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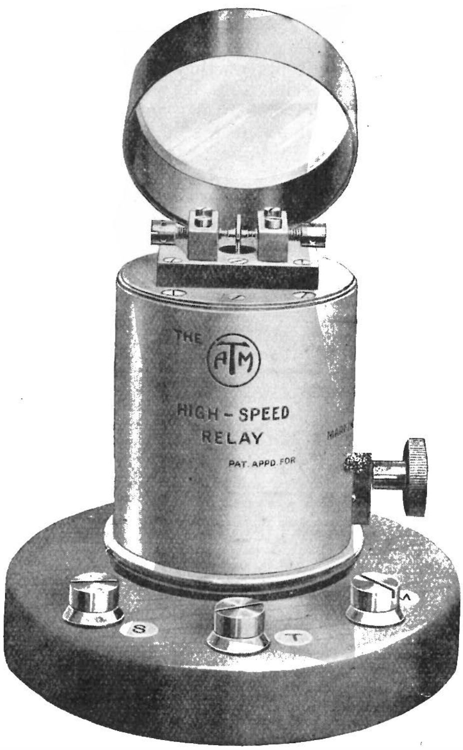

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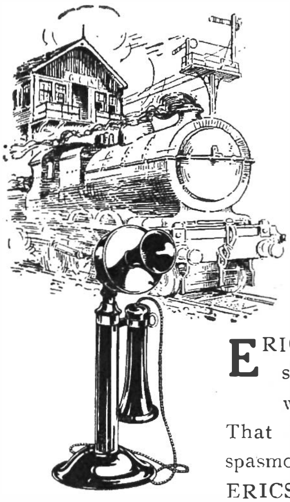

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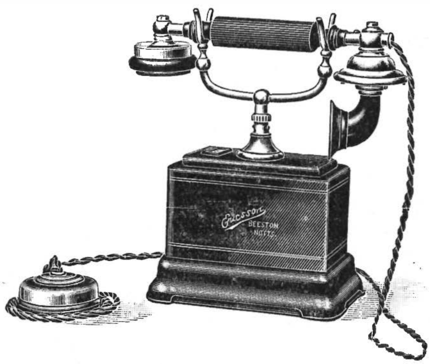

