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LAYING THE VICTORIA-TASMANIA SUBMARINE TELEPHONE CABLE.

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Introduction.

IT is the intention for this article to give an account of cable work as carried out recently during the laying of the submarine telephone cable between Victoria and Tasmania. The methods described are applicable to other types of cable or in other localities, and conversely, other methods might have been used in carrying out the present task, but it is impossible to include in one article all the experience and practices of submarine cable engineers during the last eighty years.

General.

In order to appreciate some points in laying the cable, it is necessary to know something of the route followed, the cable ship "Faraday," and the cable itself. Perhaps the chief aim in submarine cable engineering is to lay a cable and take every precaution against possible damage, as repair work is very expensive, sometimes dangerous, and in general, communication is upset for a considerable time. These facts influence every feature in the manufacture and laying of a cable.

The Route.

The first requirement in this direction is the selection of a suitable route. The sea bed should be free from rock and sudden changes in depth, and the landing points should shelve gradually, but at the same time allow the cable ship to come within, say, three-quarter mile of the shore. If possible, the site should be chosen so that the cable is not exposed to severe currents or very rough seas, as such make cable laying very difficult, or may in time cause damage to the cable. When tenders were called for this cable, alternative routes were offered to the contractors and an economic study of the offers led to the decision to lay a cable from Apollo Bay (Vic.) to Naracoopa (King Is.), thence to Perkins Bay (Tas.). At each landing point the above conditions were fulfilled, and a search through available information indicated that the sea bed was satisfactory. As a further precaution, a continuous record of the depth was taken by the S.S. "Taroona," and on four separate occasions, along slightly different routes, and before deciding on the present route the "Faraday" investigated the nature of the bottom by soundings and by dragging a grapnel slowly over the sea bed, whilst the grapnel rope was felt by holding it in the hands. In the depths experienced (30-40 fathoms) this method is very effective and sensitive. The equipment used by the "Taroona" emits a pulse of 15,000 cycles every two seconds. The receiver consists of a pile of metallic plates, and detects the reflected impulse by means of the principle of magneto striction, a continuous record being made on a chart calibrated in fathoms.

The Cable Ship "Faraday."

The cable ship "Faraday" itself is most interesting and in many ways unique. It is the second ship of that name, owned by Siemens Bros. & Co. Ltd., having been launched on 16th February, 1923, from the yards of Messrs. Palmers Shipbuilding & Iron Co. Ltd. The ship can carry about 4,500 tons of cable in its four cable tanks, and has a gross tonnage of 5,530 tons, and started the job drawing about 24 feet of water.

It is an oil-burning vessel, having two triple expansion engines, giving a speed of 12 knots or as low as ¾ knot, when the ship is grappling for cable. The four cable tanks are in line along the ship, three of them being 40 feet in diameter, each having a watertight steel cone, and all surfaces being finished flush, to prevent injury to the cable. The cable hatches all open on to a deck which runs through from bow to stern, giving as little obstruction as possible for cable work. Amidships, this deck is sheltered, having the test room and cabins on the port side, and the dining saloon, cabins and the pantry on the starboard side. Thus in rough weather a certain amount of protection can be given to the men if work is necessary, or if the ship has to stand by, the staff has ample room for exercise. Going forward from the shelter deck one comes to the winches for handling buoys, etc., and then to two control rooms for the picking-up machinery. This machinery is in duplicate on the port and starboard sides, and is on the deck below the control rooms. It is driven by Tangye steam engines, connected by double-bevel gears to drums about 7 feet in diameter, around which the cable or hauling ropes are wound. The cable or rope passes forward over a free pulley, then under the dynamometer pulley, where the tension is registered, and so out over the triple bow sheaves which overhang the clipper stem. This foredeck is used when grappling, picking up and laying buoys, or splicing a cable, and is fitted with telegraphs to the engine room and bridge, as well as necessary telephones. The after end of the shelter deck is carried over the cruiser stern, which has two cable sheaves on the starboard side. On this after deck the paying-out machinery is fitted, and facilities are provided for paying out under the control of the machinery, or allowing the drum to run free, under control of a hand brake regulated to keep a certain tension registering on the after dynamometer.

The bridge and navigation room are especially important on a cable ship, as it is probable that more precise navigation is carried out by these ships than by any others. The "Faraday" has a well-equipped bridge, giving an uninterrupted view over all operations on the foredeck. A 10-foot range finder is mounted on the navigation bridge, while perhaps the most interesting item is an automatic deep-sea echo sounder.

The Cable.

The cable itself, which was manufactured at Woolwich by Siemens Bros. & Co. Ltd., is of great technical interest, chiefly because it is the longest submarine telephone cable in the world, and is a very uncommon type. It is essentially a single conductor cable, with an external earth return. The centre copper conductor weighs 500 lbs. per naut and consists of a solid cylindrical wire, surrounded by five copper tapes, the interstices being filled with Chatterton's compound. This design is for electrical purposes, but in addition it would retain continuity, where the solid conductor alone might fracture. This conductor is surrounded by paragutta insulation, weighing 670 lbs. per naut. Paragutta consists of deresinated balata (50 per cent.) and hydrocarbon wax (10 per cent.) and de-proteinised rubber (40 per cent.), and has been developed to have a low value of dielectric constant as well as a low value of G./C. Upon these characteristics the success of the cable depends. The paragutta is covered with a linen tape over which the six copper tapes forming the return conductor (840 lbs. per naut) are wound with a long lay. These in turn are covered with a thin copper tape having a short overlapped lay to prevent damage to the paragutta from teredo worms. Over this is another linen tape, and up to this stage the cable is uniform throughout its length. At the shore end a thin lead sheath comes next and extends to a point below low water, to protect the paragutta from damage due to exposure. For most of the length there is no lead sheath and over a large layer of marline serving the galvanised steel sheathing wires are laid. In the main type, these are covered with another serving, but at the shore ends a second heavier armouring is used, as the cable is more liable to damage due to movement, prevailing tides, rocks, etc. An intermediate type is used between the shore end and deep water, and in this type a single layer of the heavier armouring is used. The weight per naut of the various types is:—

Main	6.7 tons
Intermediate	8.7 tons
Shore End	19.0 tons

Fig. 1.
Hauling end of cable ashore at Apollo Bay, using float barrels every 10 fathoms.

Mark Buoys.

The first part of the cable laying is to lay mark buoys at distances of about seven miles apart and along the line a little off the actual cable route. The position of each buoy is very accurately recorded, and these are used later on as reference points for navigation when the cable is being laid. The reason for laying mark buoys just off the route is to prevent their moorings from fouling the laid cable.

Landing the Shore End.

In proceeding to lay the cable, there are two distinct parts, firstly laying the shore end, and secondly paying out after the end is landed. The end must be hauled ashore, and in order to have unified control, the hauling is done by the ship. This unified control is a very essential feature of all cable work. Firstly, the ship comes in as close as possible and anchors, due consideration being given to prevailing winds, currents, and tides. Two wooden sand anchors are buried about 60 feet apart, and to each a running sheave is fixed. A 4-inch manila rope is run through these sheaves and the two ends must then be passed out to the ship. Usually these ends are bent on to ropes sent out from the ship. At Apollo Bay, an attempt was made to pass the ropes over the surf by firing a rocket attached to a light line from a cutter, but in each of five attempts they fell short, and finally arrangements were made to fire a life-saving rocket from the shore. In spite of its 19 years of age, this rocket was highly successful, and proved quite an interesting diversion. At the other points, ropes were landed from a cutter. After this stage, the 4-inch rope is paid out over the stern to the shore sheaves and is hauled in over the bow. To the 4-inch rope a 3 x 3 steel and hemp hauling line is fixed, and when this reaches the bow, cable hauling is started. The cable is bound at several points to the 3 x 3 rope, and as it passes over the stern an oil-drum float it attached about every 10 fathoms. Slowly the cable is hauled ashore, and when sufficient has arrived to provide any necessary spare on the beach the 3 x 3 rope is freed, and oil drums are recovered wherever possible from each end, those left freeing themselves within 10 hours as a rule. Fig. 1 shows the landing of the cable at Apollo Bay.

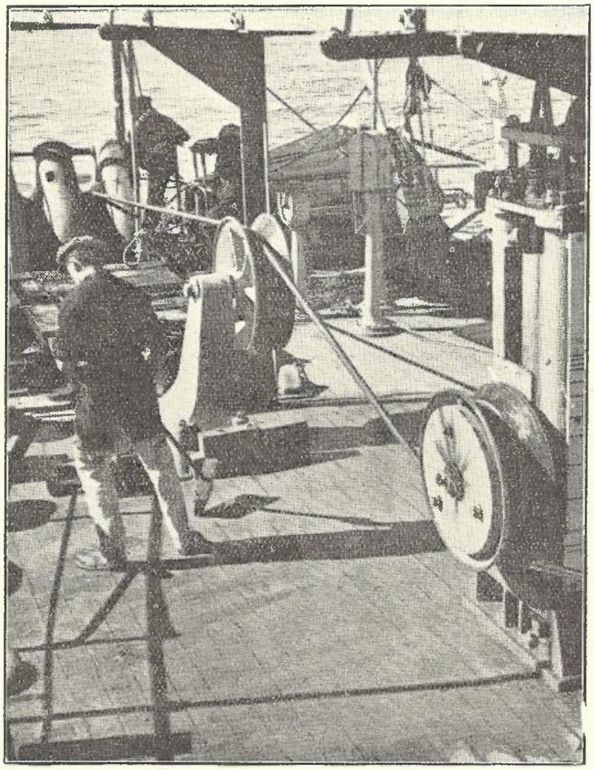


Fig. 2.
Paying out cable. Note dynamometer on right.

Laying the Main Cable.

Having landed the shore end, the ship picks up the shore party, and gets under way with the more speedy operation of laying the main cable. To a casual observer this task appears to go very easily, but a walk round the ship will show that it is really because several working units are each carrying out their own unobtrusive part of the job. Starting from the cable tank, where the cable passes out at about six nautical miles per hour, a cable gang ensures that no kinks occur, and at the end of each layer removes the wooden spacing pieces. An iron ring known as a crinoline is lowered as the tank is emptied and helps to prevent a kink from occurring. This is most important, as such a kink would certainly foul somewhere, and before the ship could stop a break would occur, and the end would carry away. The cable passes to the drum of the paying-out gear aft which runs free under control of a manual water-cooled brake that maintains a fixed tension on the cable, due allowance being made for the type of cable. Fig. 2 shows the cable being paid out between Apollo Bay and King Island. On the navigation bridge, bearings are taken on land points, or mark buoys, and at each bearing the drum room is notified, so that later the true distance between points can be compared with the length of cable laid, and the amount of slack calculated. In shallow water, such as Bass Strait, the minimum possible amount of slack, that is, about 0.7 per cent. is satisfactory when the sea bottom is smooth. In addition, the navigator's observations are used to plot the course of the cable in case repairs are necessary later in the life of the cable.

Meanwhile the test room on the ship, and the testing staff ashore, have been very busy taking d.c. tests from the ship and a.c. tests from the shore to a program which recommences every hour. In the event of any fault occurring, operations can be stopped and the trouble investigated.

The Buoyed Ends.

These operations continue until about half the distance between the cable huts has been covered, when the cable end is sealed and buoyed. In the case of the second half of the section, the end is buoyed over the stern, then picked up over the bows. The ship then manœuvres up to the buoyed end of the first half-section, and upon recovering the buoy takes that end also over the bow sheaves. When the ends are stripped, tests are made to each shore station, and the ends are then handed over for the important tasks of jointing and splicing.

Jointing and Splicing.

Before commencing this task the two cable ends are secured over the sheaves by a single strop which divides into two rope stoppers, one for each cable. Next the wires, serving, teredo tape, and copper return conductors are each carefully laid back in turn on each side of the joint, exposing the paragutta. The joint in the central conductor is made by scarfing the ends, and soldering these together, then covering the joint with fine copper wire, so that if the conductor parts, then continuity is maintained. After tapering the paragutta, the central joint is wrapped with sheet paragutta to which heat is applied with a low temperature lamp. After considerable work this is covered with two layers of guttapercha, which, with the aid of heat, makes an airtight, waterproof, homogeneous joint, over which protective rubber tapes are applied, before the return conductor is joined through by soldering. The teredo tape is then replaced, after which the final stage in the job commences, namely, the overlay splicing of the armouring wires. The overall length of this splice is about 30 feet, and the whole of this is protected with a layer of marline serving.

The completed splice is now to be put overboard, and to do this the strop is paid out until

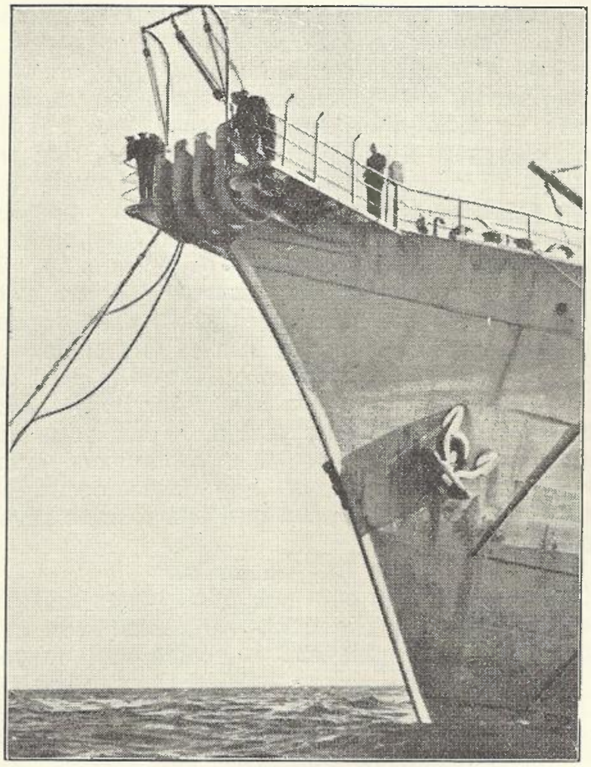


Fig. 3.
Two ends of cable inboard over bow sheaves during final splice. Note rope stoppers taking strain.

the bight of the cable is well over the bow sheaves, when the strop is chopped through, and the splice falls to the sea bed. The shore stations then make through tests, and send the results to the ship. It only remains for the ship to recover the mark buoys, and everyone can retire with a good job well done. Figs. 3 and 4 show two aspects of the final splice; the two ends of the cable inboard over the bow sheaves and the deck operations involved in the splice, respectively.

Sidelights on the Work.

It is only natural that a task of this sort is not accomplished without unusual incidents occurring. The rocket firing at Apollo Bay has already been mentioned. At Naracoopa, owing to a heavy swell, it became necessary to land two of the staff by means of a dinghy, which unfortunately overturned on a roller and precipitated the occupants into three feet of water, thereby causing a certain amount of dry amusement for the others.

Picking up mark buoys was always interesting. This could be done by a crew in the cutter, in which case there was usually a good wrestling match between the boat and the buoy, or in calm weather the ship was brought up to the buoy, which was then gently lassooed with a 4-inch manila rope.

The final splice was done with the traditional celebration of burying the "dead man." On completing the splice, the crew, headed by the bosun and a "chaplain," carried an effigy of a dead man and marched reverently up the foredeck, which was illuminated by floods and a searchlight. After reading an amended burial

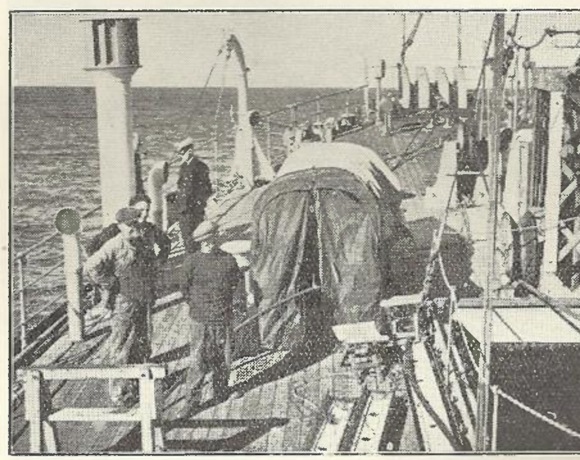


Fig. 4.
Final splice being made under protection of tent.

service the corpse was lashed to the cable. The Department's representative was then given the privilege of cutting through the strop. It was only at the third mighty swing that it was discovered that the axe provided was a good imitation made of tin. Fortunately, the dead man remained buried, for should he rise the cable is doomed to fail.

