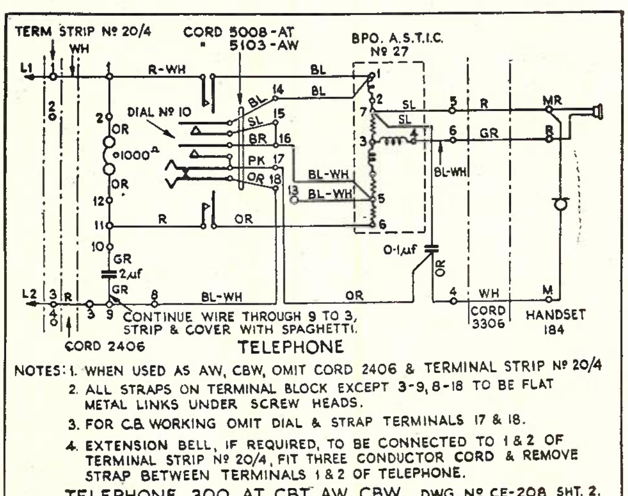


Fig. 8.—Circuit Diagram for 300 Type C.B. and Automatic Telephones.

between the generator and terminal block. The generator is designed specially for the purpose and the constructional details and electrical performance will be published in a future issue. The circuit diagram for the magneto wall or table telephone is shown in Fig 9, and the operation

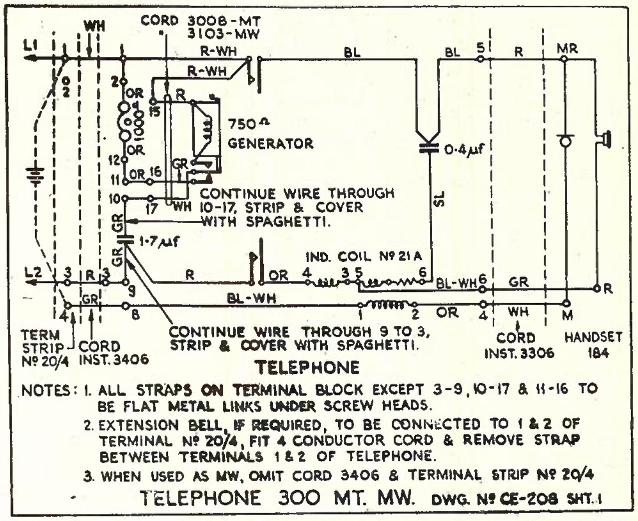


Fig. 9.—Circuit Diagram for 300 Type Magneto Telephones.

is fundamentally the same as that for the 233 M.W. telephone described in Vol. 2, No. 3, February, 1939, except that a condenser is placed in series with the signalling circuit, and the generator springset opens the bell circuit during an outgoing ring. It will be noted also that the cradle switch springs in the 300 type M.T. and M.W. conform with the standard arrangements for handset telephones, and the connection to the batteries from the table instrument is made by means of a three-conductor cord which also serves as the line connecting cord.

SPECIAL FEATURES

(1) The simplicity of the design of the plunger assemblies will be observed from Fig. 10. In earlier telephones the plungers were mounted in metal sleeves fixed in position by means of screws, whereas the 300 type plungers operate in correctly dimensioned holes in the moulded case, and the friction surfaces are metal to bakelite instead of metal to metal. Tests conducted to date indicate that the simplified plunger assembly will be just as satisfactory in service as the more elaborate metal insert type.

(2) The switchbracket assembly is provided with extension pieces as shown in Fig. 7 to facilitate the closing of the wall case. These projecting lugs engage with the bottom of the plungers and raise the latter gradually to their operating position. This obviates the necessity for holding the plungers in the upper position whilst the case is being closed.

(3) The base plate of 14 gauge mild steel performs the dual purpose in the table telephone of providing a base for the instrument, as well as a means of mounting the component parts.

(4) The table case can be used for a 332 telephone.

(5) An additional ebonite plunger is provided on the switchbracket assembly so that a second springset can be fitted if special facilities are required in the telephone. The switchbracket is drilled and tapped for two springsets.

(6) Means for the mounting of press buttons, etc., for miscellaneous purposes are provided by two mounting holes at the top of the switchbracket assembly.

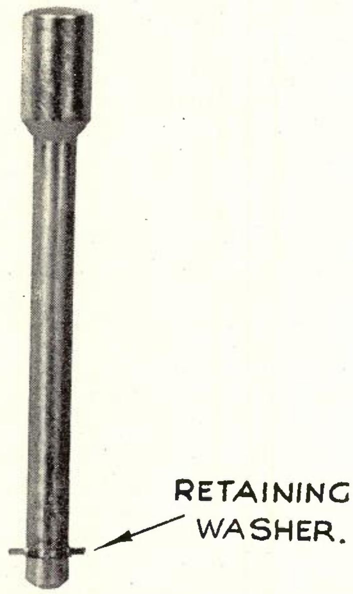


Fig. 10.—Chromium Plated Plunger Complete with Removable Retaining Washer.

(7) The terminal block containing 19 terminals provides for the maximum flexibility by the use of connecting links between terminals.

(8) A two-conductor line cord is provided on C.B. and automatic telephones for straight services. A three--conductor cord is fitted only when an extension bell is required.

(9) A 184 handset is provided. This type differs from the 164 handset previously employed on telephones in that the strap connection between one side of the receiver and transmitter is removable and the four terminals are available if required.

(10) A ready means of locking the dial and dial dummy in position is provided by a retaining plate, and the method of fixture is shown in Fig. 11.

(11) Press-in type rubber feet are used on the table instruments.

(12) The C.B. dial dummy is designed so that the label, celluloid disc and locking ring are inserted from the rear.

The entire telephone with the exception of the dial, dial cord, line cord and handset cord is made in Australia. Owing to war-time conditions the colour of the instruments has been confined to black, but it is anticipated that other colours will be available in the near future.

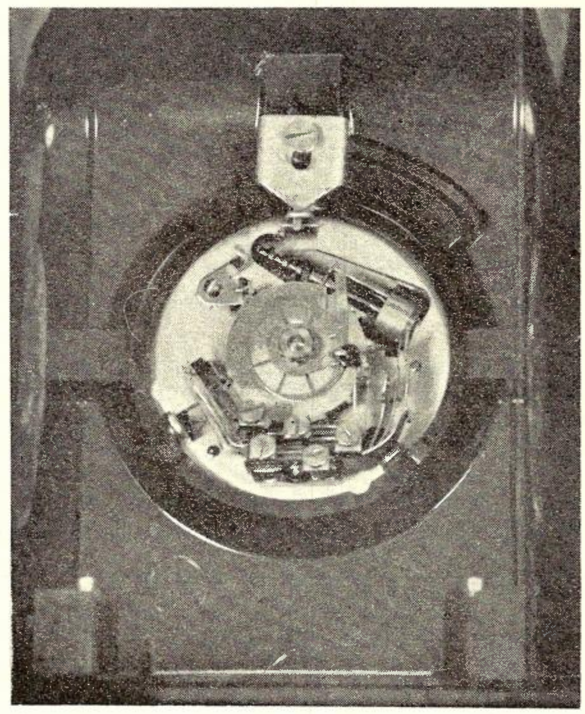


Fig. 11.—Close-up View of Dial Fixture.

CROSSTALK BETWEEN PARALLEL EARTH CIRCUIT TELEPHONE LINES

W. H. Walker, B.E., A.M.I.E., Aust.

Introduction: In country districts, particularly in pastoral areas where numerous privately erected earth circuit lines exist, the problem often arises as to what is required to keep crosstalk within tolerable limits where a number of these lines will follow the same route. With earth circuit lines, the crosstalk is determined primarily by the length of parallel and the separation between the lines, and the main object of this paper is to show the influence of these factors and provide a ready means of estimating the desirable separation or, alternatively, of estimating the probable crosstalk for closely coupled earth circuit lines.

The provision of a metallic circuit line is, of course, the best engineering solution, but the telephone service is such a vital need to many people in remote country areas that the grade of service of an earth circuit line is accepted as tolerable as compared to the metallic circuit lines, the cost of which may be so high as to place the telephone service beyond the means of many.

Factors Influencing Crosstalk Conditions: The current induced in one of the parallel earth circuit lines called the "disturbed circuit" by a current in the other or "disturbing circuit" is composed of a capacity current and a magnetically induced current, the latter, in turn, depending on the mutual inductance of the two circuits. The capacity current in this case is very small, and the calculations can be based with reasonable accuracy solely on the mutual inductance between the circuits. The mutual inductance between two parallel earth circuit lines depends upon:

(a) the length of the parallel;
(b) the separation between the wires;
(c) the height of the wires above the ground; and
(d) the resistivity of the soil over the parallel.

While the first three of these factors can be readily determined, the resistivity of the soil is difficult to assess, and varies according to the extent of stratification of the soil, the resistivity of the various strata involved, and the relative depth of the strata. Unfortunately, very little detailed information is available regarding the soil resistivities to be expected in various parts of Australia. However, the conclusions reached by the Geophysical Survey Section of the Council for Scientific and Industrial Research, which made an extensive survey of many existing and probable mining areas in Australia, were that generally the values of soil resistivity in this country range from 100 ohms/cm^3 in soils with a high saline content to 16,000 ohms/cm^3 in rocky localities with sandy soil (the resistivities may rise to more than 100,000 ohms/cm^3 in very extensive rock conditions). The more frequently occurring values are in the range 500 to 5000 ohms/cm^3.

Crosstalk Curves: The curves in Fig. 1 show the calculated crosstalk between parallel iron wire earth circuit lines for lengths of exposure of 2 and 10 miles and for separations up to 600ft. for soil resistivities of 500 ohms/cm^3, 1000 ohms/cm^3, and 5000 ohms/cm^3. Approximate crosstalk values for intermediate lengths of parallel can be obtained by interpolation. The method of calculation of the curves is set out in the Appendix.