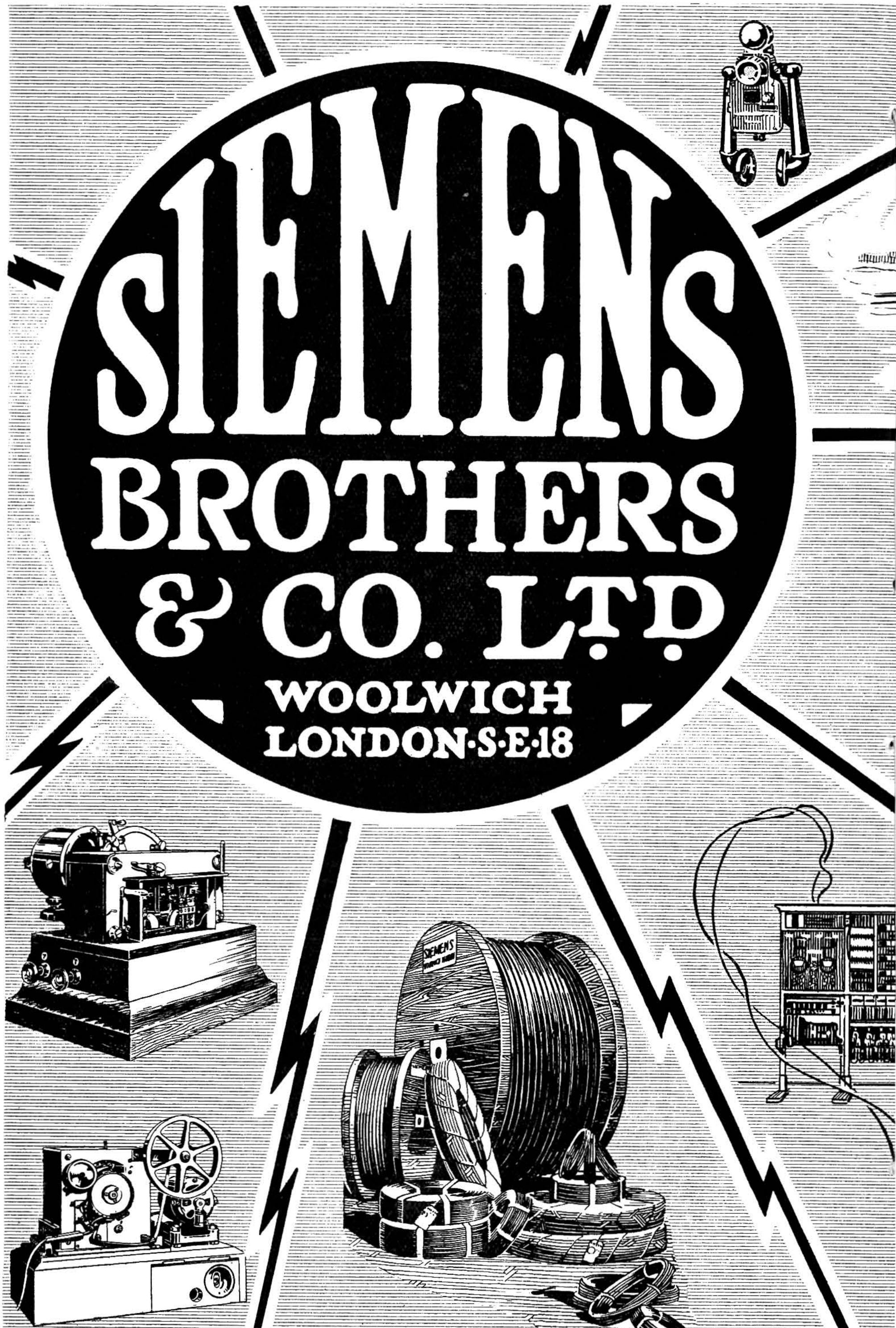
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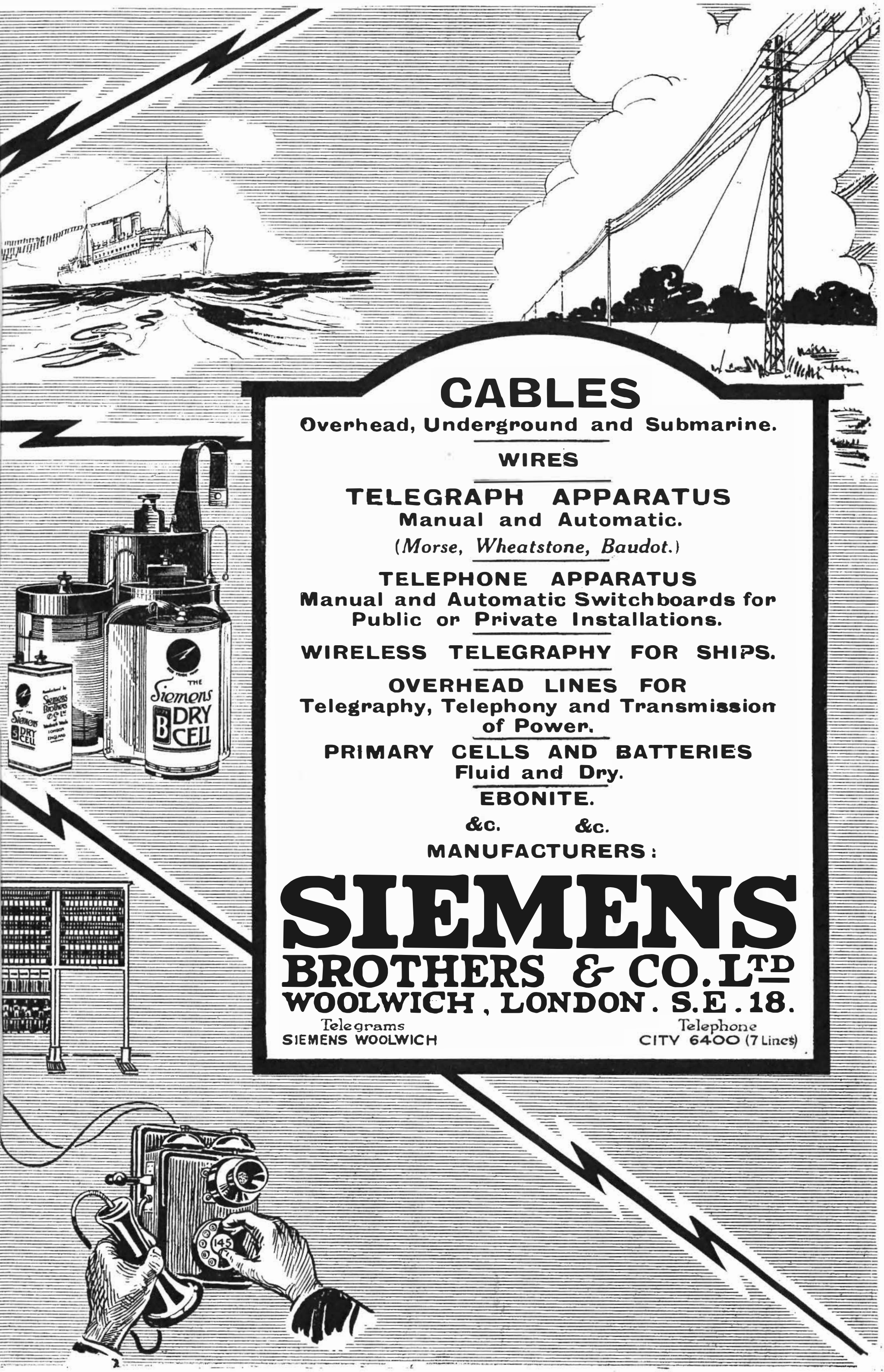
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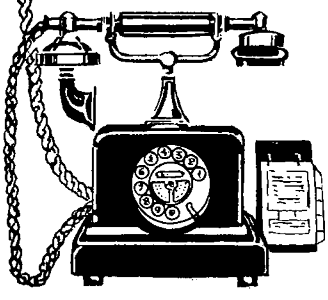