On returning to Stanley, a "final splice" dinner was held on board, followed by a volunteer concert on the shelter deck, which was gaily done out in bunting for the occasion. This function provided a very pleasant finish to a task which was carried out successfully under adverse conditions, and resulted in the establishment of a new record—the longest submarine telephone in existence.

THE MATHEMATICAL THEORY OF PROBABILITIES
APPLIED TO TRUNKING PROBLEMS IN TELEPHONE EXCHANGES

C. McHenry, A.M.I.E. Aust.

Introduction.

The object of this treatise is to present some new results derived from theoretical studies which are of direct practical interest, and which it is thought will afford closer agreement in actual cases.

General Considerations.

The essential function of a telephone system is to provide a means of point to point intercommunication.

In the design and the manufacture of the plant employed the object is to evolve an efficient system, firstly by ensuring that the service is satisfactory; secondly that the minimum amount of plant is provided to meet requirements, and thirdly that the cost of supplying, installing and running the plant is as low as possible.

The plant installed in a telephone system falls naturally into two distinct groups, which are—

The first group which comprises the component items exclusive to and directly associated with each service such as the telephone in the subscriber's premises, the line connecting the telephone with the exchange, and the equipment in the exchange on which a service is terminated such as line and cut-off relays in a manual system and first preselectors or their equivalent in an automatic system.

The second group which comprises the component items available for use by all subscribers such as cord circuits in a manual system, and group selectors, final selectors or their equivalents in an automatic system.

From a purely traffic standpoint, and excluding all questions of design, the equipment in a telephone exchange can be regarded as an aggregation of—

(a) Connecting points,
(b) Connecting channels.

Associated with each connecting point is a unit made up from the items coming under the first group, whilst each connecting channel is made up from items coming under the second group.

In the exchange the connecting points are, therefore, points of entry for originated calls and points of departure for outgoing calls. The connecting channels provide the means of collecting calls and distributing them over the connecting points.

A slight distinction is necessary with reference to the connecting channels. In a manual system these are self-contained and hence may be termed simple. In an automatic system a connecting channel is built up stage by stage as a call proceeds, by a number of simple channels connected end to end, and thus may be termed compound. The differences are due solely to design and do not affect the fundamental principles discussed herein.

The number of connecting points and their associated equipment depend only on the number of subscribers and is quite independent of the volume and distribution of the traffic passing through the exchange. As the equipment coming under this heading must be supplied on a per subscriber basis no problems arise concerning quantities. On the other hand it is well known that the connecting channels need not be provided in sufficient number to handle the maximum possible simultaneous connections and, therefore, as a generalised statement at this stage it can be postulated that the number of connecting channels depends, in some manner as yet undefined, on the volume and the distribution of the telephone traffic passing through the exchange.

The subdivision of plant into two groups as discussed, is of fundamental importance to the telephone engineer. In particular the subdivision represented by the second group is the genesis of all problems concerned with the study and investigation of the laws governing the dispersion of telephone traffic, the associated problem of trunking and the co-related question of plant provision.

Trunking may be defined briefly as the process of collecting and distributing telephone traffic. In practice, trunking arrangements vary considerably due to design and other factors, but the fundamental principle of trunking is common to all telephone systems.

The Essential Nature of Telephone Traffic.

From a statistical standpoint telephone calls are events of a certain kind having a random incidence in point of time and possessing the characteristic property of duration. The time factor is fundamental and apart from incidence constitutes the essential nature of the event: a call with zero holding time is impossible.

Telephone traffic is a phenomenon which results from an aggregation of telephone calls and is, therefore, a quantity in two dimensions, namely, call density and time.

Before the phenomenon known as telephone traffic can have any objective reality two requirements are essential—

(a) Sources which originate calls, and
(b) Means for collecting and routing these calls.

In a telephone exchange (a) and (b) correspond to the connecting points and the connecting channels respectively. In an exchange system consisting of connecting points or connecting channels only, in the sense as defined, telephone traffic would be impossible, since either arrangement by itself cannot function.

Many of the differences which have arisen in theoretical work are due to failure to discriminate between the essential nature of telephone calls and the aggregation known as telephone traffic which they cause.

Owing to the random incidence of telephone calls, the resultant phenomenon of telephone traffic is one coming within the province of Probability. From a mathematical standpoint telephone traffic is an attribute of a particular kind of statistical aggregate.

Theoretical Considerations.

With the object of developing certain fundamental ideas along formal lines, some general aspects of special importance will be discussed so as to provide a framework for the problems which are dealt with.

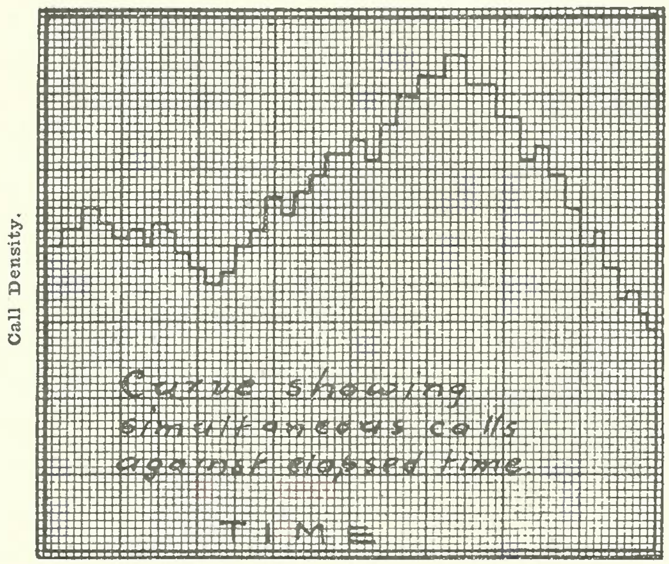


Figure 1.

Figure 1 shows a typical traffic record in which the ordinates give call density and the abscissæ indicate time. The fluctuating nature of the call density throughout the period of observation will be apparent from the irregular outline of the curve. The first point of importance which must be appreciated is the absolute impossibility of predicting the changes which occur from moment to moment; for any given trunk group no two curves of this type will ever agree as regards shape. Still keeping figure 1 in mind it will be clear that the traffic can be expressed quantitatively by the area of the curve, which reveals the second important point, namely, that although a number of different observations taken on a given trunk group in which the conditions do not change will give as many different curves when plotted in the form of figure 1, nevertheless all curves will have one factor in common, namely, the area which would be found to be practically the same for each curve.

A curve plotted in the form of figure 1 is

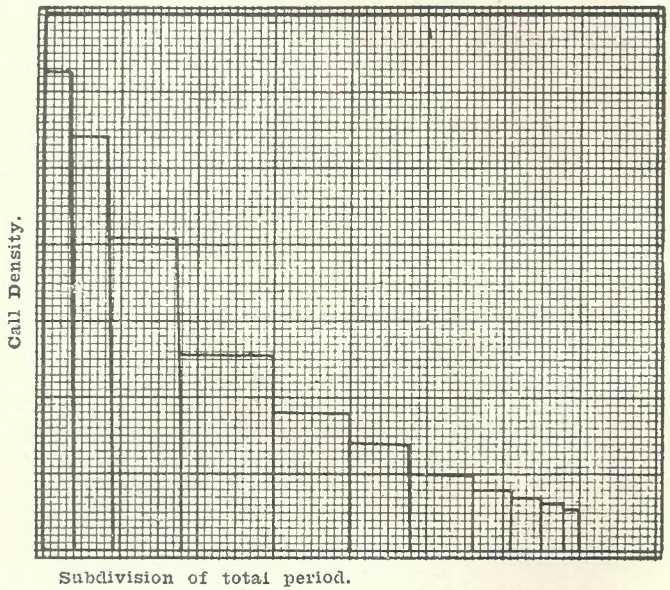


Figure 2.

unsuitable for statistical purposes and, therefore, it is the usual practice to re-arrange all primary curves of this type as in figure 2, from which is obtained what is known as a frequency distribution or more generally a dispersion. Essentially both curves are the same, but time as an independent variable has been eliminated from figure 2. Curves of the form shown in figure 2 provide a means of reducing all dispersions to a **common** basis as well as making available a convenient means for systematically comparing theoretical and practical results.

Provided the conditions in any given trunk group do not change then any number of observations carried out for the same fixed period of time will all agree closely if plotted in the form of figure 2, although the primary curves typified by figure 1 will be different for each observation.

Now proceed a step further by assuming that n observations have been made on a given trunk group in which the **average** traffic does not change and that each observation is reduced to the form of figure 2. Let the period of each observation be the same and equal to T, and furthermore let the period of time in each observation during which the call density (or number of simultaneous connections) was 0, 1, 2, 3, x be respectively t_0, t_1, t_2, t_3, t_x, then as n becomes indefinitely great and $\longrightarrow \infty$ the ratio

$$\sum t_x/nT \longrightarrow S_x \quad - - - - - - \quad (1)$$

where S_x is defined as the probability that at any given instant during a period T there will be exactly x simultaneous calls in progress, or in other words that the call density will be exactly x.

It must be clearly kept in mind that S_x is a limit. When sufficient information is available, it is possible to determine S_x mathematically without the necessity of making an indefinitely large number of observations, which in any case is an impossibility in practical work. It also follows that having determined S_x it would be a remarkable concidence if the observed ratios in any single observation agreed exactly therewith. In any single observation we can expect results in close agreement with theory, but only after taking an infinite number of observations will the average value represented by the left-hand member of (1) agree with the theoretical value of S_x. If the exact physical and mathematical significance of the function given by (1) is kept clearly in mind no difficulty should arise in appreciating the meaning of S_x.

No restrictions have been made as to T, which may be measured in seconds, minutes, hours, days or weeks, provided that t_x is expressed in the same units. Therefore, we can generalise at once and assign to T the value of unity (irrespective of its value in any system of units) and thereby express the values t_0, t_1, t_x etc., as a fraction. This actually occurs in any system of units: for example, assume T is 60 minutes and that t_x is 5 minutes then $t_x/T = 5/60 = 1/12$. If T is 3600 seconds then t_x is 300 seconds leading to the same result. On the postulate that T = 1, S_x acquires a further meaning since it then expresses the **average** proportion of the time during which x simultaneous connections are in progress. This is easily proved when it is remembered that the sum of the separate probabilities must equal 1 or certainty, and since these are referred to a period of time also equal to 1 the separate probabilities in the complete disjunction must, therefore, indicate the division of the natural time unit in respect of the various call densities.

From the hypothesis developed above and expressed mathematically by (1) it follows that the area of figure 2, that is the traffic carried by the trunk group, will be given by the expression

$$A = \sum_{x=0}^{x=X} x\, S_x \quad - - - - - - \quad (2)$$

where A = the number of traffic units or the average number of simultaneous calls in progress and
X = the total number of trunks in the group.

In the third section it was shown that telephone traffic is a quantity in two dimensions, namely, call density and time, and as time enters into the matter it will be clear that the amount of traffic handled depends on

(a) the total time considered, and
(b) the rate at which traffic arrives during this period.

Let it be assumed that the phenomenon can be represented by a continuous curve such as that depicted by figure 3, then the amount of traffic for the period T included between the limits t_a and t_b will be given by the included area between these two points, that is

$$A_T = \int_{t_a}^{t_b} y.\, dt \quad - - - - - - \quad (3)$$

from which it follows that if y can be determined as a function of time, number of

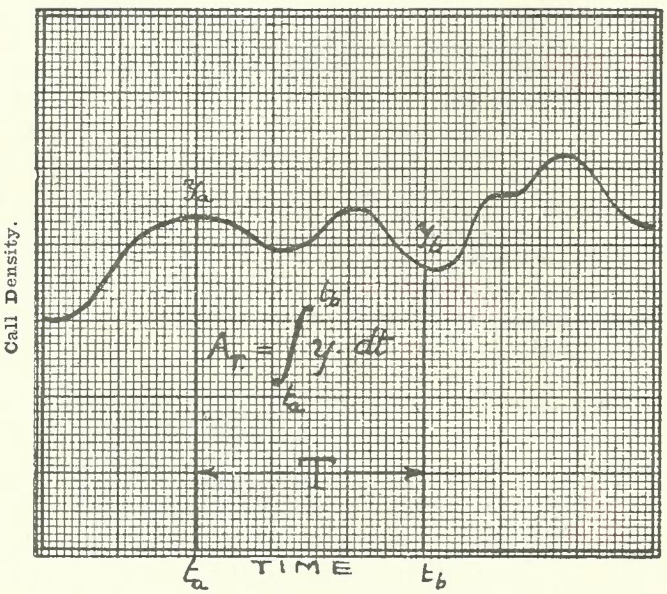


Figure 3.

trunks in the group or other relevant factors, the conditions in the trunk group can be defined. Attention is thus directed to y and it becomes necessary to ascertain the factors which cause y to change in value. The factors sought must depend on the calls and the manner in which they arrive and depart in point of time. If a call arrives, y increases; if a call ends, y decreases; if a call arrives at the instant another call ends, y remains unchanged. This immediately introduces the concept of a rate and it follows that the changes in y depend upon the algebraic sum of the rates at which calls are arriving and departing. Let this difference be represented by a then **a is defined as the nett rate at which calls arrive,** being positive when calls arrive at a rate greater than that at which they depart and vice versa. More simply a can be obtained directly since

$$a = \frac{dy}{dt} \quad - - - - - - \quad (4)$$

From the random nature of telephone traffic it follows that a is a fluctuating quantity and obeys no predeterminable law, but it is possible to ascertain the average value of a for various call densities.

It will now be seen that telephone traffic is a phenomenon which results from the merging of telephone calls, and like other phenomena the effects depend upon the medium of manifestation. In telephone traffic the number of connecting channels is the **primary** factor which determines the dispersion. For example, assume a source of N connecting points, each originating a known number of calls in a specified time. For the moment assume also that there are no incoming calls. In regard to the connecting channels three arrangements are possible, namely

(a) No connecting channels, in which case no traffic results even though calls are offered.

(b) x connecting channels, where x $>$ N, in which case some calls will be accepted and some rejected.

(c) N connecting channels, in which case all calls will be accepted.

In each of the three foregoing arrangements the essential nature of the telephone calls and their incidence is not altered. This result is important.

There are several sources of interference which affect the dispersion of the traffic associated with a group of connecting points; these are

(a) Mutual interference where the subscribers in the group call each other.

(b) External interference where subscribers from other groups call into the group.

(c) A combination of (a) and (b).

Although perhaps not readily apparent the extent of the interference caused by these three factors is governed by the connecting channels. If incoming calls are restricted there is less effect on outward calls and vice versa.

The most direct method of deriving the fundamental functions for the dispersion in a trunk group is based on what is known as the Theory of Statistical Equilibrium. In applying this theory it is first necessary to postulate that there is a large number of similar trunk groups all operating under identical conditions in which the average traffic is A and the number of trunks is x. If a particular group is examined at a given instant its instantaneous condition can be described by stating how many of the x trunks are in use. If the same group is examined again after a short interval of time Δt has elapsed two changes of different kinds will be found, namely, certain calls will have ended and new calls will have arrived. Assume now that, instead of examining one trunk group, the conditions in all trunk groups are investigated, both with respect to their momentary condition and the manner in which this alters. It will be found that a fundamental property of such an aggregate is, that notwithstanding the individual variations in each group the general conditions remain unchanged and that the individual variations of each kind cancel each other. This property is called statistical equilibrium. This principle, therefore, asserts that the overall position for all groups remains constant at all times, and if in one group a new call arrives it will be balanced by a call ending in another group, and so on, equilibrium being maintained despite the individual variations in each group.

The main theorem for the dispersion of traffic in a trunk group can now be developed.

Let a_x = the average rate of arrival when the call of density is x and

S_x = the probability that the call density is exactly x.

X = the number of trunks in the trunk group.