The curves have been calculated for iron wire, as this wire is more extensively used for this class of construction. For lines built with copper wire, the lower characteristic impedance would increase the crosstalk current slightly, and crosstalk values would therefore be a little worse than those shown on the curves.

From an examination of the curves, it will be seen that the improvement in crosstalk is not directly proportional to increased separation. This effect becomes more pronounced as the soil resistivity increases, and with a resistivity of 5000 ohms/cm^3, while there is a rapid decrease in crosstalk up to a separation of about 70ft., increasing the separation to 200ft. only improves the crosstalk by approximately 4db. Thus, with a long parallel in an area of high soil resistivity, a very large separation is required if the crosstalk conditions are not satisfactory with a separation of 70ft. The separation between the circuits is usually limited by the width of the road along which the lines are erected, and in most cases the limiting distance is between 66ft. and 200ft. This band is shown on the graphs by two vertical dotted lines.

Factors Influencing the Curves: The crosstalk calculations have been based on the following assumptions:

(a) Uniform resistivity of the soil.

(b) Transmission at equal levels in both circuits.

(c) Earth connections on the disturbing circuit sufficiently removed from those on the disturbed circuit to ensure that any effects due to the proximity of the earths may be ignored.

In considering the effect of stratification, the theoretical crosstalk values should be reasonably accurate if the overall resistivity value agrees generally with that on which the calculations are based.

When the transmission level differs in the two circuits, the difference of level in db. should be added to the allowable limit to obtain the crosstalk requirements in the particular case under consideration. With this type of circuit a difference in level may be due to one or more of the following causes:

(a) Faulty construction, including high resistance joints, and low insulation resistance.

(b) Different gauges or classes of wires in the two lines.

(c) High resistance earth in one line.

(d) A higher level input to one circuit due to connection to a trunk line.

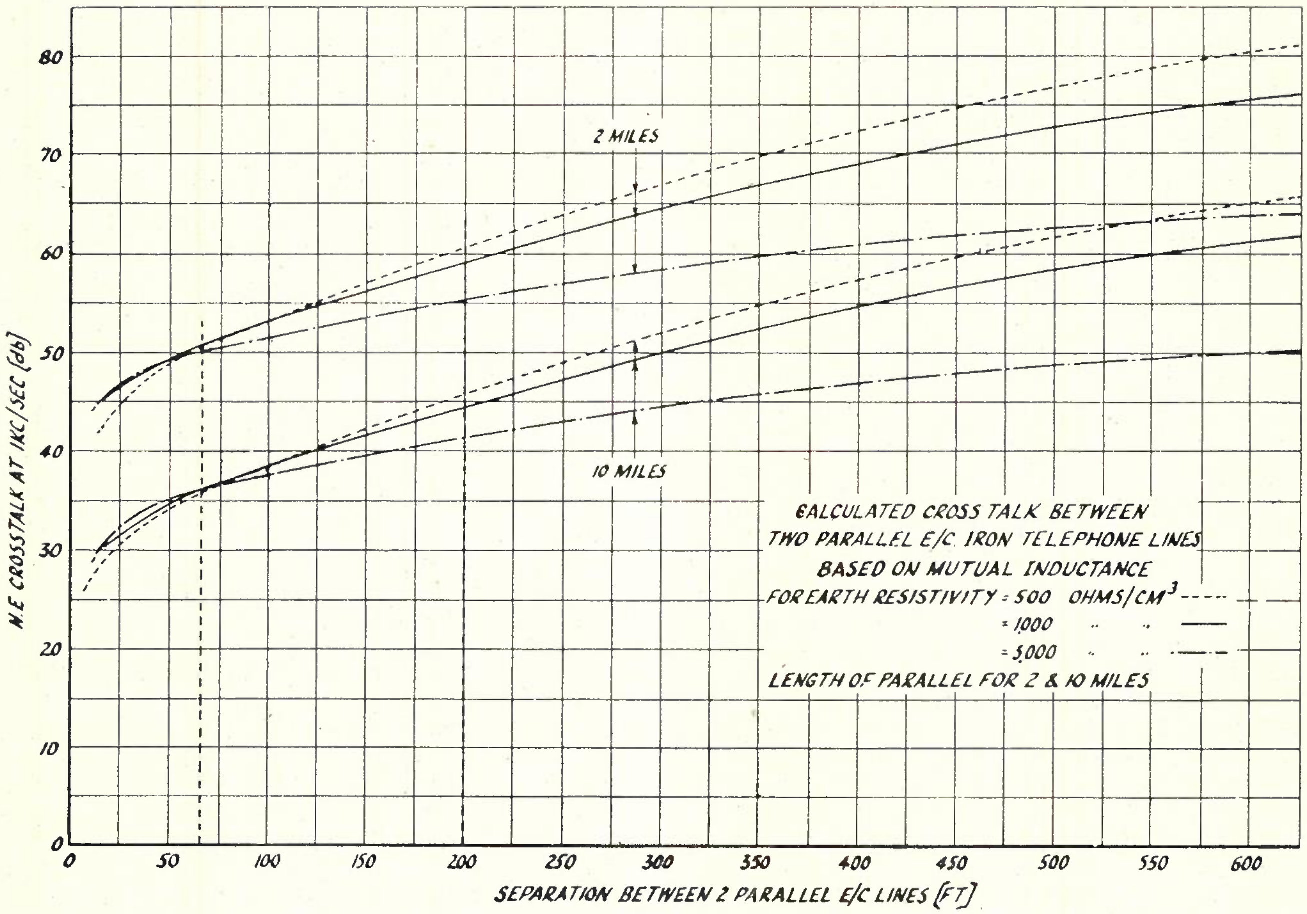


Fig. 1.

With reference to (d) it will be realised that, under certain conditions, the difference in level may be of the same order as the calculated crosstalk, and this aspect must therefore be fully considered when determining the expected crosstalk between any two circuits.

The location of the earth connections of any two earth circuit lines has an important influence on the crosstalk experienced, and if the earth connections are too close together, appreciable crosstalk can occur, even between two lines erected at right angles. From the results of tests made by the A.T. and T. Company in America, it would appear desirable to provide a minimum separation of 400ft. between the earth connections of earth circuit lines. However, with the lower soil resistivities found in Australia, this figure could probably be reduced slightly without adverse effect where its adoption would be difficult, but it is not considered that the separation of the earth connections should in any circumstances be less than 200ft. This separation should always be provided by subscribers when erecting earth circuit lines from the end of a common departmental route.

Choice of Resistivity Value: In an endeavour to make a broad classification of soil resistivities, the report of the Geophysical Survey undertaken by the Council for Scientific and Industrial Research was examined in conjunction with the results of earth resistivity measurements associated with radio field tests. Owing, however, to the skin effect associated with the very high frequencies used, whereby the current travels in only a thin surface layer of the earth, it was considered that the results of the latter were too high for direct comparison with C.S.I.R. tests. Soil resistivity tests made by the C.S.I.R. and tests made by the P.M.G. Research Laboratories both indicate that the range of soil resistivities in the North-Western district in Victoria is from 100-500 ohms/cm³. Using these values as a datum and the radio field measurements as indicating the relative values in other localities, a fairly comprehensive range of values throughout Australia was obtained.

The use of the following very general classifica-

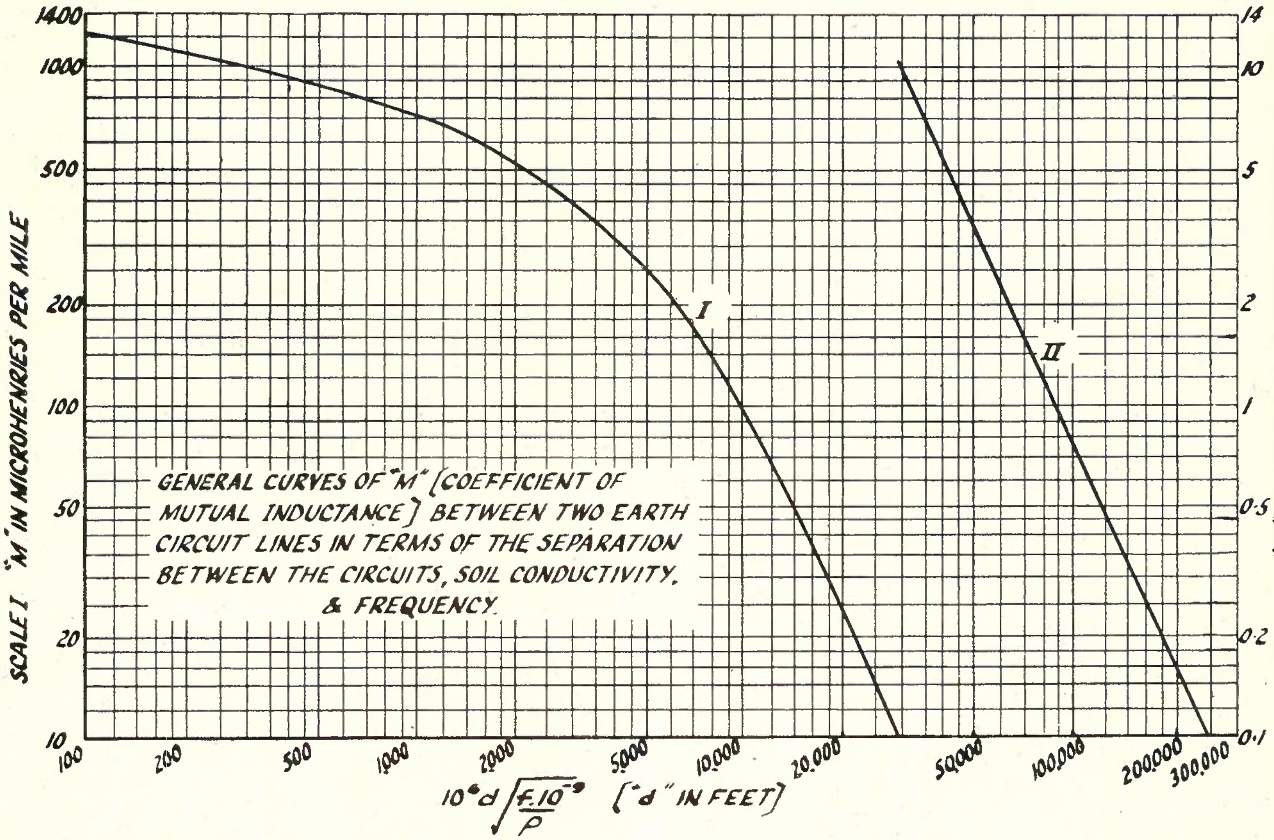


Fig. 2.

tion of areas and relative soil resistivities (where it is not practicable to make sufficient actual measurements of the particular soil resistivity conditions on a geophysical basis) will provide a reasonably satisfactory basis for the application of the curves:

(a) For those areas composed of new alluvial deposits, geologically speaking, and containing a relatively high salt content, the curves for a soil resistivity value of 500 ohms/cm^3 may be taken. Such areas include the North-Western district of Victoria and the extensive Western Plains districts of New South Wales, Queensland, and Central Australia.