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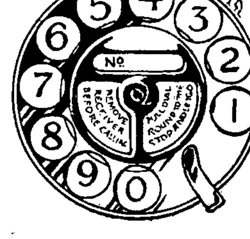

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AN INVESTIGATION OF THE LOSS INVOLVED IN TRUNKING FROM PRIMARY LINE SWITCHES TO FIRST SELECTORS VIA SECONDARY LINE SWITCHES IN STROWGER AUTOMATIC EXCHANGES.

By C. McHenry, A.M.I.E. Aust.
Lecturer in Telephone Engineering at the Technical College, Sydney, N.S.W.

In all trunking schemes an essential consideration is to dispose of a known or anticipated quantity of traffic with a predetermined probability of congestion occurring.

Congestion is expressed either as the ratio of lost calls to total calls or the ratio of time during which all trunks are engaged to the total time, the busy hour being usually the period considered. The former ratio is almost generally used and appears to be the most suitable, but there are cases when the latter would perhaps be more practical. The numerical value of the ratio chosen depends on the grade of service to be given and on economic considerations relating to the provision of plant.

1. Essential Features of Trunking Scheme.

For the purpose of fixing a basis for the present investigation a brief resumé of the essential principles involved in this method of trunking will here be given :—

(i.) *Plunger Type Line Switches.*

The subscribers' lines connect individually to switches known as primary line switches which are arranged in units of 100. Depending on the traffic originated each unit is given access to from 1 to 4 groups of outward trunks, the maximum being 10 trunks to any group. If more than one group of trunks is provided the lines in a unit are subdivided to suit. Each sub-group is controlled by an associated master switch which amongst other functions pre-selects disengaged trunks.

The trunks are always tested in a definite order. If all trunks are "busy," the master switch "swings" until a trunk becomes disengaged, all idle line switches in the meantime being rendered inoperative for originating calls.

The trunks from the subscribers' groups (generally known as primary sub-groups) terminate on switches known as secondary line switches, which are in principle the same as the primary line switches. The secondary switches are arranged in sub-groups, each controlled by an associated master switch and given access to a maximum of ten first selectors per sub-group.

As a general rule, each trunk from a subscriber's group terminates in a different secondary sub-group. In small exchanges where the number of secondary sub-groups is less than the number of trunks serving a primary sub-group, there will be several primary trunks from each subscribers' group terminating in a secondary sub-group.

It might and does happen that a secondary sub-group will be found with all out trunks busy. Under these circumstances, the circuit arrangements provide that whilst congestion continues all idle primary trunks terminating in the sub-group or sub-groups affected are caused to test busy in their respective primary sections, thereby causing all primary master switches poised opposite such trunks to move off and select other trunks.

For incoming calls each unit is served by a number of switches known as connectors, which are mounted on the reverse side of the units. Each line is multipled to each connector bank, so that in a unit any connector has access to any line connected thereto.

Other details are incorporated, but are not included in the scope of the present discussion.

(ii.) *Rotary Type Line Switches.*

In this case the master switch is dispensed with, each switch being self contained. The trunk groups have a maximum of 25 instead of 10, as in preceding case, and consequently the number of primary and secondary sub-groups required is less than in (i). Otherwise the principle remains the same, with the exception that each secondary sub-group, in the case of exchanges of medium size, will accommodate more than one trunk from each primary sub-group.

The fundamental differences between (i.) and (ii.) are far-reaching, but in this article any discussion thereon will be confined to the traffic aspects.

2. Methods of Trunk Distribution.

There are three main methods of arranging the trunk distribution, summarised briefly as follows:—

(i.) The subscribers are divided into a number of main groups with the sub-grouping indicated in (1) above. Each main group as a whole has access to a given number of first selectors, *viâ* the secondary sub-groups, to the absolute exclusion of other main groups, it being possible for any subscriber in a main group to connect with any selector serving such group.