Now examine a given trunk group at a given instant. The probability that x calls are in progress is given by S_x and the probability that during the short period of time Δt another call will arrive is therefore given by

$$S_x \cdot a_x \cdot \Delta t$$

and by hypothesis this must be balanced by a call ending in another group in which there are (x + 1) calls in progress, the probability for which is

$$(x + 1) \cdot S_{(x+1)} \cdot \Delta t$$

Since both transitions leave the balance undisturbed they must be equal, and hence

$$S_x \cdot a_x \cdot \Delta t = (x + 1) \cdot S_{(x+1)} \Delta t \quad - - \quad (5)$$

and the general state of statistical equilibrium is therefore given by

$$\sum_{x=1}^{x=X} S_{x-1}\, a_{x-1} = \sum_{x=1}^{x=X} x\, S_x \quad - - \quad (6)$$

In developing (6) transitions of the first order only have been considered. It is necessary to take into account transitions of the second and higher orders. A transition of the second order is one in which two calls arrive or end in the period Δt and by hypothesis these transitions and others of higher order are required to cancel each other. The transition from x to (x + 2) is given by

$$S_x \, a_x \, a_{(x+1)} \quad \Delta t \text{ - - - - - - } (7)$$

and in the group in which there are (x + 2) calls in progress one call can end in (x + 2) ways and thereafter another call can end in (x + 1) ways, and the complete transition is given by

$$S_{(x+2)} \; (x+2) \; (x+1) \Delta t \text{ - - - } (8)$$

Now multiply (7) and (8) by $S_{(x+1)}$ and it will be seen that the following equalities result:

$$\left.\begin{array}{l} S_x \, a_x = (x+1) \; S_{(x+1)} \\ S_{(x+1)} \, a_{(x+1)} = (x+2) \; S_{(x+2)} \end{array}\right\} \text{ - - - } (9)$$

that is (7) and (8) can be separated into two of the terms contained in the expansion of (6) and similarly for transitions of the third and higher orders. Therefore, a transition of the n^{th} order is equivalent to n transitions of the first order. This establishes the validity of (6) by proving that all possible transitions are included. The problem is simplified in that transitions of the first order need only be considered.

Returning now to (6) we have a relation between S_x and a_x in which S_x will be taken as the dependent variable. Expand (6) and equate equivalent terms, when by obvious transformations the following general expression is easily developed:

$$S_x = \frac{\dfrac{a_0 a_1 \text{ - - - - } a_x}{x\,!}}{1 + a_0 + \dfrac{a_0 a_1}{2\,!} + \dfrac{a_0 a_1 a_2}{3\,!} + \text{ - - - } \dfrac{a_0 a_1 \text{ - - } a_X}{X\,!}} \text{ - } (10)$$

thereby arriving at the fundamental theorem of dispersion. The function in (10) is a general solution in which a is the only unknown. In particular cases a can be determined quantitatively provided the parameters are known. The function in (10) is discrete, as was to be expected from the nature of the problem.

Application of Fundamental Theorem to Problems of Practical Interest.

In order to demonstrate the general nature of (10) it will be of interest to discuss several practical cases by way of example:—

Problem No. 1.

The parameters taken will be as follows:—

(a) Number of calling lines: finite and equal to N.
(b) Number of trunks = N.
(c) Average traffic/line = p.
(d) Average rate of arrival: per free line = a.
(e) No incoming calls.

From the foregoing parameters it will be obvious that the dispersion is normal, but this will be proved.

When 0 trunks are in use N lines are available to make calls, and whilst this condition holds the average rate of arrival will be Na: similarly when x trunks are engaged there will be (N — x) lines available to make calls, and the average rate of arrival under this condition will be (N — x)a. The conditions for statistical equilibrium will therefore be given by:

$$\left.\begin{array}{l} S_0 \; Na = S_1 \\ S_1 \; (N-1)a = 2 \; S_2 \\ S_2 \; (N-2)a = 3 \; S_3 \\ \overline{\qquad\qquad} \\ S_x \; (N-x)a = (x+1) \; S_{x+1} \\ \overline{\qquad\qquad} \\ S_{(N-1)} \, a = NS_N \end{array}\right\} \text{ - - - - } (11)$$

and by solving for S_x or by direct substitution in (10) using (N — x)a for a_x and $\binom{N}{x}$ for N!/(N — x)!x! the following expression is easily derived:

$$S_x = \binom{N}{x} \frac{a^x}{x!} \Bigg/ \sum_{x=0}^{x=N} \binom{N}{x} \frac{a^x}{x!} \text{ - - - } (12)$$

and it now remains to determine a. In this problem a can be derived directly. The probability that a given subscriber will make a call during any given period Δt is a compound probability made up of

(a) The probability that he is free, and
(b) If free, that he will make a call.

The probability that he is free is given by (1 — p), and therefore the probability that any given line makes a call during the short period Δt is $(1-p) \; a \cdot \Delta t$ and since during the period T the total traffic originated is p we have

$$\int_0^1 (1-p) \; a \cdot dt = p \text{ - - - - - - - - } (13)$$

which on being evaluated reduces to

$$(1-p) \, a = p \text{ - - - - - - - - - - - } (14)$$

from which

$$a = p/(1-p) \text{ - - - - - - - - - - } (15)$$

and letting A = pN the expression in (15) reduces to $a = A/(N - A)$ - - - - - - - - - (16)

and $$a_x = \left(\frac{N-x}{N-A}\right) A \text{ - - - - - - - - - } (17)$$

and the expression for S_x becomes

$$S_x = \binom{N}{x} p^x \; (1-p)^{N-x} \text{ - - - - - - } (18)$$

$$= \binom{N}{x} \left(\frac{A}{N}\right)^x \left(\frac{N-A}{N}\right)^{N-x} \text{ - - - - } (19)$$

$$= \frac{\binom{N}{x}\left(\frac{A}{N - A}\right)^x}{\left(1 + \frac{A}{N - A}\right)^N} \quad \text{- - - - - - - - (20).}$$

The expression given by (18) is generally known under the name of Bernoulli's Theorem.

Problem No. 2.

The parameters remain the same as for the first problem with the exception that N is to be assumed as being indefinitely great, that is $N \longrightarrow \infty$.

Returning to (20) for a moment the numerator is the $(x + 1)^{th}$ term of the denominator. Writing this term in full gives

$$\frac{N!}{x!\ (N - x)!\ (N - A)^x} A^x$$

$$= \left(\frac{\overbrace{N\ (N - 1)\ (N - 2)\ \text{- - - -}\ (N + 1 - x)}^{x \text{ terms}}}{\underbrace{(N - A)\ (N - A)\ (N - A)\ \text{- - -}\ (N - A)}_{x \text{ terms}}}\right) \frac{A^x}{x!}$$

As $N \longrightarrow \infty$ each term within the brackets in the numerator and the denominator becomes sensibly equal to N and in the limit therefore as $N \longrightarrow \infty$

$$\binom{N}{x}\left(\frac{A}{N - A}\right)^x \longrightarrow \frac{A^x}{x!}$$

and $\left(1 + \frac{A}{N - A}\right)^N \longrightarrow e^A$

so that we derive the expression

$$S_x = \frac{e^{-A} A^x}{x!} \quad \text{- - - - - - - - - - - - (21)}$$

which is known as the Poisson function, a theorem very well known in mathematical physics.

Alternatively if (17) is inspected it will be observed at a glance that when $N \longrightarrow \infty$

$$\left(\frac{N - x}{N - A}\right) A \longrightarrow A$$

and that $a_0,\ a_1,\ a_2,\ \text{- - -}\ a_x = A$ and therefore by direct substitution in (10) the result given by (21) is obtained.

The result arrived at in (21) is important since we can infer from it that when $N \longrightarrow \infty$, the average rate at which calls arrive is independent of the number of simultaneous calls in progress, and therefore if N is large enough in practical cases we can use (21) in preference to (18), (19) or (20) without introducing appreciable error whilst considerably simplifying computational work.

We can deduce another important property of a_x by considering the individual terms in the expansion of (6). Take the general term

$$S_x\ a_x = (x + 1)\ S_{(x + 1)}$$

then it is easily proved that

$$S_{(x + 1)} = \frac{S_x\ a_x}{(x + 1)} \quad \text{- - - - - - - - - - - - - (22)}$$

and $$a_{(x + 1)} = \frac{x \quad S_x}{S_{(x + 1)}} \quad \text{- - - - - - - - - - - - (23).}$$

Problem No. 3.

The problem now to be discussed and extensions thereof are of special importance in practical work and briefly may be described as the problem of the isolated exchange.

Assume an exchange of N lines serving the telephone needs of an isolated community, that is, all the telephone traffic handled by the exchange is confined to the N lines and there is no intercourse with other groups. Such a system represents a closed arrangement and would be typified by a telephonette system or a small type of P.B.X. installation without exchange access.

The main characteristics of an isolated system are that

(a) every complete connection requires two lines within the group;
(b) the total traffic originated is equal to the total traffic received;
(c) the maximum number of simultaneous calls in progress cannot exceed N/2 where N is even and (N — 1)/2 where N is odd and
(d) mutual interference is present.

The parameters assumed will be

N = number of lines in the group assumed even for the time being. The case where N is odd is discussed later.
p = the average traffic/line originated.
X = the number of connecting circuits available: in this instance no restriction is assumed and X will be taken as N/2 since this represents the maximum possible call density.
a = the rate of arrival/free line.
A = Np.

From this theory of statistical equilibrium when 0 calls are in progress the transition to 1 call in progress is given by

$$S_0\ .\ N\ .\ a\ .\ \Delta t = S_1\ \Delta t$$

and when this transition has taken place there remain (N — 2) lines to effect the next transition which therefore becomes

$$S_1\ (N - 2)\ a\ .\ \Delta t = 2\ S_2\ .\ \Delta t$$

and so on for other transitions. It is to be observed that the left-hand members as now derived differ from those of (11) as, of course, must be the case.

In the general term for S_x it will be noticed that an expression in the form of

$$[N\ (N - 2)\ (N - 4)\ (N - 6)\ \text{- - -}\ ]\ /\ x!$$

is encountered. To make the resultant expressions compact it is necessary to simplify this factor which is perhaps strange in the orthodox field of combinatorial analysis. Divide each term in the expression by 2 and obtain

$$\left(\frac{N}{2}\left(\frac{N-2}{2}\right)\left(\frac{N-4}{2}\right)\left(\frac{N-6}{2}\right) \text{-- x terms}\right) / x!$$

which is easily simplified into

$$2^x \begin{bmatrix} \frac{N}{2} \\ x \end{bmatrix}$$

and therefore after clearing up the statistical equations and solving for S_x the following expression is derived:

$$S_x = \frac{\begin{bmatrix} \frac{N}{2} \\ x \end{bmatrix}\left(\frac{2A}{N-2A}\right)^x}{\left(1+\frac{2A}{N-2A}\right)^{\frac{N}{2}}} \text{ - - - - - - } (24).$$

The various steps followed in arriving at (24) have not been shown in detail since in principle they are identical with those for problem 1, the only differences being due to the parameters.

Problem No. 4.

The same parameters will be assumed as for the preceding problem excepting that N will be assumed to be indefinitely great, that is $N \longrightarrow \infty$.

By proceeding along similar lines as indicated for the second problem it is easily proved that when $N \longrightarrow \infty$

$$S_x \longrightarrow \frac{e^{-A} A^x}{x!} \text{ - - - - - - - - - - - } (25)$$

which is identical with the result arrived at in (21) and therefore when $N \longrightarrow \infty$ there is no mutual interference and in practical work when N is reasonably large the effect of incoming traffic on the originated traffic and vice versa can be neglected, without introducing appreciable error.

All the problems so far discussed have one feature in common, namely, there is no lost traffic, or in other words sufficient connecting channels have been assumed available to meet all demands, and in consequence no source of hindrance has arisen owing to restriction in the number of outlets provided. The problems dealt with are not the ones of greatest practical importance since in actual trunking, economic considerations necessitate an appreciable degree of restriction in the number of connecting channels provided. and as a result another factor is introduced which we may well term hindrance, the effect of which is that all calls cannot be effectuated. The next few problems will be confined to the basic principles involved in the simpler cases of restricted access. Since a proportion of the total calls fails to mature when the access is restricted it becomes necessary to consider the additional possibilities introduced. Three hypotheses immediately suggest themselves in connection with blocked calls:

(a) Does the caller hang up and wait a reasonable time before calling again?

(b) Does the caller hang up momentarily and call again immediately, repeating this until he gets through?

(c) Does the caller hang up and abandon that particular call?—his next call being a pure matter of chance.

It may be somewhat problematical as to what actually occurs but (a) appears to be the most likely in practical experience. On the other hand, however, a solution of the problem is most quickly reached on the basis of (c), which also is free of certain indeterminate factors implied by (a) and (b) which it would be difficult to deal with mathematically. On the hypothesis of (c) calls which do not succeed when originated are definitely lost. Strictly speaking, if a caller on failing to obtain service waits for a reasonable period and then succeeds his call is not lost but delayed; nevertheless, he has been subjected to inconvenience or hindrance. The degree of inconvenience experienced by callers is termed the grade of service which is defined as the ratio of the number of calls which fail to mature on the **first** attempt to the total calls. If the grade of service is high the fact of lost calls being subsequently successful has no effect on the hypothesis in (c) and, therefore, all said and done the assumption of lost calls in the sense as defined is quite valid.

Problem No. 5.

In this problem the parameters taken will be $N \longrightarrow \infty$.

A = average call density.

X = number of connecting channels provided: where X is less than N.

On the parameters given $a_0 = a_1 = a_2 = a_x = A$ from what has been proved already; and therefore by direct substitution in (10) or by derivation from the associated statistical factors the following expression for the general term in the dispersion is arrived at:

$$S_x = \frac{A^x}{x!} \Bigg/ \sum_{x=0}^{x=X} \frac{A^x}{x!} \text{ - - - - - - } (26)$$

which is identical with the function developed by Erlang for the same parameters.

In this problem, as stated, a new factor has been introduced by the restriction in the connecting channels, and it is necessary to find an expression for a quantitative determination of the lost calls.

Calls can only be lost during periods when all the connecting channels are in use and furthermore **the amount of lost traffic depends only on the average rate at which calls arrive during periods of congestion.** In the problem being considered the rate of arrival is constant and equal to A and it therefore follows that the total traffic lost is

$$A_L = A\,S_x \text{ - - - - - - - - - - - - - - - } (27)$$

and if B represents the grade of service, then

$$B = A_L/A = A\,S_x/A = S_x \text{ - - - - - } (28)$$

which also agrees with the expression developed by Erlang for this quantity.

When $N \longrightarrow \infty$ there are other ways of arriving at B all giving the same result but when N is finite these methods give different results. The reason for the discrepancies is that the methods referred to are based on incorrect premises and, therefore, to ensure that the full significance of the statement just made is properly appreciated it is necessary to stress that **traffic can be lost in the connecting channels only when all members are in use and the loss depends absolutely on the rate of arrival during these periods, and the duration thereof.** This concept is fundamental.

Problem No. 6.

In this problem the same parameters will be taken as for the first problem, excepting that the number of connecting channels will be restricted to X where X is less than N.

There is no need to develop the dispersion in detail since it will be now evident that this is

$$S_x = \binom{N}{x}\left(\frac{A}{N - A}\right)^x \Bigg/ \sum_{x=0}^{x=X} \binom{N}{x}\left(\frac{A}{N - A}\right)^x \text{ - } (29).$$

When all trunks are simultaneously in use the rate of arrival is

$$\left(\frac{N - X}{N - A}\right) A$$

as already developed in (17) and therefore the lost traffic will be

$$A_L = \left(\frac{N - X}{N - A}\right) A \cdot S_x \text{ - - - - - - } (30)$$

and

$$B = \binom{N}{A}\binom{N-1}{X}\left(\frac{A}{N - A}\right)^{X+1} \Bigg/ \sum_{x=0}^{x=X} \binom{N}{x}\left(\frac{A}{N - A}\right)^x \text{ - - } (31)$$

The numerator of which can be expressed by alternative forms if desired.

When N is finite, the number of trunks available determines the volume of traffic which will be offered, accepted, and rejected. In any given case of N lines it is possible to obtain (N + 1) different dispersions by varying the number of trunks, but we could not possibly affect the quantity p from a theoretical standpoint although on account of other reasons, principally psychological, which are outside the scope of mathematics, p would be affected for small values of X.

Problem No. 7.

Let us now return to the isolated exchange and consider the case where the number of subscribers N is odd. The maximum number of simultaneous connections possible is $(N - 1)/2 = X$ and there will be one caller left over. Where N is odd loss or hindrance is therefore unavoidable. In evaluating the terms for S_x and B by means of (24) the factorials of non-integral numbers will be involved, that is if $N = 11$ and $x = 5$ the numerator of (24) becomes

$$\left(\frac{5 \cdot 5!}{0 \cdot 5!\ 5!}\right)\left(\frac{A}{11 - 2A}\right)^5$$

and to evaluate the factorials in the left-hand term it is necessary to use the Gamma function, tables of which are available, the required relationship being:

$$x! = \Gamma(x + 1).$$

Apart from the above comments nothing more need be said as long as it is remembered that when N is odd loss occurs, the amount being

$$B = \frac{N - 2X}{N - 2A}\,S_x \text{ - - - - - - - - - - } (32)$$

which can be simplified further if desired.

Concluding Remarks.