(b) For those areas consisting of deep soil deposits such as are usually found in agricultural and farming districts, the curve for a soil-resistivity value of 1000 ohms/cm^3 may be used.

(c) The curve for a soil resistivity value of 5000 ohms/cm^3 may be used for rocky or sandy districts, although the crosstalk values thus obtained would be rather high where large masses of rock occur, such as are found in the Australian Alps.

(d) In districts of very high soil resistivity such as rocky mountainous country, every effort should be made to avoid the construction of parallel earth circuit lines.

It will be realised that the crosstalk values based on such a broad classification should be used primarily as a guide rather than an accurate forecast of the expected crosstalk.

Crosstalk Limits: It will not be practicable to obtain the usual (equal level) crosstalk design limit of 60 db. in many cases, but it is considered that, as a general rule, the minimum allowable crosstalk attenuation should be 50 db. This value gives reasonably satisfactory crosstalk values under usual noise conditions. However, earth circuit lines are notoriously noisy, and in many cases the high noise level will make crosstalk values even 10 db. lower than this satisfactory.

Apart from crosstalk level and expected differences in transmission level, the probability of conversations being made over the two circuits simultaneously will have some effect on the crosstalk conditions. For ordinary exclusive subscribers' services, the number of simultaneous calls is only a small proportion of the total calls. In the case for party services, the proportion will be somewhat greater. Also, some allowance must be made for the likelihood of a higher calling rate during certain periods of the day. For example, the majority of trunkline calls from station homesteads would probably be made between 7 p.m. and 9 p.m., and between these hours there is a greater likelihood that two parallel party lines might be in use together.

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APPENDIX

Crosstalk Calculations Between Parallel Earth Circuit Lines

The following outlines the method adopted in calculating the crosstalk between two parallel earth circuit lines in the preparation of the crosstalk curves (Fig. 1).

The current induced in the disturbed circuit is due to (a) capacity current, (b) magnetically induced current.

The **capacity current** can be calculated from the following formula given in para. 218 of the C.C.I.F. publication of 1938, entitled "Concerning the Protection of Telecommunication Lines from Disturbances Caused by Power Lines":

$$i = \frac{7.25}{Z + 2} \times \frac{b\ c\ l}{a^2 + b^2 + c^2}\ \omega\ E\ 10^{-9} \quad \text{.. (1)}$$

where i = induced current in amperes.
E = voltage of disturbing line.
a = distance between two lines in feet.
b, c = mean height of conductors above earth in feet.
l = length of parallel section in miles.
Z = number of wires in each group (one in this case).
f = frequency in cycles per second.
ω = angular velocity = $2\pi f$.

For this calculation the current induced in the disturbed line by 1 volt in the disturbing line was calculated and the power ratio between the two currents, which is equal to the crosstalk, was converted to db. The values obtained were very high and later calculations showed that the effect of the capacity current could be neglected. (Induced capacity current at 1000 c/s for 8-mile parallel at 50′ separation is equivalent to near-end crosstalk of 90 db.)

The **magnetically induced current** can be calculated from the formula for mutual inductance:

$$e = -\ m\ \frac{di}{dt}\ 10^{-6} \quad \text{.... (2)}$$

where e = induced voltage.
i = inducing current.
m = mutual inductance in microhenries.

The C.C.I.F. has agreed that electrical calculations of this nature between telephone circuits shall assume sine wave shape for alternating current.

$\therefore\ e = -2\pi f\ m\ i\ 10^{-6}$ for a sine wave shape .. (3)
or $i = -e/2\pi f m\ 10^{-6}$ .... (4)

The value of "m" in microhenries per mile is obtained from the curves shown in Fig. 2 and derived from similar curves prepared by the C.C.I.F.

The appropriate value of $10^6 d \sqrt{f 10^{-9}/\rho}$
where d = distance between parallel circuits in feet
ρ = soil resistivity in ohms per cm^3.
is first calculated and then used to obtain a value of "m" from Fig. 2. The inducing current "i" which will induce a voltage "e" of .001 volts in the disturbed circuit is then calculated from (4). This voltage is the "open circuit" induced voltage and the induced voltage under normal conditions e/2.

Therefore the induced current $i_1 = e/2Z_0$ .... (5)

Where Z_0 is the characteristic impedance of the line. For an iron wire earth circuit line Z_0 is equal to approximately 1000 ohms, which is the average value of a number of measurements made by the P.M.G. Research Laboratories.

From (5) $i_1 = \dfrac{1}{2 \times 10^6}$ .... (6)

From (4) $i = 10^3/2\pi f l m_1$ .... (7)
where l = length of parallel in miles.
and m_1 = mutual inductance in microhenries per mile.

Having obtained "i" and "i_1"
the crosstalk in db. = $20 \log_{10} i/i_1$ .... (8)
The crosstalk at 1000 c/s from formula (8) is then
$= 20 \log_{10} 3.2 \times 10^5/m_1 l$ .... (9)

By substituting for m_1 and l values of crosstalk were obtained for various soil resistivities and lengths of parallel and the crosstalk curves drawn.

It is of interest to note that the crosstalk values thus obtained agreed to within a few db. with values obtained from the usual Mutual Inductance formula used in crosstalk calculations on metallic circuit lines. Assuming the phase change to equal 2° per kilocycle per mile, as for metallic circuit lines, the Coupling Cœfficient was calculated on the mutual inductance from the formula:

$$X = \frac{2\ M}{Z_0} \times 10^3 \quad \text{.... (10)}$$

where M = mutual inductance in microhenries.
Z_0 = characteristic impedance of circuit.

Crosstalk in C.T.U. (K) then = XC .... (11)
where C = type unbalance × frequency in kC/s for relative "P" over the length being considered.
Crosstalk in db. then = $120 - 20 \log_{10} K$ .... (12)

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. 2490.—MECHANIC GRADE 2—TELEGRAPH MAINTENANCE SECTION

A. R. Glendinning

Q. 9.—Three telegraph lines A, B and C are successively looped together at the far end and the resistance of each loop is measured. The resistance of A and B is 260 ohms, A and C 280 ohms, and B and C 300 ohms. What would be the resistance of each wire singly and of the wires A, B and C in parallel?

A.—

Line A
o————————o
Line B
o————————o
Line C
o————————o

It is given that $A + B = 260$ ohms
$A + C = 280$ ohms
and $B + C = 300$ ohms

adding $2A + 2B + 2C = 840$ ohms .... (1)
from (1) $A + B + C = 420$ ohms .... (2)
But $A + B$ is given as $= 260$ ohms
therefore, from (2) $C = 160$ ohms
Similarly, $A + C$ is given as 280 ohms
therefore, from (2) $B = 140$ ohms
and $A = 420 - (B + C)$
$= 420 - 300 = 120$ ohms

Line resistances are—
$A = 120$ ohms
$B = 140$ ohms
$C = 160$ ohms

In parallel, the joint resistance is found by means of the conductance formula:—

$$\frac{1}{R} = \frac{1}{A} + \frac{1}{B} + \frac{1}{C}$$

$$= \frac{1}{120} + \frac{1}{140} + \frac{1}{160}$$

$$= \frac{28 + 24 + 21}{3360}$$

$$= \frac{73}{3360}$$

$$\text{and } R = \frac{3360}{73} = 46.03 \text{ ohms.}$$

Q. 10.—When testing and adjusting a polarised telegraph relay, describe the main points you would watch carefully when putting the relay into condition for service.

A.—In testing and adjusting a polarised relay, the following tests and adjustments apply generally to all types of polarised relays:—

(1) Mechanical condition must be checked to ensure that all moving parts move freely, and contacts are clean and not pitted.

(2) Adjustments:

(a) Play of the tongue should be adjusted by means of the contact screws to give a gap of four mils.

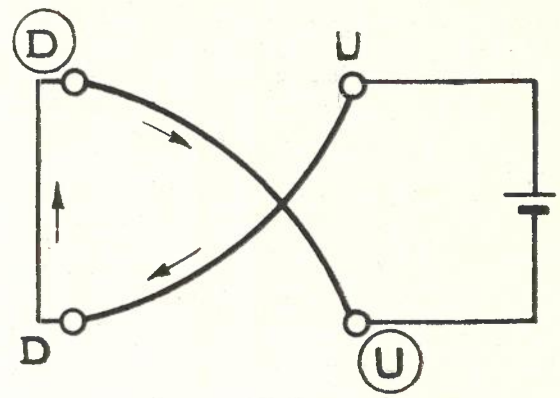
(b) Neutrality should be adjusted by means of the biassing screw. This is achieved when, with no current flowing in the coils, the tongue remains on either contact.

(3) Electrical tests:

(1) For differentiality:

(a) Series made with 100 mA through coils.

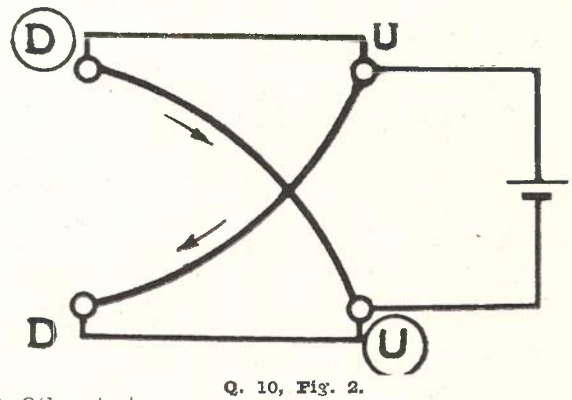
(b) Parallel made with 200 mA through coils.



Q. 10, Fig. 1.

1(a) Test shown in Figure 1 proves that with equal current in both coils, cores are unaffected.

1(b) Test shown in Figure 2, taken in conjunction with (a) proves that the resistance of both coils is identical if the cores are unaffected.



Q. 10, Fig. 2.

(2) Other tests:

(c) Check resistance.

(d) Measure lowest current at which relay will operate satisfactorily. This is known as the Figure of Merit. In the parallel case it will, of course, be double the series current.

(e) Residual Magnetism: Pass 250 mA through the coils in series. On disconnecting the current there should be no perceptible trace of residual magnetism.

(f) Insulation: Coil to coil and coils to frame should be checked with megger.

(g) Direction: Positive battery to D should move the tongue to spacing in each case.

(h) Run reversals and check for bias.

EXAMINATION No. 2473—ENGINEER TRANSMISSION—SECTION 2—RADIO TRANSMISSION

W. H. Hatfield

Q. 5.—A 10 k.w. "short-wave" transmitter is to be established in one of the larger States of the Commonwealth to provide the following services:—

(i) A broadcasting service for an area bounded by the arms of an angle of approximately 100° and lying between distances of from 300 to 2,000 miles from the transmitter.

(ii) An emergency point-to-point telegraph service to a city located approximately 1,500 miles distant, for use in the event of interruption to the land-line circuits.

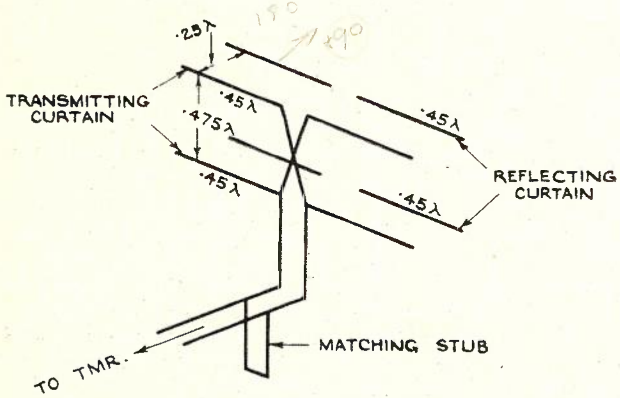
Describe the types of transmitting array you would use for each service, giving the reasons for your choice. Reference should also be made to the type of transmission line you consider most suitable for each type of array and their relative merits should be discussed.

A.—In designing an aerial to provide a short-wave broadcasting service to an area as specified, some form of directional aerial, to concentrate the maximum radiation in the desired direction, would be necessary.

A directional system has the advantage that a greater signal strength can be laid down in the preferred direction, but has the disadvantage that an even signal strength is not provided over the area to be served, the signal strength being a maximum in one direction and falling off on either side.

To provide the best service possible, it is desirable to erect an aerial giving as high gain as possible in the direction of transmission; but high gain can only be obtained by reducing the width of the directional pattern, and the selection of a suitable design becomes a compromise between gain and width of pattern.

As short-wave transmission depends on reflection from the ionosphere, it is necessary to concentrate the maximum radiation in a vertical plane at such an angle that the downcoming wave will reach the ground at the inner boundary of the service area. For E layer transmission, and a distance of 300 miles for the first hop, the angle of departure of the radiated waves should be approximately 20° above the horizontal.



Q. 5, Fig. 1.

A satisfactory aerial system for the required service, and satisfying most nearly the compromises referred to above, is shown in Fig. 1.

This consists of a broadside array, made up of—

(a) a transmitting curtain, 2 tiers high, each tier consisting of two horizontal half-wavelength elements, the lower tier being a half-wavelength above ground, and the vertical distance between tiers being a half-wavelength;

(b) a reflecting curtain, similar to, and a distance of a quarter-wavelength behind, the transmitting curtain, but not fed with power from the transmitter.

Due to the capacity of the supporting insulators, which reduces the velocity of propagation of the wave, the length of the half-wavelength elements and the vertical spacing between elements is somewhat less than a half-wavelength in free space. The length of the aerial elements is usually made 0.45 λ and the vertical spacing between elements 0.475 λ where λ is a wavelength in space.

The feeder line is twisted through 180° between the upper and lower elements to preserve the correct phasing between elements.

The array described, which would be erected in a direction normal to the direction of transmission, has a maximum gain of 10.3 db. and a wave angle of 20° above the horizontal.

At the boundary of the service area, i.e., 50° either side of the maximum, the signal strength will be 9 db. below the maximum.

To provide a reliable broadcasting service, allowing for the daily and seasonal variations in the ionosphere, three arrays, cut to different frequencies, say, 6 megacycles, 9 megacycles and 11 megacycles should be provided, each having an individual feeder line, with suitable methods of switching the transmitter output to the required line.

For an emergency point-to-point telegraph service, the determining factors in choice of a transmitting aerial would be:—

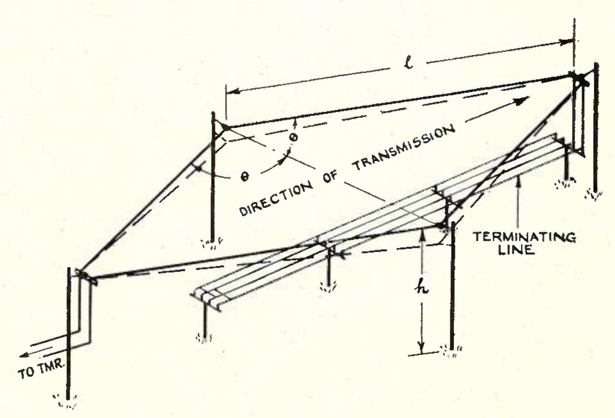
(a) Low cost.

(b) Reduction of width of radiation pattern.
This would increase the gain and also reduce the possibility of interference with other services.

(c) Ability to operate over a wide frequency range, preferably about 3 to 1.

The rhombic antenna meets the necessary requirements and would be used.

The rhombic is a non-resonant type of antenna, and as shown in Fig. 2 consists of two wires, each forming two sides of a diamond, several wavelengths long, and fed at one end with energy from the transmitter.



Q. 5, Fig. 2.

To obviate reflections from the far-end of the rhombic, which would create unwanted resonance effects, the far-end, that is, the end remote from the fed end, is terminated in a resistance of the same impedance as the rhombic and capable of absorbing 50% of the radio-frequency power supplied to the aerial by the transmitter. This terminating line will be of black iron wire because of its high attenuation, and as it will be of considerable length to provide the necessary power dissipation, it will be run backwards and forwards on poles within the rhombic itself.

The dimensions of a suitable rhombic would be:

$$\left.\begin{array}{l} l = 370 \text{ ft.} \\ h = 55 \text{ ft.} \\ \theta = 70^\circ \end{array}\right\} \text{see Fig. 2.}$$

As the separation of the antenna wires is continually changing, between the end and side poles, the impedance of the antenna is not uniform along its length, and a second wire, shown dotted in Fig. 2, may be added to overcome this effect.

The gain of a rhombic is not constant for all frequencies, but increases as the length of the side (l), in wavelengths, increases. Thus the gain increases with frequency.

The "angle of departure" of the wave becomes more horizontal as the height of the antenna (in wavelengths) increases, hence, as the frequency is increased, the wave angle is reduced.

The performance of a rhombic as described will be:

	Gain	Wave Angle (Above Horizontal)
5 mC.	3.2 db.	35°
10 mC.	10.0 db.	20°
20 mC.	13.6 db.	9°

In medium frequency broadcasting, where a vertical radiator, which is unbalanced with respect to ground, is used, it is common practice to use an unbalanced transmission line in the form of a concentric line, in which the shield or outer conductor is at earth potential and the inner conductor at high potential. This type of line is costly to construct and maintain, but has the advantage that there is no radiation from the line, in comparison with the open wire line.

For the short-wave aerials discussed above, both types are balanced with respect to ground and an open wire, two-wire line of 600 ohms characteristic impedance which is also balanced with respect to ground would be used. With the array used for the broadcasting service, the connection of the feeder to the aerial is at a point of high impedance, and it will be necessary, by the method known as stub matching, to match the aerial impedance to the line impedance, in order to avoid standing waves of current and voltage on the line.

If the broad frequency characteristic of the rhombic is to be fully utilised the feeder system should be similarly broad. An open wire line of the same characteristic impedance as the rhombic, 700 ohms to 800 ohms, is, therefore, ideal. Size and spacing of wires required to achieve this characteristic impedance does not make for a satisfactory mechanical job, and it is usual to provide a 600 ohm two-wire line and accept the loss of power due to the mis-match which results.

The use of a matching stub is not desirable, as this would limit the operation of the line to a narrower band of frequencies centering about that for which the stub was adjusted.