The practical application of the main theorems have been shown in a number of cases. The discussion of other problems such as grading, interconnecting and other forms of access is an extension of the main theorem developed in (10) and it is proposed to deal with these problems in a subsequent issue. Space considerations have made it necessary to omit curves for the functions so far developed where N is finite, but curves and tables where $N \longrightarrow \infty$ (Erlang's functions) have already been published.*

* P.O.E.E. Journal, January, 1918.

A COMPREHENSIVE TELEPHONE SERVICE.

J. S. Silvester, A.M.I.E. (Aust.)

THE adaptation of telephone equipment to provide for particular requirements of individual subscribers is of common occurrence, but the many special features of an installation recently completed in Sydney for the Australian Gaslight Coy. are worthy of description. The equipment installed is as follows:—

(1) A 300-line Private Automatic Branch Exchange.
(2) Customers' order desks of 10 operators' positions.
(3) Branch order desks of four operators' positions.
(4) Open order desks of four operators' positions.
(5) Order despatch desks of six operators' positions.
(6) Customers' account panels of 32 operators' positions.
(7) Observation desk.

Figure 2 shows a general view of the customers' order, branch order and open order desks.

The Private Automatic Branch Exchange provides facilities for automatic extension to extension and extension to exchange service for the administrative staff, whilst an associated two-position manual switchboard is utilised for filtering incoming exchange calls. Standard P.A.B.X. equipment is employed. The associated power plant also serves the desk equipment.

The Customers' Order Desks handle all complaints, enquiries, etc., and are served by a separate group of 15 direct incoming exchange lines and 10 transfer circuits from the P.A.B.X. manual switchboard. These circuits terminate on line finders.

The Branch Order and Open Order Desks are required for the internal organisation for the supply of information relative to orders, works on hand, etc., and are served by extensions from the P.A.B.X. These circuits terminate on lamps and keys in multiple on each position.

The Order Despatch Desks control all employees working on construction and maintenance in the field within a radius of 20 miles from the head office. These desks are served by 10 direct incoming exchange lines which terminate on line finders.

The Customers' Account Panels (Figure 1) are connected as extensions from the P.A.B.X., each panel having jacks for two circuits. The operators are equipped with head and breast telephones and plug in at the panel adjacent to the record card required. The signal lamps are mounted on the partition above and at the rear of the filing cabinets, and indicate the row in which the account required is located. Each circuit is in multiple over four panels.

Observation Desk. In order to ensure that a high grade of service is provided, and to enable the staffing of positions and desks to be modified to meet the varying loads experienced, the exchange lines and operators' circuits are multipled on the observation desk. The circuit arrangements are such that general service observations cannot be made on exchange lines used by the administrative staff. On the several large exchange line groups a waiting call indicator is provided per group and mounted on the observation board. The method of connection is shown in Figure 3. Ammeters are used for this purpose, the usual scale being replaced by a scale graduated in "calls," in order that the controller may readily ascertain the number of calls waiting in a particular group at any instant.

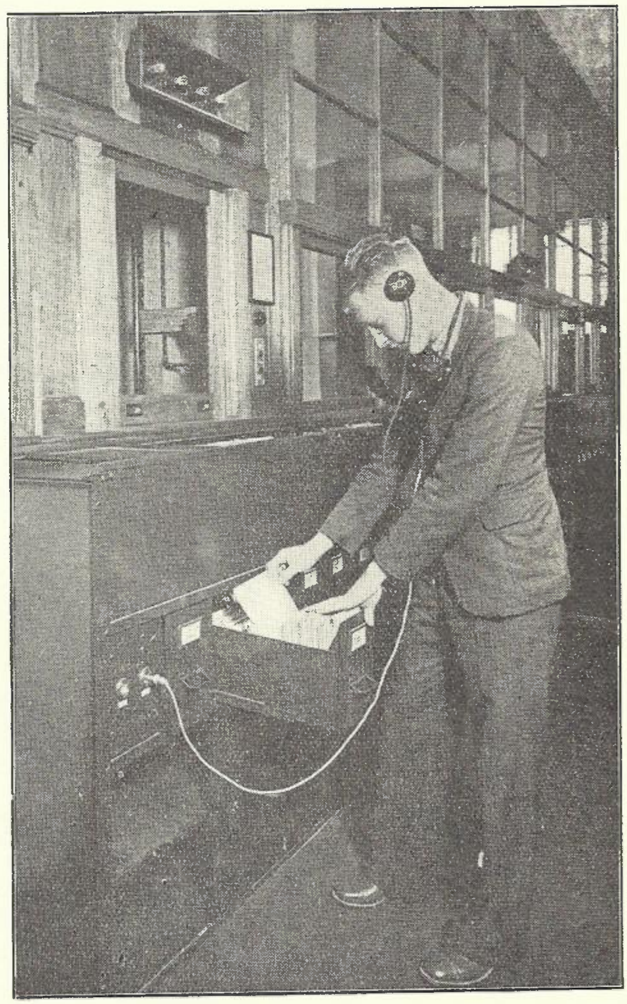


Fig. 1.

Details of Facilities provided on the Customers' Order and Despatch Desks.

Incoming Lines. The exchange and transfer circuits are terminated on line finder bank contacts.

Desk Provision. Three line finders are provided per position, and the circuit arrangements are such that if required calls on any circuit may be held or, alternatively, switched to the P.A.B.X. manual switchboard. In addition, each desk has an "out" extension to the P.A.B.X.

Method of Operation (Figure 3). When a call is received a white waiting call lamp glows on each position, and any operator may search for the call by depressing either the "hold" or "speak" key associated with an idle finder on her position. When the calling line is found the white lamps are extinguished and a green lamp glows on her position only. If more than one operator is attempting to pick up the call, the first finder to locate the line switches it through and other hunting finders return to normal. The white lamp being extinguished and the green lamp not glowing indicates that the call has been taken by another operator. The circuit is cleared by restoring the speak and/or hold keys to normal, after which the finder returns to normal.

Should the P.A.B.X. be required, the transfer key is depressed until the associated guard lamp glows. The speak key is then restored and the finder circuit held from the P.A.B.X. The line is then through to the P.A.B.X. manual switchboard, and the line lamp on the incoming transfer circuit glows. If required the line may be switched to a P.A.B.X. extension. On the exchange subscriber clearing the answering supervisory lamp in the P.A.B.X. cord circuit glows, but the back guarding feature of the repeater in the public exchange operates and holds the finder circuit until the connection is taken down on the P.A.B.X. manual switchboard when the finder circuit is automatically released and restores to normal.

The functioning of the line finder in locating a calling line is of interest. On the hold or speak key being depressed, relay LX operates via SR1 and completes the RM circuit at LX1.

Fig. 2.

The switch then hunts over earthed busy or disengaged contacts until it reaches the calling line, when it tests into battery on the associated P bank contact. LY operates in series with RM from earth on the homing arc. LY1 and 4 switch the calling line through to the operator; LY3 grounds the private bank and operates relay B of the calling line, whilst LY2 closes the circuit of the green position lamp. The release of the common start relay SR prevents hunting by other finders which may be searching for the call; these finders restore to normal by means of the earth on the homing arc. The connection is released by the restoration of the "speak" key which opens the circuit of LX which restores, short circuits LY and completes the RM circuit to earth on the homing arc. The switch then steps to the home position. On transferring a call to the P.A.B.X. manual switchboard the transfer key must be depressed until SA operates and operates D via SA1. The operation of D provides a holding circuit for the line finder through the P.A.B.X. line relay L.

The circuit arrangements of the open order and branch order desks are similar to the above, with the exception that line finders have not been provided, as they are not justified because of the lesser number of lines connected. The circuits are in multiple over the four positions on each of the two classes of desk.

Mounting of Apparatus for Desks. The apparatus for the customers' order and order despatch desks is rack mounted in conjunction with the P.A.B.X. equipment. The relay equipment associated with the desks is mounted in cabinets at the end of the suites.

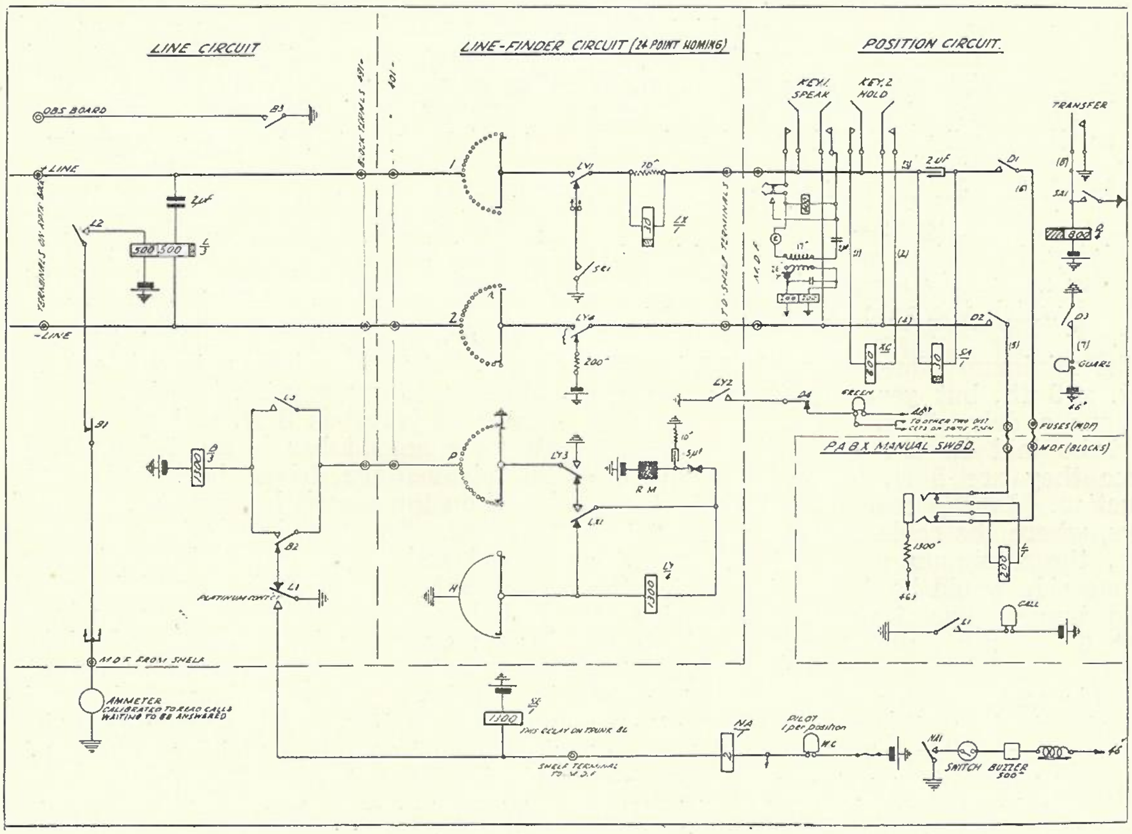


Fig. 3.

PIPE LAYING UNDER OBSTRUCTIONS.

R. Ridgeway.

HIGH-CLASS roadways and footpaths present costly obstruction to the laying of conduits. It is also expensive to lay conduits under rail and tram tracks, underground drains, water mains and similar services. The minimum depth of conduits under train and tram tracks is 3 ft. in Victoria, and in Melbourne the tunnel of the cable tramways is 4 ft. 6 ins. deep. An open cut across train and tram tracks is a slow and expensive operation and is not viewed favourably by the traction authorities, not only for the delays to traffic, but mainly because of the interference with the permanent way. In fact, on main railways such as the Sydney-Melbourne track, and on concrete tramway tracks, the traction authorities strongly oppose any proposal to make an open cut across the tracks.

In the case of concrete and other high-class roadway surfaces, there is not only the cost of cutting through and the expensive reinstatement charges, but also the objection that the surfaces cannot be satisfactorily restored must be allowed.

In each of the instances cited an open cut may be avoided by a drive or tunnel. This method has serious disadvantages:—

(a) Driving, timbering, and spawl packing for re-filling are costly manual labour items, in each of which the rate of progress is very slow.

(b) The minimum dimensions of a drive are 3 ft. x 3 ft., but generally it is necessary to have a drive 5 ft. deep. The conduits must be laid on the floor of the tunnel, hence they are 5 ft. deeper than the obstruction. In the case of the cable tramways, where the cable tunnel is 4 ft. 6 ins. deep, the minimum depth of the conduits on one side would be 4 ft. 6 ins. under the cable tunnel, plus 5 ft. for drive plus at least 6 ins. for grading, a total depth of 10 ft. Considering drainage, the drawing of cable and working expenses, it is most desirable to have the conduits and pits as shallow as possible. The normal depth of a one-way duct does not exceed 2 ft. and multi-way ducts 4 ft., hence the objections to a 10 ft. depth will be obvious.

The tunnel or drive may be avoided by the use of the following implements:—

(a) Hydraulic Pipe Layer.
(b) Rack and Pinion Pipe Pusher.
(c) Thrust Borer.

Each of these methods demands the use of iron pipes and normally black iron is used.

All methods have the advantage of providing ducts—

(a) without disturbing roadway surfaces or traction tracks;
(b) at the minimum possible depth;
(c) without risk of subsidence;
(d) less cost than drive or tunnel.

The choice of implement is governed by the size of pipe to be laid. The smallest pipe that can be pushed is 1½ inch pipe because smaller pipes buckle under the pressure. The Thrust Borer has consequently been developed for the smaller pipes and, since the Pusher is satisfactory for the larger sizes, no attempt has been made to extend the use of the Thrust Borer beyond 1¼ inch pipe.

From one aspect, however, the development of the Thrust Borer for the larger sizes is worth consideration, and that is that the Hydraulic Pipe Layer and the Pusher are heavy machines and require considerably more handling than the Borer, which is very light and portable. As the heavier machines develop as much as 4½ tons per sq. inch pressure, it will be appreciated that they must be of very substantial structure with consequent bulk and weight.

The Postmaster-General's Department does not own an Hydraulic Pipe Layer, but one has been obtained on loan from the Melbourne City Council several times. This Pipe Layer consists of two oil-operated pistons which travel from the cylinders through bearings of the framework of the machine. These pistons carry clamps which grip a solid iron bar 1½ in. diameter. As the pistons travel out from the cylinders, they carry the iron bar forward. The length of travel is 3 ft. and at the end of the stroke a second bar is coupled on to the first, the pistons are driven backwards and a grip taken on the second bar and the forward thrust repeated. The first bar is thus driven into the ground and as the forward thrust is completed another bar is coupled on and thrust forward. Each bar is 3 ft. long. The pump is connected to the cylinders by a length of high-pressure hose so that the pump may be operated from the surface. This remote control permits minimum excavation for the machine and allows a freedom of operation which would not be available in the underground position.

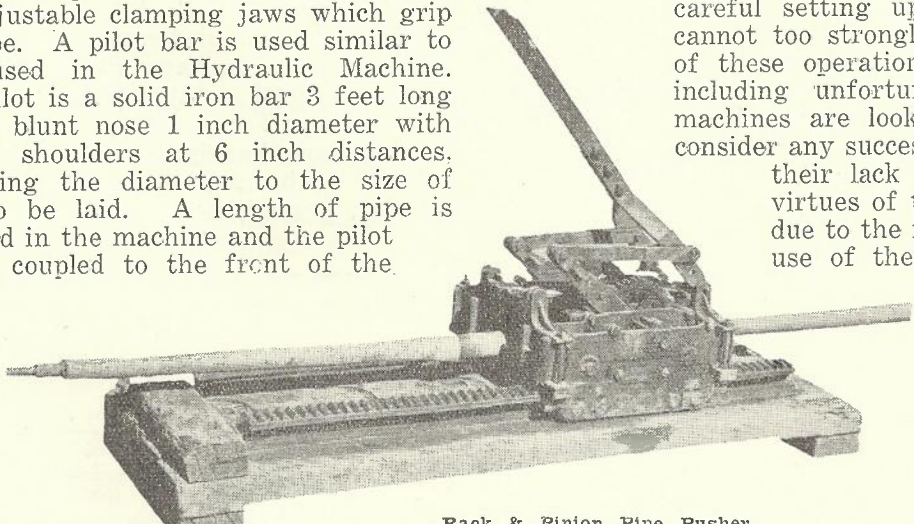
When the pilot bar reaches the objective on the far side of the road, it is uncoupled and another bar is fitted in its place. This bar is designed to take a bell-shaped coupling which varies according to the size of pipe to drawn in. A length of pipe is coupled to the bell and the machine is reversed. The bars are pulled back, the bell coupling further compresses the soil to the diameter required so that the pipe follows easily. As the machine reverses so the operation is reversed, that is, as the travel of the pistons is completed, a bar is uncoupled, a fresh grip is taken, and the operation repeated till the pipe arrives at the machine.