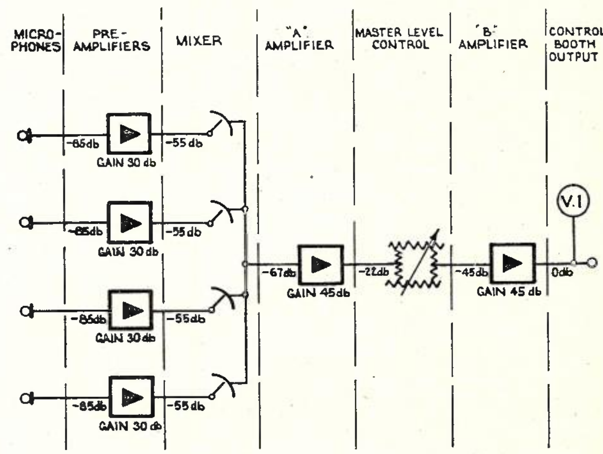
Q. 6.—Assuming the output level of a studio microphone to be minus 85 decibels referred to 6 milliwatts, give a description of the amplifying and associated equipment which would be required to provide an output level from the control booth of 6 milliwatts. State the reasons for any special features which you consider should be incorporated in the amplifiers. Allowance should be made for the use of faders to introduce up to 4 microphones at will and for gain control in the circuit. Illustrate your answer with a block schematic diagram and indicate the operating levels at the various points throughout the circuit.

A.—As shown in block schematic form in Fig. 1, the transmission channel from the microphone to the output terminals of the studio control booth equipment is arranged in the following sequence:—

Microphone, pre-amplifier, Mixer, "A" amplifier.

Master Level Control and "B" amplifier.

A volume indicator, which is essentially a high-speed milliammeter, calibrated to read power level directly is bridged across the output terminals.



Q. 6, Fig. 1.

In an audio amplifier it is desirable to make the ratio of signal to noise in the circuit as high as possible. Noise may consist of inherent circuit noise, e.g., thermal agitation; shot effect; microphone effect, caused by vibration of the tube elements altering the internal characteristics of the tube and causing variations, of audible frequency, in the plate current; or of external noise, introduced into the circuit, e.g., ripple in the d.c. power supply.

The output level of the microphone being so low, about 45 db. above the inherent circuit noise, which is usually about —130 db. with reference to 6 milliwatts, the introduction of any losses such as by insertion of the mixer, before amplification, would adversely affect the signal/noise ratio.

Individual pre-amplifiers having a gain of 30 db. are, therefore, used with each microphone to raise the level of the microphone output to approximately —55 db. before the introduction of any further losses in the circuit.

Due to the low-level input to the pre-amplifiers special features must be introduced in this stage to reduce circuit noise to a minimum. Two methods are usually adopted:—

(a) The use of non-microphonic tubes. These are designed to provide a very rigid mounting of the elements, with a view to reducing vibrations of the elements to a minimum.

(b) Extra filtering of the power supply, with the object of further reducing the amplitude of the ripple component of the d.c. tube supply.

Following the pre-amplifiers is the 4-point mixer unit, which allows for the introduction of up to 4 microphones simultaneously into the circuit, and which consists of four balanced faders, with their inputs connected to individual pre-amplifiers and their outputs commoned to the input of the "A" amplifier. The insertion of the mixer introduces a loss of approximately 12 db. into the circuit.

After pre-amplification and mixing, it is then necessary to provide amplification sufficient to raise the output from —67 db. at the output of the mixer to the required level of 0 db., allowing for the loss of approximately 23 db. introduced by the insertion of the master level control.

Due to the high gain required, two amplifiers, designated the "A" and "B" amplifiers, each having a gain of 45 db., provide the amplification in two steps:—

The "A" and "B" amplifiers are usually two-stage resistance coupled audio amplifiers, the final unit being a power amplifier, having a power output of at least 120 milliwatts.

No gain control is provided in the amplifiers, a single master level control, in the form of a balanced ladder-type attenuator, inserted in the circuit between the "A" and "B" amplifiers, providing the operator with means of controlling the outgoing programme level.

EXAMINATION NO. 2473—ENGINEER—TRANSMISSION, LINE AND RADIO

SECTION 3.—LONG LINE EQUIPMENT

H. W. Chamberlain, B.Sc.

Q. 7.—(a) In providing power plant for long line equipment purposes, discuss the advantages and any disadvantages of arranging the plant on a "floating" routine basis as compared with a charge and discharge basis.

(b) In establishing the power plant of a new carrier station on a floating routine basis, how would you determine the size (i.e., capacity) of motor generators or rectifiers and batteries that are to be used? Illustrate your answer by assuming current drains that would be applicable to a typical station. Show also by means of an outline, but approximately dimensioned sketch, how the batteries and other power plant would be arranged in the battery and power rooms, indicating briefly any precautions required in determining the size and arrangement of the associated power cables.

A.—(a) The system of floating batteries is standard practice for all long-line equipment offices when reliable commercial power supply systems are available. The advantages of the scheme over the charge and discharge routine may be summarised as follows:—

(i) The total battery capacity required is substantially less than that necessary for charge and discharge working because in the event of a power failure the total battery capacity is available. Smaller batteries also require less space for their accommodation, effecting savings in building costs where new installations are planned.

(ii) The size of the associated power plant can also be reduced with lower first costs and saving in floor space.

(iii) As energy is supplied direct from the charging equipment to the equipment busbars, losses are reduced.

(iv) The average life of the battery plates is increased. Recurrent battery charges and discharges necessarily involving "gassing" periods and cell temperature variations ultimately result in rapid deterioration of the battery, which is manifested as distortion of the plates and the gradual deposition of active material.

(v) Since gassing is reduced to a minimum, there will be considerable savings in the consumption of distilled water.

The chief disadvantage of floating arises from the presence of audio-frequency fluctuations or "ripple" in the output from the generators or rectifiers, which in turn is transmitted to the equipment busbars. This condition is a particularly serious one where long line equipment is concerned, insofar as the filament battery is widely used for the derivation of grid bias, and any ripple superimposed on the supply will be amplified, resulting in noisy circuits. The ripple voltages can be reduced to a satisfactory value by the insertion of smoothing circuits consisting of chokes and electrolytic condensers in the output leads from the generators or power rectifier units. The ripple voltages cannot be eliminated altogether, and the required degree of smoothing is indicated in specifications issued for the relative generating equipments.

An efficient continuous floating scheme also requires constant voltage from the floating generator or rectifier. This will enable the battery to be kept in a satisfactory condition, and at the same time provide a steady voltage for the discharge circuit. Automatic regulation is favoured, and may be accomplished by the familiar carbon pile voltage regulator and vibrating contact generators. Other methods, such as diverter pole generators and contact voltmeters operating regulating resistors, can be applied. In addition, there are many types of regulated rectifiers available using saturated choke control, phase shift control and the special properties of certain gas-filled tubes.

The initial economies of the "floating" system are, therefore, somewhat offset by the additional equipment required to effect sufficient smoothing and maintain constant output voltage from the generators or rectifiers.

(b) It will be assumed that the new carrier station is required to accommodate and provide for the 20-year development of long line equipment at present installed in a congested office. The old office accommodates, say, 10 three-channel terminals, six single-channel terminals, two carrier programme terminals, two 18-channel V.F. telegraph terminals, V.F. repeater installations and associated ringing, testing and supervisory equipment.

The approximate present and estimated 5, 10 and 20-year battery drains are summarised in the following table:—

Battery	Present average hourly load (amps.)	24-hour loads (amp-hours)			
		Present	5-yr.	10-yr.	20-yr.
— 24V. Fil.	125	3000	4000	5000	7000
+ 130V. Anode	8	192	240	300	400
+ 130V. Teleg.	1.5	36	50	70	120
—130V. Teleg.	1.0	24	36	50	80

The above office is also of sufficient importance to warrant being equipped with an emergency engine alternator set, which would be brought into use consequent on a failure of the commercial mains supply.

A continuously floating routine would be practicable, permitting the use of much smaller batteries of each type but capable of providing a total capacity sufficient to carry the 20-year load for a period of 12 hours.

It is usual practice to provide duplicate batteries, and to float at a voltage of 2.15 volts per cell, the optimum voltage at which cells can be kept in good condition. Each battery would be connected to the main busbars on alternate weeks.

Bearing in mind the fact that the current drains for long line equipment are practically constant and are not subject to wide variations as with exchange equipment, the power plant required for the above office is determined as follows:—

Batteries: Provide battery tanks whose total capacity is sufficient to carry the load for 12 hours at the 20-year load rate, but plate initially for the 10-year requirements. Ten to 12 years is generally accepted as the life of the battery plates under floating conditions. The requirements would, therefore, be:—

(i) —24 V. Filament: Two 11-cell 1350/1800 A.H. batteries.

(ii) + 130 V. Anode and + 130 V. and — 130 V. Telegraph. } : Three 60-cell 180/288 A.H. batteries.

The batteries have been chosen having regard to the capacity required and standard sizes usually obtainable from the manufacturers.

Motor Generators and Power Rectifiers: In general, duplicate auto-regulated and smoothed output units are supplied for each battery type, the rating of one being equivalent to the five-year load, and that of the other to the 20-year load. The smaller unit should be adequate for charge-discharge working if the need ever arises, whilst the combined outputs of the units should be capable of charging the batteries in eight hours. The units required for the station to the nearest standard higher rating would then be:—

1 — 35 V./200 A. Motor Generator.
1 — 35 V./300 A. Motor Generator.
1 — 180 V./40 A. Motor Generator.
1 — 130 V./15 A. Rectifier for floating the anode battery.
2 — 130 V./5 A. Rectifiers for floating the telegraph batteries.

Figure 1 shows how the batteries and other power plant would be arranged in the battery and power rooms.

Precautions which would be observed in determining the size and arrangement of the associated power cables are:—

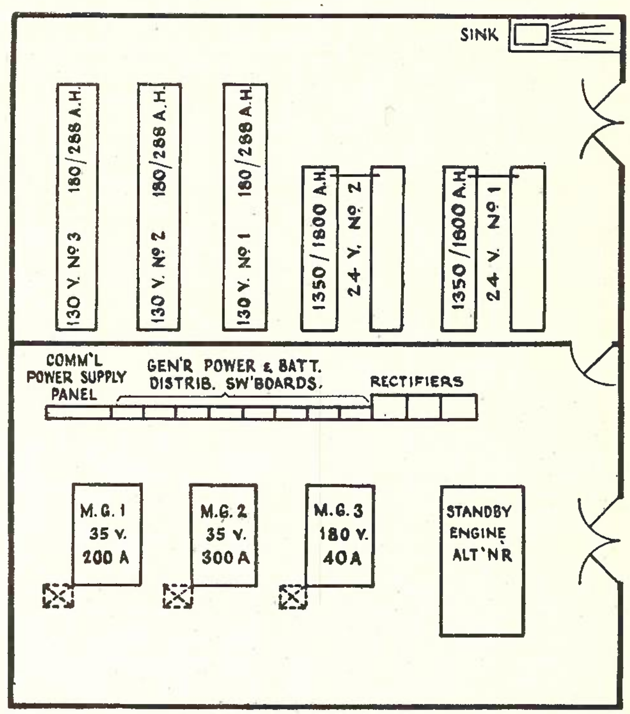
(i) Provide separate routes for the A.C. input and D.C. output cables to and from the generators and rectifiers.

(ii) Provide separate charge and discharge battery cables in order to reduce machine noise.

(iii) The charging cables would be capable of carrying the ultimate eight-hour charging current at a rate of 1000 amps per sq. inch.

(iv) The discharge cables would be capable of carrying the 20-year peak load at a rate of 500 amps per sq. inch.

(v) Ensuring low battery impedances by taking the shortest possible cable routes and by arranging each battery in halves, thereby forming a "loop" which has the effect of reducing the battery circuit inductance.



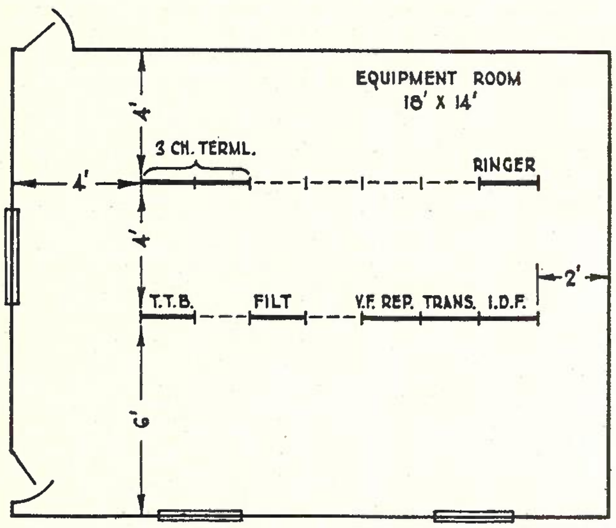
Q. 7, Fig. 1.

Q. 8.—(a) A small long line equipment station is equipped with a trunk test board, an intermediate distributing frame, a filter bay, transformer bay, V.F. repeater bay, ringer bay and one three-channel carrier telephone terminal. Show by means of an outline floor plan diagram how these items of equipment would be laid out in a typical equipment room.

(b) One of the lines entering this station is a physi-

cal trunk circuit, with a cailho telegraph circuit superimposed. It is also equipped with a V.F. terminal repeater, and is used to carry the three-channel carrier telephone system located at the station.

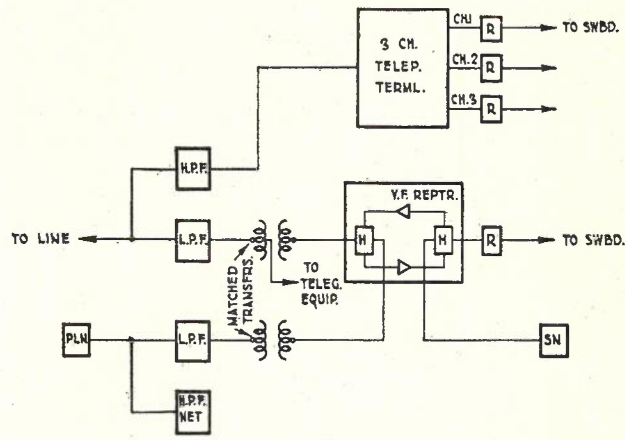
Furnish: (i) A block schematic diagram of the circuit arrangement of the items of terminal equipment; (ii) A diagram showing how you would arrange the wiring between the various racks, including the test jacks, to connect up suitably the items of equipment concerned, indicating also in what sections, if any, shielded wiring should be used.



Q. 8, Fig. 1.

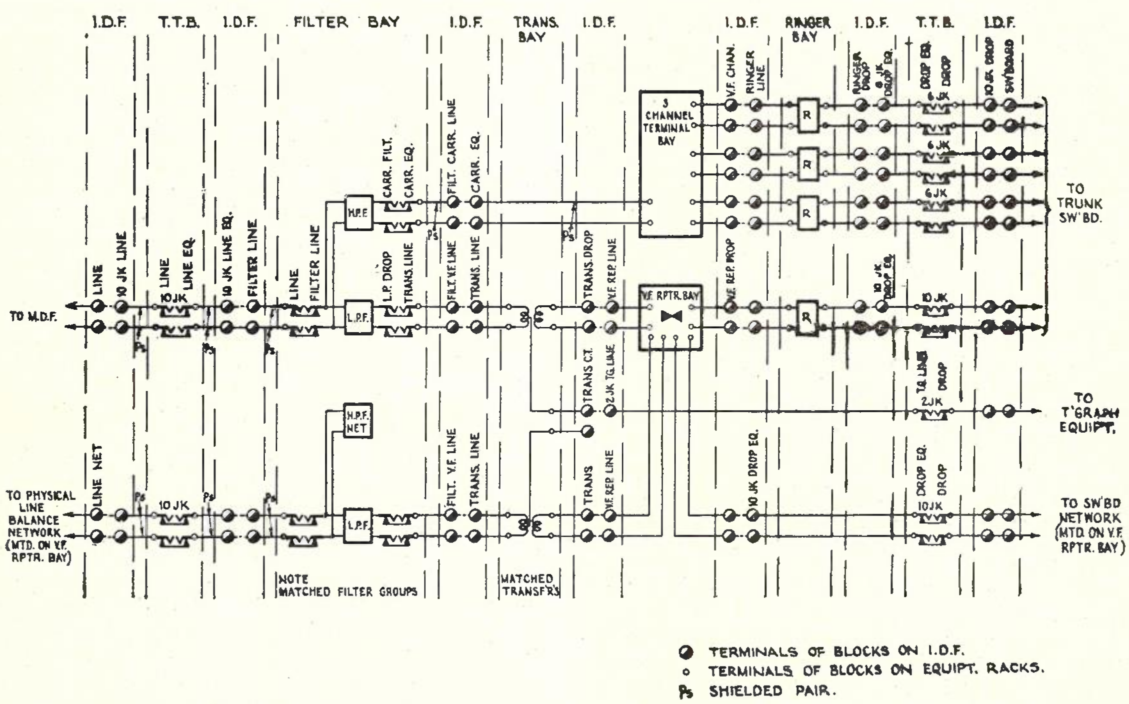
A.—(a) A suitable arrangement of the equipment is shown in Fig. 1. Rack-mounted testing equipment, consisting of a variable frequency oscillator and a transmission measuring set will ultimately be required for an office of this size, and, when installed, it should be located in the spare position adjacent to the Toll Test Board. The three-channel terminal is shown as occupying two racks, which would be representative for most terminals of this type at present in use. Future terminals or repeaters will occupy only one rack, so ample provision exists for development..

(b) (i) A block schematic of the circuit arrangement of the items of terminal equipment is shown in Fig. 2.



Q. 8, Fig. 2.

(ii) The various items of equipment should be wired together as shown in Fig. 3. It will be seen that each piece of terminal apparatus is wired to the I.D.F. to provide a fully flexible arrangement. Alterations to the circuit at a later date would then be carried out at only one point, viz., the I.D.F.



Q. 8, Fig. 3.

Q. 9.—(a) Describe the equipment required to provide a complete voice frequency signalling system to supply ringing facilities over the channels of several three-channel telephone carrier systems in a large terminal office.

(b) Describe the operation of such a system, and illustrate the description with a schematic diagram, showing the circuit of the ringer relay equipment and its location in the circuit for an individual channel of a telephone carrier system.

A.—(a) The most general form of signalling over carrier derived telephone channels is carried out by the transmission of a voice frequency of 1000 c.p.s. interrupted at 17 c.p.s. Other signalling systems utilising two different voice frequency tones are now being introduced, and will ultimately supplant the existing single frequency method, but, as installations of this type are as yet few in number, the equipment needed for a large installation of the more widespread single frequency type will be described.

Briefly, the system provides for an outgoing 17 c.p.s. ring from the exchange being accepted by a ringer panel, which in turn converts this l.f. signal to a v.f. tone of 1000/17 c.p.s. for transmission to line and to the distant terminal in the manner of speech. At the receiving terminal the ringer has to re-convert the 1000/17 c.p.s. signal to 17 c.p.s. in order to operate the switchboard signalling equipment. The office must therefore furnish two signalling frequencies, viz., 17 c.p.s. and 1000 c.p.s. interrupted at 17 c.p.s.

Both the frequencies are provided by duplicate motor generators, one working and one spare. The 17 c.p.s. machines are an integral part of the equipment of any trunk office, irrespective of whether carrier derived channels terminate there or not, since 17 c.p.s. is the normal ringing frequency for most local circuits.

The 1000/17 c.p.s. motor generators are mounted together with the associated controlling apparatus upon a Generator Bay. The generator is usually rated at 35 mas. 6 volts, and is capable of supplying current to a total of 400 ringers. By the use of solid and split rings used in conjunction with collector brushes, two sources of 1000/17 c.p.s. supply are readily obtained from the one generator.