The Rack and Pinion Pusher acts on slightly different principles. It consists of two parallel iron racks mounted on a solid wooden base. These racks are 5 feet long and form the tracks for cog wheels. A machine consisting of four cog wheels driven by ratchet, pawl, pinion and lever, travels along this rack. The machine has adjustable clamping jaws which grip the pipe. A pilot bar is used similar to that used in the Hydraulic Machine. This pilot is a solid iron bar 3 feet long with a blunt nose 1 inch diameter with several shoulders at 6 inch distances, increasing the diameter to the size of pipe to be laid. A length of pipe is clamped in the machine and the pilot bar is coupled to the front of the pipe. The machine is then driven forward by the operation of the hand lever till the machine has travelled the full length of the rack. The clamps are then released and the machine drawn back to the end of the rack and a fresh grip taken on the pipe. The operation is repeated and new lengths of pipe coupled until the pilot reaches the objective, where it is uncoupled, the operation being then complete.

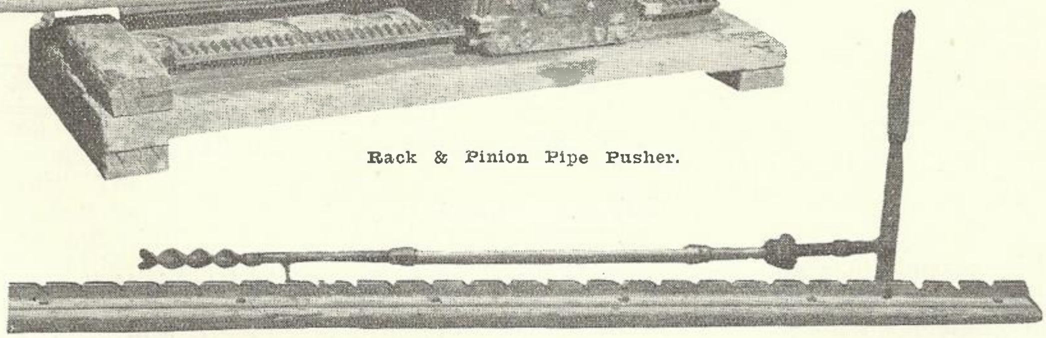
It will be noted that in this case the pipe to be laid is actually pushed in, whereas with the Hydraulic Layer the pipe is drawn in after solid bars have been pushed in and then withdrawn. There is, however, no reason why the same solid bar method should not be used with the Pusher. In good ground, however, time is saved by using the pipe itself for pushing. In very stiff clay, where undue resistance is met, the pipe may be withdrawn and the hole flooded with water. The pipe will then travel much easier.

Iron pipe is usually supplied in 20-foot lengths. The coupling of such lengths entails the opening of a suitable length of trench. In many cases depth, class of footpath, or obstructions make it preferable to cut the pipe to the length of the machine. The short lengths must, of course, be threaded at both ends for coupling. Where there is a big slope or embankments, such as railways, or where the pipe is not deeper than 3 feet, the full length of pipe may be profitably used.

The essential features for the successful use of these machines are the accurate plotting of section of the ground to be crossed and the careful setting up of the machine. I cannot too strongly emphasise the value of these operations. By many officers, including unfortunately Engineers, the machines are looked on askance. They consider any success a "fluke." But I find their lack of appreciation of the virtues of these machines is often due to the fact that they leave the use of them entirely to linemen. The alternative may mean weeks of work with tunnels, spoil, barriers, night lighting, obstruction to traffic—the visible effects of brute force—in place of the less spectacular but far more economic and efficient scientific operation.



Rack & Pinion Pipe Pusher.



Thrust Borer.

Therefore, I urge that economies and results warrant the personal attention of the Engineer in these operations.

To plot the cross section of the ground to be crossed, levels must be taken with a Dumpy Level.

Accurate records of all services and obstructions must be obtained. The surface contour and positions of all services (gas, water, drains, sewers, power) must be accurately plotted at sufficient scale to enable the line of operation to be determined. This line will give the angle of elevation of the pipe line and on it is based the setting up of the machine. It will be obvious that rough methods are useless.

The diagram shows a typical case. Two 4-inch pipes were required across Rathdown Street, Carlton (Victoria), at Richardson Street. There is a cable tramway in Rathdown Street and on the west side is a 3-ft. barrel drain 4 feet deep. Water and gas mains are as shown. Other mains which did not affect the pipe laying are omitted from this sketch, but were plotted in the first instance.

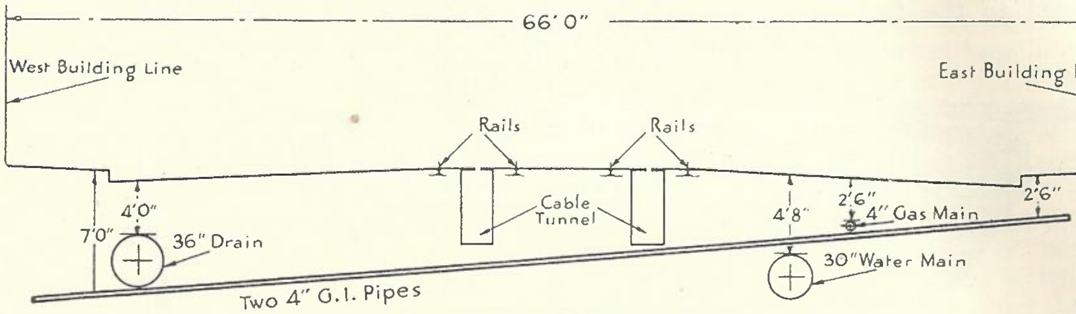
Having accurately plotted the section to be traversed, the next step is to decide where the machine is to be placed and then the angle of elevation. The method I adopt to correctly elevate the machine is to obtain the bead position of a long spirit level (not less than 3 feet) for the required angle and solidly pack the machine at the desired elevation. The elevation, of course, is taken with a length of pipe clamped in the machine, the spirit level being used on the pipe. In passing, it might be mentioned it is better to push upwards rather than down. It would be possible in a down-grade push to be deflected further down and thus waste effort. On an up-grade push an upward deflection will make itself known by penetration of the surface or by blockage on an obstruction. It is, of course, necessary to keep an accurate record of the pipe pushed in (including the pilot bar), so that if necessary the position of the pilot at any time may be known.

The depth of the lower side having been determined, a shaft is sunk of sufficient dimensions to accommodate the machine and deep enough to allow the pipe to be pushed at the correct level. A length of pipe is placed in the machine, which is lined up in the correct direction by plumb bobs suspended over the centre line of the pipe. The correct elevation is then obtained as described before and the base of the machine solidly packed to prevent alteration of level or alignment. Remembering that $4\frac{1}{2}$ tons per sq. inch pressure may be reached, the necessity for substantial packing is apparent.

Once again I wish to stress the value of time and care bestowed on the accurate setting of the machine. Laxness in this regard generally renders the pipe-pushing effort abortive, and it most certainly robs the method of the efficiency and economy which are its greatest advantages. Your men will be over-anxious to commence the pushing and will pay little attention to accurate setting up if not carefully controlled.

The case illustrated in the diagram is only one of many successful operations I have carried out. It will be seen from the diagram that very little deviation from the line was permissible. When the machine was set up a circle 1 foot in diameter was marked on the excavation on the east side. If the pipes had not arrived in this circle when the full length had been pushed, then they would have been diverted and it would have been necessary to have withdrawn them and made a fresh push. Actually the pilot came through the circle.

If it is necessary to withdraw the pipes and make a fresh push, a new entrance must be made in virgin ground, as the pilot will always follow the original track if it gets near enough to break into it.



Section across Rathdown Street, at Richardson Street, Carlton.

Similar cases to that illustrated are:—

(1) 4/4-inch pipes across Hardings Road, in Sydney Road, Coburg.

(2) 4/4-inch pipes under the North-East Railway Tracks at Essendon.

(3) 1/2-inch pipe under a concrete road and Electric Tram Track, Sydney Road, at Norman Street, Coburg. In this case the natural formation is solid stone and two pot holes were necessary to clear the pilot—one in the centre of the tracks and one on the east side of the road.

(4) Numerous cases where the cost of laying a pipe by other methods would have been prohibitive.

The benefit to the Department in the moral effect on the officers of Traction and Roadway Corporations is of considerable value, and their one-time apprehensions of our proposals have mostly disappeared.

Before leaving the Pushers, I might mention that experiments have been made with various types of pilots, such as sharp-tapered ones and also hollow ones. In the latter type it was thought that the earth could be cut into the pipe at far less effort than solid compression. This is true to a certain extent, but it is necessary to bore the earth out of the pipe, as it compresses into a very solid mass. This, coupled with the disadvantage (common to all types other than the solid, blunt pilot) of a tendency to wander from the straight and narrow path, has led to adherence to the blunt-nose pilots. Efforts have also been made to feed water to the front of the pipe, but they have not been very successful. The idea, however, has not been abandoned.

It is found that pipes under 1½ inch will not stand the strain of being pushed. Also, the Pusher is too big for small pipes in footpaths. The advent of "Direct Leads" and small pipe distribution lead to the evolution of the Thrust Borer.

This machine consists of three parts:—

(1) An Earth Auger which consists of a 2-foot length of high-class steel similar to a soft wood auger of 1½-inch diameter with the cutting edges slightly bevelled.

(2) A ball thrust housing with pipe coupling capable of rotation at one end and a handle attached for applying pressure at the other end.

(3) A rack composed of two angle irons mounted on a board, 1 inch apart. The irons are notched at 3-inch intervals with bayonet slots. The rack I use (after many trials) is 6 feet long. This is not an arbitrary length, but is the most suitable length considering width of footpaths and right-of-ways consistent with the cutting and threading of pipes.

The object of the machine is to allow us to push pipes along footpaths with the minimum excavation. The rack is 6 feet long by 6 inches wide and as pipes are pushed in both directions from it, the dimensions stated are the maximum opening necessary over at least 200 feet. When right-of-ways are available it is generally unnecessary to open a good class footpath, except for the pits.

The method of operation is to cut a neat fit for the rack at a depth of 1 foot. It will be said that we could lay the pipes shallower than 1 foot, but experience has shown that the borer has a tendency to rise and either lift or penetrate the surface if it has not at least 1 foot of soil above it.

The depth, of course, will be governed by the depths of house drains, gas and water services. But, since excavation is not involved, a depth of 2 feet is not objectionable. Obviously when an open cut is made a depth of several inches is all that is necessary, but when boring the excavation for the rack is negligible and it is safer and surer at 2 feet than at 6 inches.

The rack is placed in position with a suitable drainage grade. The auger is coupled to the ball thrust with a 2-foot length of pipe. The lever handle is drawn back at the top and engaged in a suitable notch in the rack. **Very light** pressure is applied to the handle and the short length of pipe is turned with pipe tongs. It is profitable to employ two men turning with tongs. The turning allows the auger to grip and bite its way in. The pressure from the handle is to clear the earth from the core of the auger.

(Go easy on the pressure.)

When the end of the rack is reached the thrust and short length are uncoupled from the auger (which has now entered the soil), and a 6-foot length of pipe (of the diameter to be laid) is coupled to the auger at the front and the thrust at the rear. The lever handle is again placed forward to engage in a suitable notch in the rack and **slight** pressure applied while the pipe is turned with the tongs. As the lever comes forward at the end of its travel, it is lifted out of the notch, turned backwards and the foot engaged in another notch as forward as possible. The operation is repeated till the end of the rack is reached, when another length of pipe is coupled, and so on till the desired length is laid.

The full length is pushed in first. The openings for the joint boxes should be made before the pushing is commenced so that the progress of the pipe might be checked. The pipe is then withdrawn and cuts or uncouplings made at each of the pits. Withdrawal is made by reversing the rack and reversing the lever action.

The whole outfit is inexpensive and can be made in the Departmental Workshops or any engineering shop for approximately £5.

It is very light and portable and can be handled by one man.

Both Ball Thrust and Borer should be made with male ends to take reducing sockets to fit the various sizes of pipes to be laid.

It is well known to all Engineers, and particularly Municipal Engineers, that even cheap-class footpaths cannot be satisfactorily reinstated. The best that can be done is only patchwork and the footpath is never the same after reinstatement. In the Metropolitan Area cheap footpaths have gone and Council Engineers are developing higher-grade paths every day. Although we may be prepared to meet high reinstatement charges, yet we must take cognisance of the fact that open cuts nullify the Council Engineers' effort.

Although I have not yet definitely proved it, I am of opinion that boring is cheaper than cutting good-class paths. Even if it is more expensive, it would not only be politic, but also in the interests of the general public to avoid damaging good-class paths.

Obviously, I am not advocating boring where nature strips or easily lifted slabs are available. My remarks apply particularly to the bituminous cement paths which are being generally constructed in the Metropolitan Area.

It is scarcely necessary to add that pushing and boring cannot be carried out in stony ground. But it is frequently possible in stony country to push or bore for a certain distance till stopped, then pot-hole to remove the obstruction and push as far as possible again. Such pot-holing is cheaper and less repugnant to road authorities than a continuous open cut.

In short lengths, such as traffic entrances to premises and sections of concrete footpath, the Earth Auger, Post Hole Borer and Hammer and Cap for driving pipes have been profitably used.

The Earth Auger is similar to the Auger described for the Thrust Borer. It is used with a cross-piece handle similar to a wood auger with short lengths of pipe to extend the handle as the auger progresses. It is necessary to frequently withdraw the auger to clear the soil from the core.

The Post Hole Borer is a tool which, with a turning movement, cuts the earth into the central place between the cutting flanges. The tool is then withdrawn, the earth emptied out and the operation repeated. After the hole is bored the pipe is then pushed in. The borer should be only a shade larger than the pipe, otherwise subsidence may occur.

The Hammer and Cap method consists of fitting a plug in the forward end of the pipe and a cap on the after end. The pipe is driven in by striking the cap with a hammer.

Successive lengths are added as progress is made. This method is effective in sandy, swampy or loose made-up ground.

Unless the staff is thoroughly instructed in detail they cannot exhibit the skill necessary to effectively use the devices we have discussed. It behoves the Engineer to devote sufficient time and interest to the education of his staff in the use of these implements, and if he does so he will be pleasantly surprised at the profitable field to be exploited and the consequent reductions in his plant costs, both provision and maintenance.

BALLAST RESISTANCE LAMPS.

H. K. Gregg.

On long subscribers' loops connected to C.B. exchanges, two factors detrimentally affect transmission—they are, voice frequency losses in the conductor, and the reduced sending level consequent upon reduced current through the transmitter because of the high conductor resistance.

The transmission bridge of a subscriber's line connected to an automatic exchange consists of a 200/200 ohms relay through which is fed the exchange battery of 50 volts. In order to comply with the standard transmission limits, the maximum loop resistance allowable with this type of bridge and employing a handset telephone using a No. 10 type transmitter inset is 430 ohms. To increase the loop resistance over which satisfactory transmission is possible, the resistance of the feed relay could be reduced, which would result in an increase of current through the transmitter. Whilst this would be quite satisfactory for long loops if the same feed relay were used on short loops, there would be excessive current through the transmitter. It is to overcome this disadvantage that the ballast resistance lamp is employed. This device consists of a tungsten or iron filament in hydrogen gas enclosed in a glass envelope. It offers a comparatively low resistance to small currents, but high resistance to large currents. This characteristic has led to its use, associated with a 50/50 ohms relay in the transmission bridge.

Ballast resistance lamps have been designed for operation with several different current values, but the one of special interest because of its more general use operates on approximately 100 milliamps. This type offers a resistance of 130 ohms to currents of about 85 milliamps, but from 85 to 95 milliamps the resistance increases rapidly until with 100 milliamps the resistance is approximately 350 ohms. With a feeding bridge having such a ballast lamp in series with a 50/50 ohms relay, it is obvious that any gain in transmission resulting from the increased current through the transmitter will be lost via the low wound relay. To prevent this voice frequency loss, nickel iron sleeves are placed over the core of the relay. The effect is to greatly increase the impedance of the relay to voice frequencies, but not affect its D.C. resistance, nor are the impulsing characteristics of the relay adversely affected.

Fault conditions such as a short circuit or an earth on the battery wire do not affect the characteristics of the ballast. Moreover, with a direct ground on the line side of the battery coil there is only approximately one watt to be dissipated, whereas with the 200/200 ohms type about 12½ watts are involved under similar circumstances.

An example of the advantage of using this type of equipment is of interest. As indicated above, the minimum permissible loop resistance employing the existing type of transmission bridge is 430 ohms, which is equivalent to 2.4 loop miles of 10-lb. conductor. Employing a 50/50 ohms relay and a 100 milliamp type ballast lamp as a transmission bridge for a 50-volt exchange and a handset telephone, the maximum permissible resistance is 500 ohms, equivalent to 2.8 loop miles of 10-lb. conductor. That is, the use of 10-lb. cable conductor can be extended for a further 0.4 miles, thereby effecting considerable economy in line plant.

3GI, GIPPSLAND REGIONAL BROADCASTING STATION.

H. S. Robertson, B.Sc.

WITH the official opening of 3GI Gippsland Regional on October 31st, 1935, another link was added to the chain of stations constituting the National Broadcasting System of the Commonwealth. As is now generally well known, the National Stations broadcast the programmes of the Australian Broadcasting Commission, technical control and operation of the service being the responsibility of the Postmaster-General's Department. The addition of 3GI raises the total number of broadcasters in the National network to fourteen, comprising eight metropolitan stations situated in the capital cities of each State and five regional stations in country centres, all operating within the medium wave broadcast band (1,500-500 kilocycles), together with one short wave station (3LR, Lyndhurst, Vic.) operating on 9,580 K.C.

As 3GI is the second completed unit of a group of eight stations now building, it will be realised that the broadcasting service is developing into an important branch of the Department's activities.

In the following notes a brief description is given of the station equipment and its associated studio and programme line facilities.

Regional broadcasters, as the name implies, are designed to provide a service in areas where reception of existing National Stations is unsatisfactory.

The region to be served by 3GI is known as Gippsland and comprises the greater part of South-Eastern Victoria, bounded on the north by high mountain ranges, by the sea coast on the south, and low ranges of hills to the west. Broadcast reception generally throughout the district has always been poor and unreliable, mainly on account of fading, distortion and high noise level of atmospheric electrical disturbances "static" at the low field strength of received signals.

The service area having been defined, it is then necessary to determine the transmitting frequency and power to be employed. The desired conditions are a received signal of sufficient strength at any point within the service area, to provide at all times freedom from fading distortion, together with a high signal to noise ratio.

A study of the available channels in the medium wave broadcast band (1,500-550 kilocycles) in relation to power, frequency and site location of existing stations, together with wave propagation characteristics of the Gippsland area, resulted in a choice of the frequency 830 kilocycles and aerial power 7 K.W. for 3GI.

The position of the site is the next consideration and is influenced by such factors as:—

(a) Distribution and density of population.

(b) Topography of the terrain, e.g., high mountains have a marked screening effect when situated between the transmitter and receiver.

(c) Soil conductivity. It is important that soil in the immediate vicinity of the site should have high electrical conductivity to reduce attenuation of radiated signal.

(d) Proximity to source of electricity power supply and telephone trunk route for the economic provision of programme lines.

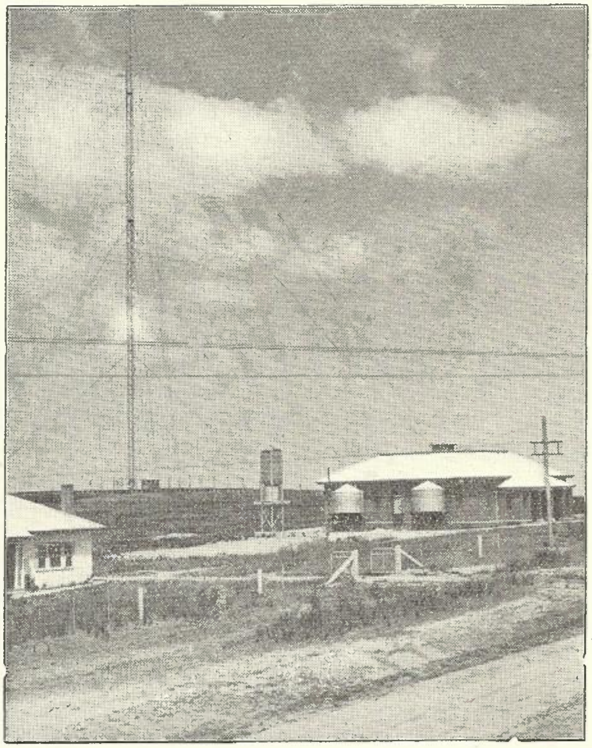


Figure 1.

(e) Reliability and suitability of water supply.

(f) Purchase price of land and costs of clearing for erection of radiating system.

The greater portion of the population of Gippsland is concentrated in towns along the two main railway lines, the Eastern to Bairnsdale and Orbost and the South-Eastern to Foster. A preliminary study of this geographical distribution, together with the topographical features of the territory, suggested a location in the neighbourhood of Sale. Several possible sites were selected by inspection and from soil conductivity tests. This was followed by field measurements, using a portable radio transmitter and a final choice made of an area of 63 acres at Longford, situated about six miles south of Sale. The site is distinguished by the 500-ft. mast of the aerial system. See Fig. (1).

The broadcaster equipment is contained in a single floor brick building, separate quarters being provided for the resident senior officer in charge of the station.

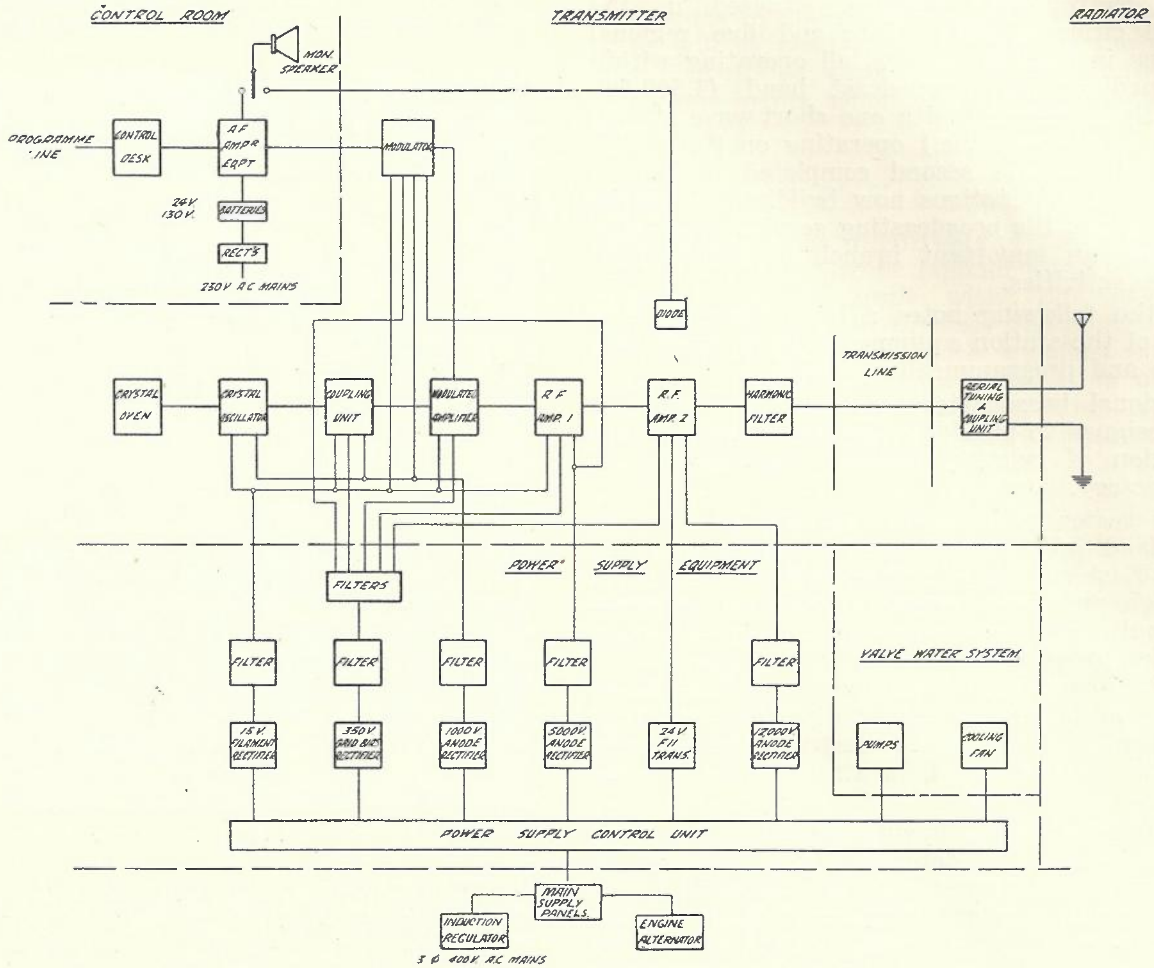
Station Equipment. The broadcaster equipment was supplied by Messrs. Standard Telephones & Cables Ltd. and manufactured at their works in Sydney, New South Wales. Installation was effected by departmental staff under direction of the contractor's engineers.

The equipment as operated delivers an unmodulated carrier power of 7 K.W. to the aerial and is capable of being modulated linearly up to 95 per cent. Provision is made in the design for operation if desired at any other carrier frequency in the range 1,500-550 kilocycles, the change being effected by simple alterations in the circuits. Modulation is effected at low power level by a modification of the Heising plate modulation method, then the modulated carrier amplified to the output power level. The overall frequency response characteristic does not vary by ± 3 db. throughout the audio frequency range 30-10,000 cycles per second.

A feature of the transmitter is the careful attention to electrical screening of all circuits to minimise interaction. The unit type of construction is employed, all units with the exception of the final power amplifier being enclosed in duralumin boxes having a minimum of external connections and readily accessible, enabling the unit to be withdrawn on runners for inspection.

The power supplies necessary for the generation and modulation of the carrier are wholly obtained from stationary equipment, either by transformation or rectifier conversion from the

FIG. 2
3GI GIPPSLAND REGIONAL STATION
BLOCK SCHEMATIC OF BROADCASTER.



400V mains. The only rotating machinery used is the motor driven circulating pump in the valve water-cooling system.

Fig. 2 shows in block schematic form the general arrangement of equipment. The building layout provides for disposition in various rooms as follows:—

(a) A main transmitter hall containing the transmitter and associated power supply and control equipment.

(b) The control room for audio frequency equipment and associated battery room for power supplies. Both of these rooms are completely surrounded by closely woven wire mesh to shield the equipment from radio frequency electromagnetic field.

(c) Engine room for a standby engine alternator set and main power supply control and distribution panels.

(d) Pump room for valve water-cooling equipment and circulating pumps.

Main Power Supply.

Electricity power supply for operating the broadcaster is obtained from a special extension of the State Electricity Commission's 6,600-volt H.T. mains from Sale. This is stepped down to 400 volt 3 phase 50 cycles per second and led into the station via underground cable. An automatic induction regulator permanently connected in the mains reduces to a minimum the effect on the transmitter of line voltage fluctuations. To safeguard the service against failure of power supply a reserve engine alternator set is installed. It comprises a Ruston Hornsby 5-cylinder, 1,000-r.p.m. vertical compression ignition (Diesel) engine of the airless injection type rated at 80 H.P. and direct connected to an alternator and exciter of output 60 K.V.A. at 400 V. 3 phase 50 cycles. The set is mounted on a massive concrete foundation, mechanically insulated from the main building structure to minimise transmission of engine vibration.

Starting of the engine is effected by compressed air at 300 lbs. per sq. inch contained in a receiver charged from a small petrol engine driven compressor. The main engine is water cooled by gravity flow from an elevated tank through the engine into an underground storage tank. A pump driven by the engine raises this water to a louvred cooling tower above the elevated tank. The incoming supply mains and the alternator controls terminate on panels equipped with the usual meters, fuses and switches for controlling and interchanging supplies, and the distribution to the various power and lighting circuits.

The transmitter and associated power supply equipment are situated in the main hall.

The whole transmitter is enclosed by perforated metal screens fitted with suitable doors to facilitate access, opening of the doors automatically switching on strip lights to illuminate the interior. The front is faced with slate panels and fitted with the necessary controls and meters.

The carrier frequency of 830 kilocycles is normally generated by a crystal controlled valve oscillator, an alternative valve oscillator being installed for use on other frequencies if required. In order to obtain the high degree of frequency stability necessary in modern broadcasters, the quartz crystal, together with a spare, is enclosed in an electrically heated chamber, the temperature of which is regulated within predetermined limits by automatic thermostat control. It is possible by this means to maintain the carrier frequency within a few cycles of the required value.

Carrier output from the master oscillator is amplified in a coupling unit of two stages—first a single valve, second two valves connected in balanced push pull, all of 50 watts rating. This unit is designed to prevent variation of the carrier frequency which might be caused by circuit variations in subsequent portions of the transmitter being reflected back to the oscillator circuit. The carrier is then further amplified in the modulated amplifier comprising two 50-watt valves in push pull in the plate circuit, of which modulation is effected by a modified Heising method.

The Modulator valve rated at 1.5 K.W. is preceded by two stages of audio frequency amplification, each employing one 50-watt valve.

The Modulated carrier is amplified to the final power level in two stages, the first using two 1.5 K.W. valves in push pull, and the second with two water-cooled valves of 15 K.W.

To reduce to a minimum the interruption to service caused by the failure of one of these water-cooled tubes, a spare is mounted beside each working valve, the changeover being effected by the simple operation of a switch mounted inside the unit.

The output from this stage passes through a radio frequency filter unit designed to suppress radiation of harmonics of the carrier frequency, thence an aerial transmission line to the radiating system.

The line presents a substantially non-reactive impedance of 600 ohms and an artificial aerial which may be substituted consisting of a non-reactive resistor of this value is provided in the transmitter hall for testing purposes. The resistor is cooled by circulating water and is fitted with thermometers and water flow meter for enabling the power absorption to be calculated.

The transmitter power supply and control equipment is segregated in a power enclosure within the transmitter hall. A switching unit faced with slate panels contains the various meters, switches and circuit protective equipment.

With the exception of the final stage, power supplies for all valve filaments (14 V. D.C.) and anodes (1,000 V., 5,000 V. D.C.) are derived from Westinghouse 3-phase copper oxide rectifiers. The filaments of the final power valves are heated with alternating current at 24 volts, while the anode is fed from a 3-phase 12,000-volt D.C. thermionic rectifier employing water-cooled valves. The grid supply (350 V. D.C.) for all valves is obtained from a 3-phase metal rectifier.

The whole of the rectifier equipment is installed within the power enclosure and segregated into units. The metal rectifiers are arranged in series parallel groups to give the required voltage and current output, groups being separately fused for protection and mounted on sliding trays fitted to steel racks to facilitate removal for inspection or replacement. The output of each rectifier is filtered in the usual way to produce smooth direct current.

The heat generated by all water-cooled valves is dissipated in water circulated by a motor-driven pump and passes through a heat radiator unit, cooled by air blast from a fan. As the anodes of the final power amplifier valves are at 12,000 volts potential above earth, water is conveyed to and from the valve jackets through lengths of rubber hose. It has been found necessary to use distilled water for cooling on account of the low anode to earth resistance with rain water collected from the building roof. The improvement effected is indicated by a resistance of 8 megohms with distilled water as against 0.8 megohm for the latter.

Flow alarm contact devices in each water return circuit protect the valves against water failure by causing disconnection of power from the transmitter when the flow falls below a safety limit. Excessive water temperature is detected by an alarm bell operated from contacts on the thermometers fixed in the water outlet from each valve.

Careful provision is also made for the safety of operating personnel. Contact with dangerous circuits is impossible, since access to either the transmitter or power enclosures is gained through entrance doors which are normally locked. A safety isolator switch in the "open" position disconnects all high voltages from the equipment and connects the outputs of anode supply circuits to earth in order to discharge filter condensers. Two master keys are normally inserted in locks on the isolator switch and it cannot be closed unless they are in position, also it is necessary to open the switch before they can be removed from the locks. The enclosure doors are unlocked by these keys and can only be removed when the door is closed and locked. The switching operations in starting up the transmitter function semi-automatically by means of three push buttons controlling magnetically operated switches. No. 1 button controls the filament, No. 2 the 1,000 V. and 5,000 V. anodes, and No. 3 the 12,000 V. anode supplies. All Grid voltages are automatically applied with the closing of the isolator switch. Time delay features are incorporated in certain switches to ensure that voltages are applied at appropriate time intervals.

Control Room.

In this room facilities are provided for amplifying controlling and monitoring programmes, as well as means for originating a local programme for emergency and testing purposes. The latter is available from a control desk fitted with a moving coil microphone, two synchronous motor gramophone turntables and Western Electric 4A gramophone reproducers, with individual fader units for smooth volume control of output. A microphone gramophone amplifier raises the level of these instruments to a suitable value for input to a main amplifier. The output from this amplifier is fed into the modulator unit of the transmitter. The incoming programme lines are terminated on the usual protective equipment with the addition of filters for suppressing radio frequency energy picked up in the open wire section of the route, particularly in the vicinity of the station where the field strength is high.