The remaining equipment required to complete the system comprises a number of identical Ringer Bays. A fully equipped ringer bay of the type required for use with machine derived A.C. supplies consists of a 10′ 6″ rack, on the front and rear sides of which are mounted 11 ringer panels, a ringer test panel, a jack or U-link field for patch and test purposes, and a distribution panel. Thus each rack will accommodate a total of 22 ringer panels. As the installation is large, ringer test panels should be provided on the basis of one front and one rear side per three bays. On those bays where ringer test panels are not equipped it is usual practice to mount an additional ringer panel.

The operation of the ringer panel is described in (b) below.

The ringer test panel permits the operation of the ringer panel to be tested when it is supplied with 1000/17 c.p.s. current on the line side, or 17 c.p.s. from the exchange side. This panel also checks the sensitivity and the timing delay of the panel, and its immunity from operation by speech currents.

The distribution panel affords a convenient means of distributing the two 1000/17 c.p.s. sources from one of a number of different transmission levels to two groups of ringers, usually the front side units forming one group and the rear units the other. Ringer Bays are purchased initially wired to accommodate the full complement of ringers, and equipped with only those ringers required for immediate use. Loose panels can then be added as the need arises.

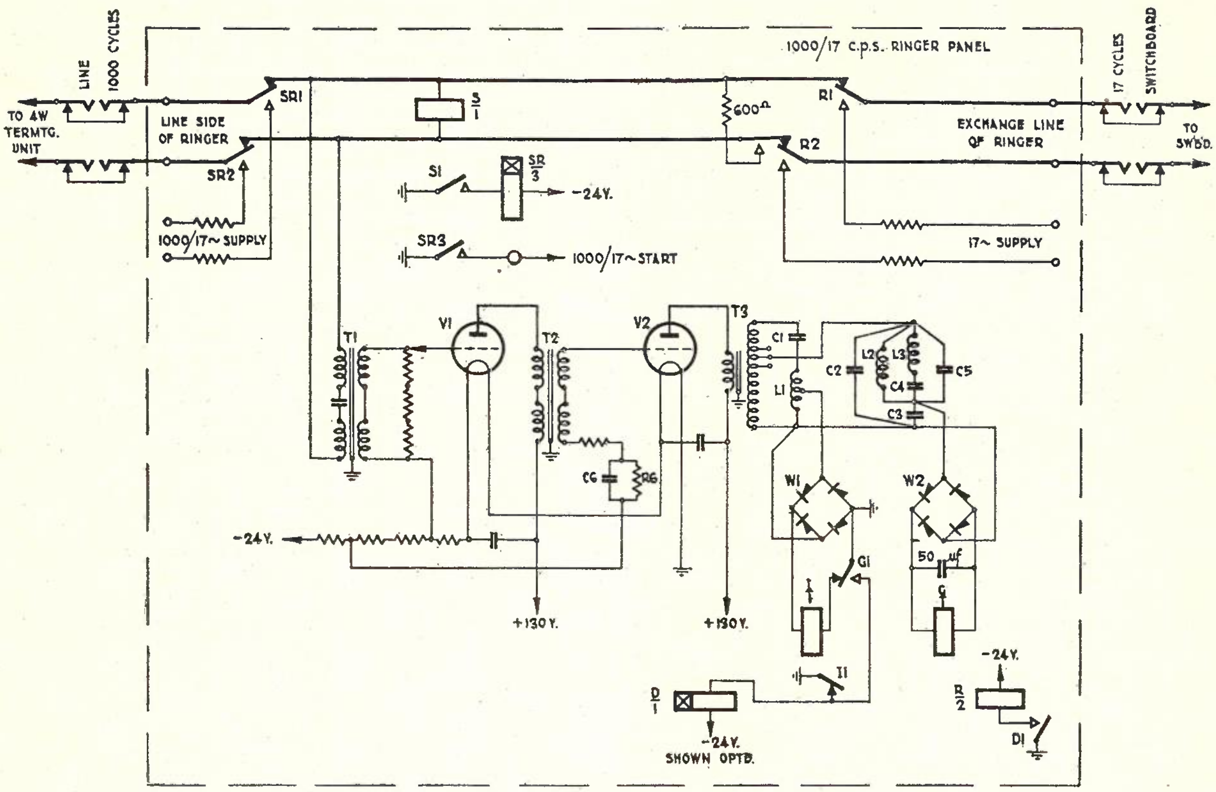
In offices requiring no more than 44 ringers ultimately, the 1000/17 c.p.s. supply is furnished by means of a valve oscillator and a relay interrupter panel. The initial bay mounts two oscillators (one spare), an interrupter panel, two ringer test panels, two jack fields, two distribution panels, and 20 ringers (nine front, 11 rear). The second bay, requiring no ringer test panels, would mount 24 ringers (12 each side).

(b) A schematic circuit of the ringer panel, showing its location in the circuit of a carrier telephone channel, is shown in Fig. 1. The ringer panel functions as follows:—

(i) **On an outgoing call:**
Seventeen c.p.s. signalling currents from the exchange switchboard are accepted by the A.C. relay S, bridged across the line. Also bridged across the line is the high input impedance 1000-cycle branch of the ringer, consisting of two stages of amplification followed by two tuned detector circuits and a relay train. The insertion of a condenser between the two halves of the primary winding of T1 ensures that the shunting impedance of this path to 17 c.p.s. currents is very high, so that its effect on the low frequency outgoing signal is negligible. The make contact S1 closes the circuit of relay SR, which in operating disconnects the voice frequency line from the exchange and connects the line to the 1000/17 c.p.s. supply at the change-over springsets SR1 and SR2. Make springset SR3 supplies an earth to a start relay associated with the 1000/17 c.p.s. equipment. The 1000/17 c.p.s. frequency is thus transmitted to the modulator unit of the channel, where it modulates the carrier frequency in the same manner as speech.

(ii) **On an incoming ring:**
The 1000/17 c.p.s. frequency produced at the output of the channel demodulator at the receiving terminal is passed via the four-wire terminating set and normally closed contacts SR1 and SR2 of an identical ringer panel to the primary winding of transformer T1, thence per two stages of amplification in valves V1 and V2. A grid leak and condenser combination R6, C6, is included in the grid circuit of valve V2 for the purpose of maintaining a constant output from this tube, notwithstanding large variations in the input voltage. This A.V.C. feature functions in such a manner as to increase the negative grid bias of V2 as the input signal level increases.

The amplified output from V2 passes to transformer T3, the secondary side of which is connected to two tuned circuits in parallel. The first consists of C1 in series with L1 and is resonant at 1000 c.p.s. The second circuit consists of condensers C2, C3, C4, C5 and the inductances L2 and L3, which combination is anti-resonant at 1000 c.p.s. Two dry-plate rectifiers W1 and W2 are tapped across portions of the resonant and anti-resonant circuits



Q. 9b, Fig. 1.

respectively. Relays I and G are also connected across the bridge points of the same rectifiers.

When a pure 1000/17 c.p.s. signal is received, relay I will immediately operate, and at I1 open the circuit of the normally operated D relay. D releases, after a period of approximately 300 msecs., and springset D1, in falling back, closes the circuit of relay R. Changeover springsets R1 and R2 disconnect the exchange from the line and connect the 17 c.p.s. supply to the exchange in order to operate the switchboard signalling equipment. In the process a 600-ohm termination is connected across the line for the period of the ring.

Since the 1000 c.p.s. branch of the ringer is bridged across the transmission path, it is only natural that, because of its sensitivity, frequencies present in speech will be of sufficient intensity to operate the ringer and cause faulty operation if sustained long enough, unless special precautions were taken to render it immune from operation due to this cause. The guard relay G exercises this particular function. All frequencies other than 1000 c.p.s. will be accepted by the anti-resonant circuit, causing G to operate. The changeover springset G1 opens the circuit of relay I and maintains the operating circuit of relay D, thus preventing the operation of relay R and the consequent transmission of 17 c.p.s. signal to the exchange equipment.

The guard circuit, together with the A.V.C. feature incorporated in the grid circuit of valve V2 and the delay period of approximately 300 msecs. in the release of relay D, ensure a high degree of immunity from voice operation.

EXAMINATION No. 2473.—ENGINEER.—TELEPHONE EQUIPMENT

K. B. Smith, B.Sc.

Q.1.—(a) One level of a rank of selectors, which has an availability of 20 to the subsequent rank, is graded to 80 trunks. If the average busy hour traffic on the level is 47.69 traffic units and the grade of service is 0.005, what would be the average number of calls recorded per busy hour on the overflow meter associated with the grading? The average duration of a call is 180 seconds.

(b) State the rules that should be observed in allotting selectors to the trunks from a grading.

(c) At telephone exchanges, pure chance traffic and smooth traffic may be met with. What do you understand about both of the above types of traffic?

A.—(a) The average busy hour traffic = 47.69 TU.

The average duration of calls = $^1/_{20}$ hr.

Therefore the average number of calls carried during the busy hour is given by

$$C = \frac{A}{T}$$

where C = number of calls

A = traffic in TU

T = holding time

C = 47.69 × 20

= 953.8

Grade of service = 0.005, i.e., 5 calls lost in every 1000 originated.

Let x = No. of calls lost.

$$\text{Then } \frac{x}{953.8 + x} = \frac{5}{1000}$$

$$x = \frac{4769}{995} = 4.8$$

Therefore an average of 4.8 calls will be lost during the busy hour.

(b) The following rules should be observed in allocating selectors to the trunks from a grading:—

(i) The traffic loading on the selector multiples should be equal.

(ii) Each grading group should have access to as many different shelves as possible.

(iii) Consecutive and near consecutive choices in a grading group should not be allocated to the selectors on the same shelf.