The incoming programme is then connected to the main amplifier through a fader and mixer unit, enabling smooth changeover to local programme when required. A master fader in the input of the main amplifier is used for regulating the volume input to the transmitter to the required value for correct modulation. Visual indication of this level is afforded by a volume indicator meter mounted on the control desk. A comparison of programme quality at the input and output of the transmitter is available from a loud-speaker monitor, the input programme being obtained from a monitoring amplifier bridged across the main amplifier and the output programme from a diode rectifier mounted in the final power amplifier unit. The overall frequency response characteristic of the control room equipment does not vary by more than ± 2 db. from 30-10,000 cycle per sec. An audio frequency oscillator of the beat frequency type with a range of 20-11,500 cycles per sec. is installed and used for testing purposes. Power supplies for the equipment are derived from 24 V. and 130 V. batteries floated across metal rectifiers, a feature being the inclusion of manually operated induction voltage regulators giving a remarkably smooth control. All apparatus with the exception of the control desk is rack mounted on 7-ft. racks.

Radiating System.

The transmitter output is fed into a transmission line of 600 ohms impedance leading to the aerial tuning hut at the base of the mast, where connection is made to the radiator through coupling circuits.

The radiator consists of two parts, the aerial and earth systems. The aerial is of the half-wave type, designed to give a circular polar diagram for the distribution of radiated energy. This type of aerial gives a strong horizontal or ground wave with a minimum high angle or sky wave resulting in a maximum service, arc free from fading distortion caused by interference between these two radiations. The aerial array is of the umbrella pattern and consists of three wires, each of total length approximately three-quarters the transmitting wave length and symmetrically spaced about the mast. They are commoned together at the tuning hut equipment, then approximately one-third of each length is taken out radially from the mast on the top of 11-ft. poles, the remainder (half-wave length) being led to the top of the mast.

The exact lengths of the horizontal portions are adjusted when the aerial is tuned during lining up of the equipment.

The wires are insulated from the mast, ground and each other after leaving the tuning hut.

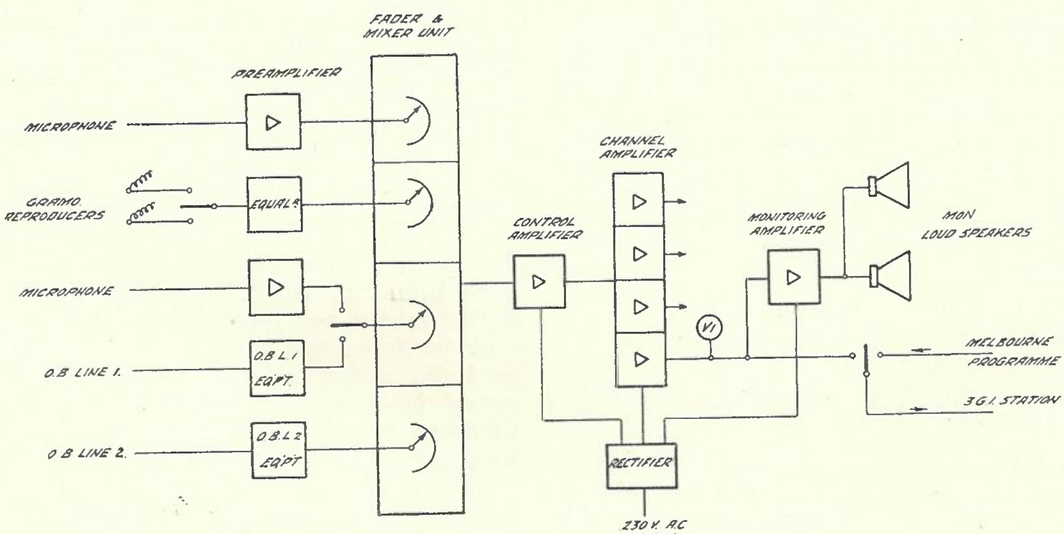
The mast is a lattice galvanised steel structure of triangular section 500 feet in height. It is electrically insulated from the ground by six porcelain cylinders, which have to withstand all vertical stresses on the structure. The mast is guyed at four points along its length by three sets of guy wires symmetrically spaced 120 deg. about the mast. Protection is afforded aircraft by the provision of warning signals taking the form of alternate black and chrome coloured bands painted on the upper portion of the mast for daylight flying and three groups of red obstruction lights for night use.

The radiating earth system consists of a network of underground wires radiating from the mast to a distance of 450 ft. and spaced at 2½-deg. intervals. The wires are buried at a depth of 9 ins. and are bonded together only at the mast end, then led into the tuning hut with bus-bar copper connectors. Some 12 miles of 14-gauge tinned copper was laid by means of a mole-drainer plough, resulting in considerable savings in time and labour costs. Owing to the presence of buried tree roots and surface scrub, a considerable amount of preparatory grubbing and clearing work was necessary before the laying of the wires could be commenced.

FIG. 3.

SALE STUDIO

BLOCK SCHEMATIC OF EQUIPMENT.



Studio Equipment.

The greater portion of the programme material broadcast from 3GI is relayed from the Melbourne studios by land line, but provision is made for items of local interest to be transmitted from a studio in Sale. This studio is situated in the Post Office building, and as it will be used for announcements, talks and gramophone reproduction, it is of size sufficient only for this purpose. Acoustic treatment to give suitable characteristics consists of a ceiling of "Sorb-sound" material and a heavily carpeted floor. The whole of the technical equipment for operating is installed within the studio, harmonising in external appearance with the decorative treatment of the room. This equipment, which is of departmental design, operates wholly from 230 V. A.C. mains and was manufactured in the Melbourne workshop.

It consists of an Announcer's Control Desk and an Equipment Rack. Fig. 3 is a block schematic of the circuit arrangement. Provision is made on the Announcer's desk for control of the equipment and various programme and telephone circuits by suitable switching operations. The facilities include:—

(i) Two moving coil microphones for the announcer and a second speaker.

(ii) Duplicate self-starting synchronous gramophone motors, dual speed (78 r.p.m. and 33⅓ r.p.m.).

(iii) Two W.E. 4A gramophone reproducers with a record equaliser to correct for low frequency response in disc recordings.

(iv) A key-switching panel with four-point fader and mixer unit for controlling microphones, gramophones and programme lines incoming from Melbourne or local field broadcast points and outgoing to 3GI. A programme key selector circuit enables either 3LO or 3AR studio programme to be switched to the programme line at Melbourne as desired.

(v) Facilities for loud-speaker and headphone monitoring at various points in the circuit.

(vi) Telephone circuits to 3GI and Sale Exchanges.

On the equipment rack are mounted the various amplifier panels with their associated power supply, measuring and patching facilities. Separate amplifiers are used for the different functions as follows:—

(a) Preamplifier—single stage of fixed gain 30 db. for amplifying very low level output from moving coil microphone prior to switching and fading operations.

(b) Control amplifier—a four-stage resistance capacity coupled unit amplifying the output from the fader and mixer unit to approximately reference volume level (6 milliwatts).

(c) Channel amplifier—single stage high impedance input bridged across the control amplifier output, and providing four separate programme outlets. The overall maximum gain from control amplifier input to channel amplifier output is 87 db.

(d) Monitoring amplifier—two-stage high impedance input for driving two loud-speaker monitors. Provision is made for switching this amplifier across the channel amplifiers and the incoming Melbourne programme as desired.

Programme Lines.

It is important to realise the exacting requirements of a broadcasting service, particularly in regard to freedom from programme interruption. Continuity is essential, as every interruption is immediately evident at the listener's receiver, producing dissatisfaction and irritation. In addition, the programme material lost during even a short interval cannot usually be repeated. The programme line to regional stations is a vital link, and when it includes open wire construction over long distances it may well be the most vulnerable portion in the system.

In the case of 3GI the Melbourne programme is transmitted a distance of 138 miles over a line consisting of a 10-mile section of 40-lb. M.T. trunk cable to Oakleigh, then 128 miles of 200-lb. open wire to 3GI station. The cable and open wire sections are separately equalised for amplitudinal distortion, having attenuations equivalents of 35 db. for Melbourne-Oakleigh and 22 db. Oakleigh-3GI. A two-stage unidirectional amplifier of working gain 33 db. is inserted in the line at Oakleigh Telephone Exchange to ensure a satisfactory programme level into the open wire line. The overall frequency attenuation characteristic between Melbourne studios and 3GI does not vary about a horizontal line through the 1,000-cycle value by more than ± 3 db. throughout the range 30-10,000 cycles per second. The programme level sent to line from the Oakleigh amplifier is set + 4 db. above reference volume and is determined by the requirement of maximum signal to noise ratio at the receiving end of the line, together with the upper limit imposed by the inherent value of crosstalk between the programme and other voice frequency communication circuits on the same pole route.

The open wire route to Sale consists of a number of sections having various types of construction and different transposition schemes which necessitated careful selection to obtain the best circuit for the programme line.

Alternative programme lines normally used for telephone traffic are provided between Melbourne-Sale and Sale-3GI for emergency use in the event of failure of the main line. To facilitate rapid restoration of service, a relay switching circuit controlled from Melbourne and 3GI is utilised to interchange programme and telephone equipment at Oakleigh, Warragul and Sale.

MECHANICAL MESSAGE HANDLING IN TELEGRAPH OFFICES.

W. Galley.

THE great reduction, during recent years, in the average delay time for telegrams between the major traffic centres of the Commonwealth, has focussed attention on the large percentage of overall transit time, for which the "internal circulation" may be responsible.

It is not proposed here to detail the means by which the handling of the long-distance telegraph traffic has been brought to its present state of efficiency, but it may be desirable to refer to the contributing factors as falling under two main headings:—

(a) The provision of ample channels by the use of carrier and voice frequency systems.

(b) The introduction of direct printing machine telegraph equipment.

The term "internal circulation" strictly speaking covers the handling of telegrams between the time of lodgment at the receiving counter and the time of placing before the sending telegraphist. Conversely, the term applies equally to the routing between the receiving operating position and the delivery section. It will be convenient, however, to regard certain City post offices as extensions of the receiving counter so that the transmission of telegrams between such offices and the Chief Telegraph Office, when effected by means of pneumatic tube, may be regarded as "internal circulation."

It is proposed in this article to deal with the mechanical methods which have been adopted to assist in effecting a reduction in the "internal circulation" time or "office drag" commensurate with the speeding up of long-distance transmission. Incidentally, this mechanisation, in addition to greatly improving the service, enables important cost economies to be effected.

Particular reference will be made to recent installations of pneumatic tube plant in Melbourne, as these have included certain features which are original and other features which, although incorporated in one other installation (Sydney C.T.O.), are probably not familiar to most readers.

Three methods are in use in Australia for the mechanical conveyance of messages, each serving a well-defined purpose:—

(a) Belt conveyors;
(b) Kick-back carriers;
(c) Pneumatic tubes.

Belt Conveyors.

The belt systems, which have been installed in the larger Chief Telegraph Offices of the Commonwealth, are used to collect received telegrams from the operating positions and to deposit them in a central sorting bin. The messages as received at the bin may be destined for onward transmission via another telegraph circuit terminating in the same C.T.O., they may be intended for local delivery, or for delivery from a city office served by pneumatic tube, or they may be of the increasing groups handled by the phonogram section.

A boy, or boys, stationed at the sorting bin, places the incoming messages in conveniently placed trays or compartments, whence other boys despatch the forms by the appropriate kick-back carrier or pneumatic tube.

Double width operating tables are used and a belt runs in an elevated framework along the centre of each table. The framework consists of two side members, each about 6 inches deep of 16 gauge mild steel carried by cast-iron standards. The side members of the frame are $11\frac{1}{4}$ inches apart to allow clearance for the 11-inch rubber impregnated cotton belt, which runs on ball-bearing rollers. At the two ends of the frame for each table the rollers are 3 inches in diameter and are locked to their spindles, with the outer races of the ball bearings carried in housings which can be adjusted longitudinally relatively to the framework, for tensioning and centreing the belt. The spindle of the roller at the delivery end of the belt is extended to carry a V-grooved pulley, which is driven by a round belt from a small motor carried on a platform above the conveyor belt. The intermediate or idler rollers are spaced at 3 ft. 6 ins. centres under the upper working face of the conveyor and under the return side of the belt to prevent undue sagging. The rollers are $1\frac{3}{4}$ in. diameter and are carried on the outer races of their ball bearings; the spindles are fixed at each end in the frame sides.

The top of the belt frame is 19 ins. above the table and, as the full width of the table, including the belt space, is 4 ft. 6 ins., it is within comfortable reach for the operator when placing messages on the belt. In order that forms may be retained on the belt and to prevent scattering by air currents, the rollers are placed so that the conveyor surface is 3 ins. below the top edge of the side members of the frame.

The table belts discharge on to a main belt running at right angles to the operating tables and of similar construction to the table belts, but carried on floor standards. The discharge area is well screened to prevent loss of messages at these points. Unfortunately the configuration of our operating rooms is such that it is not always possible for the main belts to deliver telegrams directly into the sorting bin, and it becomes necessary to include a vertical or inclined lift in the belt layout.

The way in which forms are picked up and discharged at a higher level is shown in Fig. 1. These twin belts are the source of the major trouble in the operation of conveyor belts, in that the forms, when passing between them,

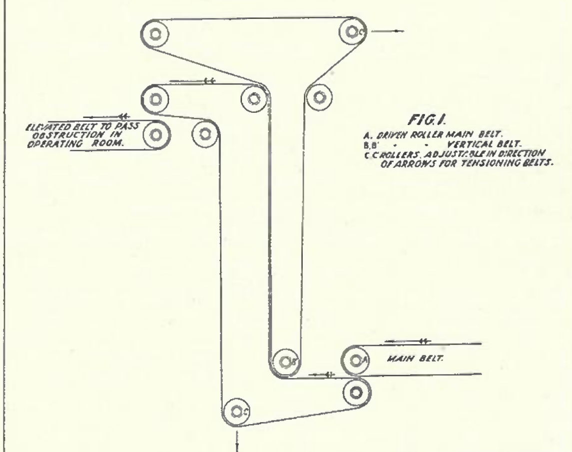


FIG. 1.
A. DRIVEN ROLLER MAIN BELT.
B, B' " " VERTICAL BELT.
C C ROLLERS. ADJUSTABLE IN DIRECTION OF ARROWS FOR TENSIONING BELTS.

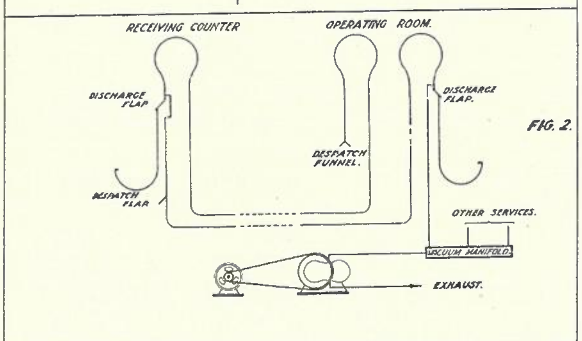


FIG. 2.

tend to acquire a static charge which causes the paper to adhere to the belts or frames. The expedients to ameliorate this difficulty include rotating or fixed brushes at points where forms may be carried over to the return side of the belt, and spraying the belts with water or a mixture of water and glycerine. Under certain conditions of low humidity and with certain classes of paper, these devices are not fully effective, and it is therefore necessary to provide catchments for over-carried forms and to institute frequent and thorough inspection to ensure that no messages are delayed by becoming lodged in crevices in or about the belt framework. Some other methods for combating this difficulty are still in the course of development.

Special attention is paid to keeping the belt channels free of obstructions or irregularities, as experience has shown that messages may be caught and retained by almost imperceptible projections. On the other hand, it must be impossible for forms to be left standing on edge against the side members of the belt frames. This might occur where telegrams are discharged from one belt to another, such as from a table belt to a main belt, but is prevented by a row of small weights hung on threads across the discharge path, which cause the forms to drop well into the centre of the lower belt without presenting a sufficiently rigid obstruction to cause blockages. An alternative method is to fix a number of smooth domes, such as cycle-bell tops, to the belt frame opposite the discharge point; these throw any forms which hit them on to the track of the belt, but have no crevices in which the corner of a telegram might lodge.

Kick-Back Carriers.

Kick-back carriers are used to convey telegrams from the central sorting bin to suitably located sub-centres in the operating or phonogram rooms, whence they are distributed to the correct operating positions for actual transmission.

The kick-back carrier is a variation from the familiar Lamson cash carrier as used in many stores. The carriage has attached to its underside a cylinder which is open at the front end, and instead of a latch to hold the carriage at the end of the outward journey, it runs into a loop of special elastic cord. The elastic is stretched in bringing the carrier to rest quickly, and immediately restores, imparting sufficient velocity to the carrier to return it to the firing point.

The sudden reversal of motion of the carrier causes the telegrams which had been placed loosely in the cylinder to be ejected from the open end. A cylindrical chute of diamond mesh wire lined with clear celluloid is provided to confine the messages as they drop into a wire basket.

Pneumatic Tubes.

The pneumatic tube systems used by the Department may be grouped as "house" tubes and "street" tubes.

House tubes are operated on the continuous loop low vacuum system, with a Roots blower as the means of producing the necessary vacuum. A line diagram of a simple installation is given in Fig. 2. The degree of vacuum maintained at the blower for a house tube service is from one to three inches of mercury, according to the lengths of the tube runs operated.

As the name implies, the house tubes generally serve to connect the operating room with the receiving counter and the despatch section, but if a tube service is required to another building within a few yards' street distance of the telegraph office, the house tube plant may be utilised.

With the street tube installations, carriers are propelled away from the operating room by pressure, and toward the operating room by vacuum. In a few instances tubes up to, say, quarter of a mile in length are operated by individual Roots blowers, separate from the house tube machines, and capable of maintaining vacuum and pressure up to 5 inches of mercury. The standard form of power plant for street tubes is reciprocating air pumps which maintain fixed pressure and vacuum values at common manifolds at the tube station in the operating room.

The tubes are 2¼ ins. internal diameter and within buildings are of seamless brass, usually 18 gauge in thickness. The street portions of the older tubes are of lead, laid in cast-iron pipes, but this construction is extremely expensive, and although practically everlasting in the straight lengths, a certain amount of trouble is experienced at some bends due to puckering of the lead.

A great deal of underground pneumatic tubing, chiefly in cable tunnels, has been provided in steel-cased brass tubing. This material consists of 20-gauge brass tubing, forced into a 16-gauge steel tube during manufacture so that the two metals are in such intimate contact that no penetration of moisture between them is possible. In tunnels, this composite tubing is suspended in suitable hangers and periodically treated with preservative composition. For laying in excavations, the tube is supplied by the manufacturer with a heavy jute lashing impregnated with pitch.

The two latest installations, which provide service between the Chief Telegraph Office and two Melbourne newspaper offices, have introduced a new type of construction. In these works brass tubing was used throughout, the most interesting development being in the excavated sections, where the 18-gauge brass tubing is protected by enclosure in 4-inch reinforced concrete pipes.. It was considered desirable that the brass tubing should not lie in direct contact with the concrete, and, in the first service provided, the tube was laid on small porcelain blocks placed at one end of each 6-feet length of pipe. On the second installation, the route of the tube included a steep gradient, and cast spiders with their feet anchored at the pipe joints to prevent any tendency to "walk" downhill were used, to keep the brass tube roughly central in the protecting pipe. The concrete pipes were laid on a sand bed in a well-rammed trench, particular care being taken to ensure even gradients, in order to avoid possibility of accumulations of drainage water, and to prevent irregularities in the tube line and stressing of tubing and joints.

The tubing in the tunnels for these services is of 16-gauge brass suspended from the roof hangers without further protection.

On the earlier of these two installations the joints were, in the first instance, of the usual brass sleeve type with a litharge and glycerine cement, but some early failures occurred and the sleeves were then thoroughly annealed and plumbed with wiping metal to the tubing at each end. The sleeved and wiped joints were used on the second installation, and have proved entirely satisfactory.

This all-brass construction was accepted, not only as being cheaper than the previous standards, but as offering much earlier completion of the work on account of all material being of Australian manufacture.

Where the volume and nature of the traffic warrants, as in the case of most city post offices, separate tubes are provided for "up" and "down" traffic, but for other services a single tube conveys carriers in both directions. This necessitates provision of means for applying either vacuum or pressure to the tube, a signalling system to indicate when a carrier is in transit, and suitable arrangements for despatching and discharging carriers.

Fig. 3 shows in schematic form the principal features of the terminals supplied for the operating room and of the two newspaper tubes previously mentioned. The figure shows the terminal with vacuum applied to the tube, the balanced double mushroom valve A being held open by the cam B. The tube is sealed against loss of vacuum at the discharge end by the leather flap valve C.

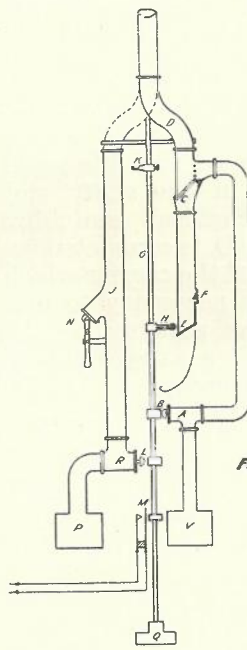


FIG 3

An incoming carrier which is being propelled by atmospheric pressure behind it will pass through the short movable section D and strike the flap C with sufficient velocity to break it from its seat. Immediately the seal at C is broken the air will become rarified in the short length of tubing between C and another flap at E, which will then be held firmly against its seating by the atmospheric pressure outside. The pressure on each side of C will, therefore, become approximately equal and the weight of the carrier will then be sufficient to open the valve fully and allow the carrier to fall through. Just before reaching E the carrier will strike a small trigger at F, which lifts a trap and admits sufficient air to cause the flap valve E to open easily and quietly, as by this time the main flap at C will have restored, shutting off the section E-C from the vacuum manifold. After leaving E the carrier is brought gently to rest in an open semi-circular trough. In the condition for receiving carriers as just described, the terminal is in its normal or "rest" position and as vacuum is continuously being applied to the tube, carriers may be despatched from the distant end without any necessity for prior communication with the Chief Telegraph Office.

When a carrier is to be transmitted from the Chief Telegraph Office, it is inserted through the opening N, which is then closed by a leather-faced disc attached to the toggle lever shown below it. The operating handle H is then moved radially forwards and at the end of its travel a tongue projecting to the side of the handle prevents release of the toggle at N. The handle H is attached to a shaft G, which when rotated, through about 120 degrees, brings the short movable tube section at the top of the terminal into position for effecting through communication between the main tube and the despatching section J of the terminal. The shaft also carries a cam B which, when the terminal was in the receiving condition, opened the vacuum valve A previously mentioned. The handle now being in the sending position, the cam B allows the valve A to close and another cam L opens a similar double mushroom valve R just before the handle H reaches the end of its travel towards the sending position. Immediately after leaving the control valve R, the air passes through an oil filter which causes any oil vapour present to be condensed and trapped, so that it may be removed periodically by washing of the filter and drainage. A spring coupling in the shaft, not shown, ensures that the mechanical switching movement of the tube section D is completed before the cam L admits air behind the carrier which has been inserted at N. This is necessary to prevent damage to carriers, and possibly to the terminal, which might occur if a carrier travelling under full air pressure were to strike the junction at D before a full bore opening was available for it to pass through. The shaft is turned to the sending position against the control spring in a door closer movement Q mounted at the bottom of the shaft, but is held in the sending position by a latch which engages with arm K.

The latch which holds K in position forms portion of the timing mechanism mounted on one of the rear members of the terminal. This timing mechanism comprises two units, the top member being a cylinder containing a piston, to the underside of which the compressed air is admitted at the same time as it is applied to the tube for the despatch of the carrier. The bottom end of the rod of this piston is attached to the retarding mechanism which is contained in another cylindrical case and consists essentially of a rack and pinion, which through a train of gears revolves a pair of vanes in an oil bath. The piston is thus permitted to rise very slowly, and after a predetermined period, a collar on its rod lifts the latch holding the arm K, and the operating shaft, in the transmitting position. When this occurs, the closer movement Q takes charge and restores the terminal to the receiving condition.

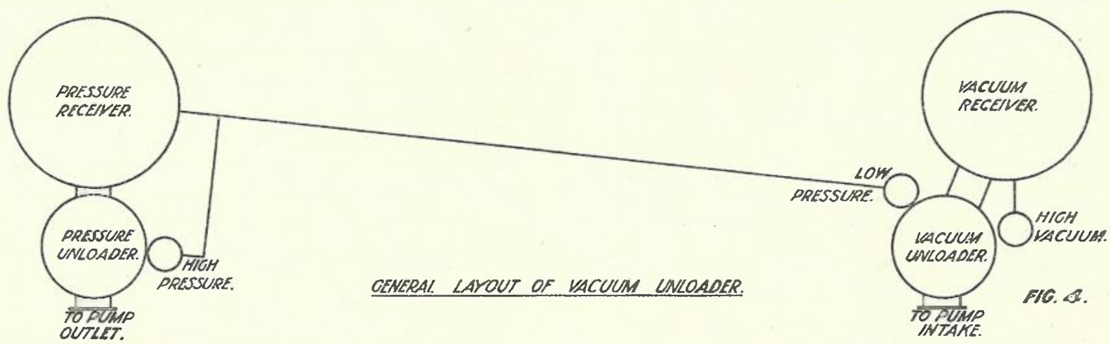
The third cam M on the main shaft G closes a pair of contacts at the same time that air is admitted through the valve R and gives a signal to the distant station, indicating that a carrier is in transit. The timing mechanism is adjusted by altering the set of the oil-immersed vanes, and the position of the collar, to release the shaft K after the known transit time for carriers to the distant station, plus an allowance of 10 to 20 per cent., has elapsed.

The terminal arrangements at the far end of the tube may be made much simpler, and, in fact, reasonably satisfactory operation is obtainable with an open tube discharging into a trough or other suitable means for bringing the carrier to rest without noise or damage. Some form of time-controlled signal is, however, necessary and there is some small advantage as regards air consumption in closing the distant end of the tube with a flap valve when vacuum is applied to it, but no carriers are in transit. These requirements have been met by incorporating in the terminal a barrel containing two alternative outlets for the end of the tube. One of these outlets is a "through" passage without obstruction, and the other is closed by a leather-faced flap valve. This barrel is turned to the position where the "through" opening is accessible when a carrier is to be transmitted, and returns by gravity under the control of a rack and pinion timing mechanism to its normal position ready for receiving from the chief office. The timing mechanism also serves to control a signal to the chief office indicating the despatch of a carrier. The signal from the out station is, actually, more important than that from the chief office, as it is obviously impossible for the sub-station to send a carrier against one coming from the Chief Telegraph Office under pressure applied from that point, whereas the attendant at the central control might, if he had no knowledge of an incoming carrier, reverse the air and blow back to the outer terminal a carrier already in transit. As an alternative to the terminal and timing arrangements for the out station, as just described, a circuit has recently been installed on one service based on the use of a telephonometer at the sub-office for giving a signal to the operating room, of duration slightly greater than that required for transit of a carrier. This arrangement avoids the necessity for any mechanism at the outer terminal, but does not provide the slight advantage of closing the distant end of the tube when no carriers are in transit.

If separate tubes are used for "in" and "out" traffic, the mechanical change-over switch at the Chief Telegraph Office is, of course, not necessary, and it is usual for vacuum to be continuously applied to the "inward" tube during working hours. With these variations the sending side of the terminal described, from the section J downwards and including the shaft G and timing mechanism, might be permanently connected to the "outward" tube; similarly, the receiving side could be permanently joined to the "inward" tube. Terminals on the Melbourne double tubes are not of this type, but by the addition of timing mechanisms have been arranged to perform the same functions.

ated on the underside of the tube terminal table in the Chief Telegraph Office. The pump side of each of the two receivers is closed by a check valve operating in the correct direction for preventing loss of vacuum or pressure when the unloaders open the pump line to atmosphere. These unloaders are mounted on the check valve casings, but on the pump side of each valve. The relative positions of the unloaders to the receivers and pump inlet and outlet are shown in Fig. 4, together with the pilot pipe connections between the receivers and the unloaders.

Fig. 5 shows in schematic form the operation of the vacuum unloader. The ½-inch pipe A connects the vacuum receiver to a pilot cylinder and, when the vacuum rises to a predetermined figure (in the case of the Melbourne plant 10-



GENERAL LAYOUT OF VACUUM UNLOADER.

FIG. 4.

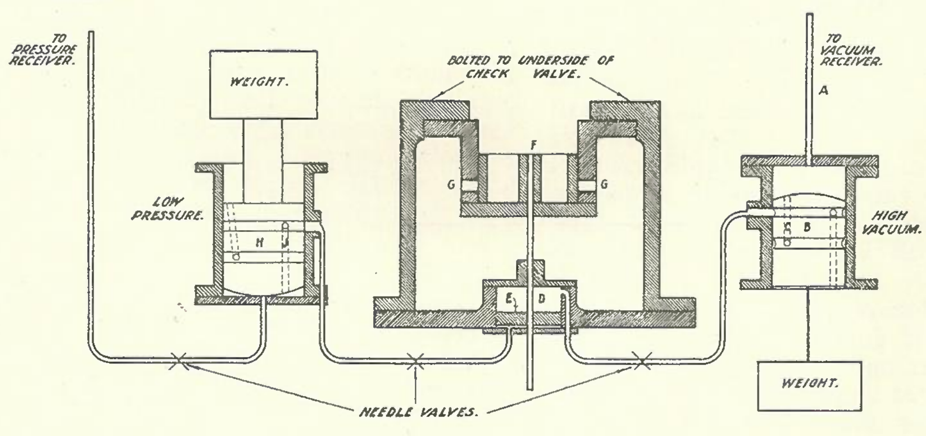


FIG. 5.

It has been mentioned that the air supply for the street tubes is obtained from reciprocating pumps supplying constant pressure and vacuum. The plant consists of single cylinder double-acting pumps working on the "pumping through" principle. In the "pumping through" system instead of separate pumps being provided for maintaining vacuum and pressure, a single pump draws rarified air from the vacuum receivers and delivers it under pressure to the pressure receiver. The vacuum and pressure receivers are connected by pipe lines to the vacuum and pressure manifolds which are situ-

inch mercury vacuum), the piston B is raised, uncovering the port shown, so that, through the channel C in the piston, vacuum is admitted to the upper end of the control cylinder D in the unloader. The piston E operating in the control cylinder therefore rises, and the piston valve F uncovers the large ports G, thus opening the pump side of the check valve through the hollow piston F to atmosphere. The action of the unloader is, thus, to prevent rise of the vacuum above the fixed figure and to provide free access of air to the intake side of the pump.

A second pilot cylinder is associated with the vacuum unloader and is connected by a ½-inch pipe to the pressure receiver. Provided the normal pressure of 7½ to 8 lbs. is being maintained, the pressure applied to the underside of the piston H will be sufficient to keep the piston H with the weight carried above it at the top of the cylinder, but if the pressure falls below the fixed lower limit, the piston descends and the port is uncovered, admitting air through the passage J to the underside of the control piston E in the main unloader valve. The action thereafter is the same as when vacuum is applied to the upper side of this cylinder, namely, the intake side of the pump is opened to atmosphere. The inclusion of the low pressure operation of the vacuum unloader is based on the assumption that, provided the pump is of suitable capacity and running at a correct speed, low pressure will only occur when the closing of a majority of the vacuum tube lines, in conjunction with the opening of a majority of the pressure tube lines, prevents the supply of a sufficient mass of air to the intake side of the pump to enable it to deliver the required volume and pressure on the output side.

The pressure unloader is generally similar to the low pressure and unloader portions of Fig. 5 with the exception that the ports in the high pressure pilot cylinder and piston are arranged to provide a through passage when the piston is at the top of the cylinder. The present adjustment of the Melbourne plant is such that the piston rises to this position when the pressure reaches 8 lbs. above atmosphere. In the case of the high pressure unloader, to the function of maintaining constant pressure is added the function of securing economical running by unloading the pump and providing a free outlet at little above atmospheric pressure on the discharge side of the pump. The effect of the unloader on the economical working of the plant is shown in the current consumption of the driving motor, which under present conditions in the Melbourne plant drops from about 60 amperes when delivering to the receiver to about 30 amperes when running unloaded. It is considered that this method of operation will compare favourably as regards power costs with the former method of operation, which included motor speed control automatically adjusted according to pressure in the receivers, while, owing to the lag between pressure variations and the compensatory speed adjustments, the pressure regulation was not comparable with that obtained by the present unloader method.

The author desires to thank the Engineering Agency Company, Sydney, for permission to publish descriptions of pneumatic tube equipment designed, and installed in Melbourne, by that Company.

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