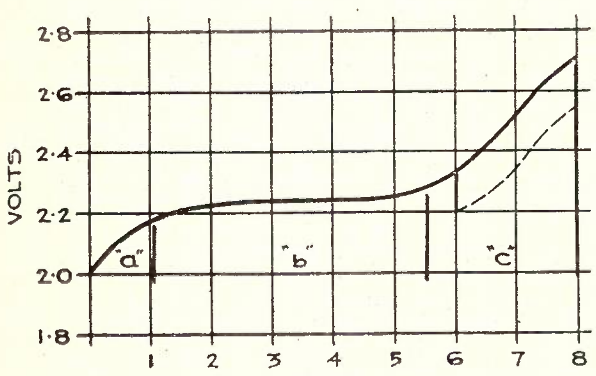
(c) **Pure Chance Traffic.**—Traffic originated in such a way that a call is just as likely to occur at any instant as at any other. The traffic originated by a large group of subscribers during the busy hour approximates very closely to Pure Chance Traffic.

Smoothed Traffic.—Where the traffic on a group of trunks does not deviate from the average at any time by more than a small percentage, and, where the calls occur more or less regularly, the traffic is said to be smoothed. The traffic offered by 1st selectors to 2nd selectors is smoother than Pure Chance Traffic.

Q. 2.—(a) Give a brief explanation of the voltage changes that occur during a complete charging period of a lead acid secondary cell. Illustrate your explanation, with a graph drawn neatly in freehand, of the voltage changes compared with time elapsed during the charging cycle.

(b) State the merits of the floating battery system of supplying power to a large telephone exchange as compared with the charge/discharge system.

A.—(a) During the charge period of a lead acid type secondary cell, three distinct phases are encountered. These three phases are indicated by the sections "a," "b" and "c" of the curve showing the rise in voltage as the charge progresses (see Fig. 1).



Q. 2, Fig. 1.

During the section "a" on the curve, which occupies approximately one hour, the voltage rises rapidly, due chiefly to the rapid building up of a polarization counter E.M.F. Following phase "a" comes phase "b," which is characterised by a steady rise in voltage over a period of about five hours at normal charging rate. The voltage rise is much slower than in phase "à," as it is caused by:

(i) The slowly increasing density of the electrolyte.

(ii) The slowly increasing concentration of acid in the facets of the plates.

(iii) The slow increase in potential of the positive plate.

When the lead sulphate has been reduced to a very small concentration, the charging current is expended in the decomposition of the water in the electrolyte. The voltage at this stage depends upon the charging rate, which is usually reduced to minimise gassing. The abrupt rise in section "c" of the curve indicates the voltage necessary to continue the initial charging rate. The dotted portion indicates the voltage rise at a reduced rate of charge over phase "c."

(b) The following advantages are gained by floating a secondary battery, used to supply power to a large exchange:—

(i) The life of the battery is increased because the deterioration of the plates by constant charging and discharging is avoided. The batteries are always charged, which is their healthiest condition.

(ii) Gassing is almost eliminated, and distortion of the plates is eliminated, thereby reducing maintenance.

(iii) Since the battery is always charged, the required reserve capacity can be obtained with a battery of smaller capacity than with the charge/discharge system.

(iv) The performance of switching equipment is improved because the voltages are maintained within closer limits.

Q. 3.—Consider the present-day technique in a 2000 type automatic exchange, and discuss the features and refinements of the equipment which can render the system expensive and complicated. Comment on the extent to which you consider these features necessary and worthwhile.

A.—The following features in present-day 2000 type exchange technique may be considered to render the system more expensive and complicated:—

(i) The use of line finders.

(ii) The full subs. I.D.F.

(iii) The D.S.R.

(iv) 10/20 selectors.

(i) The Bimotional Linefinder is not economically justified unless partial secondary working is used. The introduction of this principle certainly results in savings where not more than 25 finders/group are required, and, in these cases, their use is probably justified in spite of the rather complicated circuit. However, where more than 25 finders per group are required the use of other methods of dealing with the traffic must be considered.

(ii) The full subscriber's I.D.F. was introduced to enable the traffic load on primary equipment to be balanced. The facility undoubtedly increases the cost and complexity of cabling. The full I.D.F. is useful, but it is considered that a modified form giving limited facilities by the provision of additional terminal blocks and jumper rings at the rear of the Final Selector rack is sufficient.

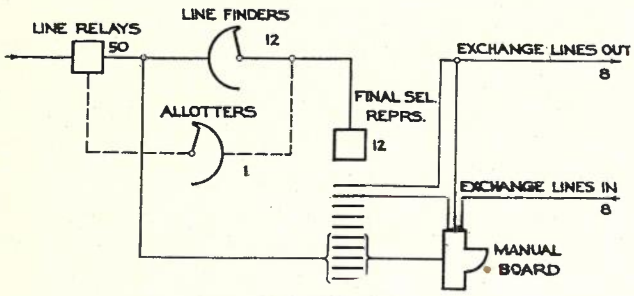
(iii) The D.S.R., being a very large and complicated switch, is expensive because of its size and because of the large amount of space it occupies. The additional facilities provided by the D.S.R. are very valuable, however, and the saving in main exchange switching equipment justifies their use in spite of the additional cost of the Branch Exchanges.

(iv) The 10/20 type selectors, although introduced overseas before the advent of 2000 type equipment, may be considered as essentially 2000 type so far as Australia is concerned. The switch has a more complicated circuit than the 10/10 switch, and is slightly more expensive. Also, the use of 660-point banks is necessary. The additional cost, however, is balanced by the reduced number required because of the increase in availability.

Q. 4.—(a) Prepare a schematic trunking diagram for a Departmental type "E" P.A.B.X. and indicate thereon the number of each unit of equipment provided for a fully equipped type "E" P.A.B.X.

(b) Detail the functions of a final selector repeater associated with a type "E" P.A.B.X.

A.—(a) The diagram is shown in Fig. 1.



Q. 4, Fig. 1.

(b) **The Final Selector Repeater.** This switch functions as a final selector on levels 1 to 9, but special facilities are provided on the "O" level. The "O" level is reserved for outgoing exchange lines from the P.A.B.X. and an automatic search is provided. When a free outlet on the "O" level is found, the Final Selector functions as a repeater, and subsequent digits dialled by the extension are repeated to the public exchange. The facility for automatic rotary search can be connected to any other level, and in some cases it is provided on level 9 for trunks to the manual board. An extension may be barred access to exchange lines, and the switch will not search when this extension dials "O"; busy tone is returned to the extension.

Q. 5.—(a) State briefly the advantages and disadvantages of providing through clearing facilities at subscribers' P.B.X.'s.

(b) State the essential facilities which must be included in the cord circuit of a private branch exchange arranged for through clearing.

(c) What do you understand by the term "non-uniform" cord circuit as applied to a private branch exchange?

A. (a) The following are the advantages and disadvantages of providing through clearing on a P.B.X.

Advantages:

(i) The holding time on exchange lines is reduced.
(ii) Transmission losses are reduced by the omission of the hold-coil.
(iii) Through-dialling is possible.
(iv) The operator's work is reduced, particularly when a trapping circuit for follow-on calls is provided.
(v) No special facilities are required for night switching; any extension can be night switched.

Disadvantages:

(i) A more complex circuit is necessary at increased cost.
(ii) Unless a button is provided at each extension, the operator cannot be brought in on an outgoing call.

(b) The following essential facilities are required in the cord circuit of a through-clearing P.B.X.:—

(i) Independent battery feed coils with positive lamp supervision each side of the cord circuit.
(ii) A trapping circuit for follow-on calls.
(iii) Provision for holding and transferring exchange calls.
(iv) The lines must be terminated during switching to prevent unbalancing of V.F. repeaters in trunk lines.

(c) A non-uniform cord circuit is one in which the functions of the front and rear cords cannot be interchanged, i.e., all calls must be answered with the rear cord and all calling must be carried out with the front cord.

Q. 6.—Detail the essential differences between the 2000 type and the pre-2000 type bimotional switch mechanism. What improvements do you consider might be made to the 2000 type bimotional switch mechanism? Your reasons for any suggested improvements to the bimotional switch mechanism should be stated.

A.—See Answer to Question 3, Examination No. 2425, Page 251, Volume 4, No. 4.

Q. 7.—What considerations justify the provision of automatic routiners at an automatic exchange? State the precise functions of each of the following items as associated with an automatic routiner:—

(a) Access equipment.
(b) Continuous routine key.
(c) Step on key.
(d) Reset key.

What test lamps are provided normally on a routiner for group selectors of the 2000 type?

A.—The introduction of automatic routiners in exchanges is justified by the following considerations:—

(i) **Improved performance of plant.** The automatic routiner can apply more tests more rapidly than can its manual counterpart. The increased speed of test permits the frequency of routining to be increased.
(ii) **Convenience.** The automatic routiner is a permanent installation and therefore is more convenient than portable manual equipment. The fact that the routiner is automatic makes it possible to carry out routine tests during slack periods when staffing is light.
(iii) **Economics.** The reduction in maintenance staff and the fact that the routine testing itself can be carried out by comparatively unskilled staff during off-peak periods greatly outweighs the increased cost of the equipment.

(a) **Access Equipment:** This is normally mounted on a rack containing six units. Each unit provides access to 100 switches. As the name implies, the access equipment serves to connect the routine testing equipment to the switch under test. It busies the switch under test as soon as it is seized.

(b) **Continuous Routine Key:** This key provides the facility of performing a continuous routine on one particular switch. It also enables the operator to select a particular switch for test.

(c) **Step-on Key:** When a fault is detected, the momentary operation of the step-on key will restore the testing circuit to normal, and step the access selector to the next switch.

(d) **Reset Key:** When a switch fails under continuous routine test, the momentary operation of the Reset Key restores the testing circuit to normal, and testing is recommenced on the same switch.

(Test lamps, see P. 116, Vol. 4, No. 2.)

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