(ii.) The total subscribers form one main group with the usual sub-grouping. Each sub-group has access to a given number of first selectors, *viâ* the secondary sub-groups, but the individual selectors accessible from one primary sub-group are partially or wholly inaccessible from other primary sub-groups, depending on the two sub-groups considered.

(iii.) A combination of (i.) and (ii.).

The above methods of distribution are no doubt generally familiar. In the first case the first selectors form a number of real and distinct groups, but in the second case they form one composite group in which the component groups overlap. A scheme of trunking arranged according to (ii.) may best be likened to a cyclic distribution, but a cyclic distribution is not, however, the only distribution which will satisfy (ii.).

3. General Considerations.

Speaking generally, all present exchanges using plunger type line switches have not a dialling tone provided. In future Strowger exchanges the selectors, no doubt, will incorporate a dialling tone. Under present conditions, therefore, a caller has no indication as to whether a trunk is available or not, and consequently, after removing the receiver, proceeds to dial the number required. If all trunks are busy, and remain so whilst dialling, a caller is still in the same position as when the receiver was removed, excepting for the delay, but if congestion lifts whilst dialling the call will be mutilated and actually lost so far as the caller is concerned, but *not* lost as regards switch occupation. Obviously, if a high grade of service is to be given, mutilated calls must count as lost calls.

On the other hand, if a dialling tone be provided, then a caller not receiving same upon removing the receiver will wait a reasonable time in anticipation of receiving the tone before he finally hangs up. If congestion in such a case happens to any extent, there may be several simultaneously waiting callers in a primary sub-group, so that when a trunk becomes available the result is that they all seize it and become cross-switched and are, in consequence, to state it mildly, further inconvenienced. It is, therefore, problematical as to whether a dialling tone will prove to be of any benefit in Strowger equipment using plunger type line switches; but where rotary line switches are used the foregoing remarks do not apply, and in the latter case there should be no objection to the use of a dialling tone other than apply generally to any system.

4. THEORETICAL CONSIDERATIONS.

After review of the preceding paragraphs, it will be quite evident that the only congestion which *directly* affects the subscribers is that which occurs in the primary trunk groups. When a secondary sub-group becomes congested the effect is to reduce the available number of trunks from the primary sub-groups trunking into the particular secondary sub-group affected. Therefore, the problem must be approached from the primary trunk groups, and in considering the probability of any one of these groups being congested the probability of certain of the trunks therein being busy due to congestion in the secondary sub-groups must be taken into account.

To avoid confusion the following general terms are used with the restricted meanings assigned when referring to the primary trunk groups:—

(*a*) "Engaged."—To signify that any given number of trunks are in use by callers, *i.e.*, carrying telephone traffic.

(*b*) "Busied."—To indicate that any given number of trunks are unavailable due to congestion in the secondary sub-groups.

(*c*) "Busy."—To include "*a*" and "*b*," or in referring generally to either.

In the mathematical treatment it will be obvious that the probability of finding any given number of primary trunks busy constitutes an event which may happen in several mutually exclusive ways.

For example, the number of mutually exclusive ways in which 0, 1, 2 and r trunks in a primary group may be found busy are as follows:—

0 Trunks busy:—

(i.) No trunks engaged: No congestion in the secondary sub-groups.

1 Trunk busy:—

(i.) 1 trunk engaged: 0 trunks busied.

(ii.) 0 trunks engaged: 1 trunk busied.

2 Trunks busy:—

(i.) 2 trunks engaged: 0 trunks busied.
(ii.) 1 trunk engaged: 1 trunk busied.
(iii.) 0 trunks engaged: 2 trunks busied.

r Trunks busy:—

(i.)—r trunks engaged: 0 trunks busied.
(ii.) $(r-1)$ trunks engaged: 1 trunk busied.
(iii.) $(r-2)$ trunks engaged: 2 trunks busied.
$(r+1)$ 0 trunks engaged: r trunks busied.

and the total probability in any of the cases shown is the sum of the probabilities for each of the individual ways in which the event may happen.

So far as concerns this article,* I propose to use the theory advanced by A. K. Erlang, which states that if the average number of calls is A, the probability of exactly r trunks being engaged if the total number be x is:—

$$\frac{\dfrac{A^r}{r!}}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^r}{r!}+\cdots\cdots+\dfrac{A^x}{x!}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

and under the assumptions made by Mr. Erlang, the proportion of lost calls is represented by:—

$$B=\frac{\dfrac{A^x}{x!}}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^x}{x!}} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Let x and y be the number of trunks in each primary and secondary sub-group respectively, and let the number of secondary sub-groups be not less than x, each primary trunk, therefore, terminating in a different secondary sub-group. Let it be further assumed that each primary sub-group originates an equal volume of traffic A, and that the total traffic is uniformly distributed throughout the secondary sub-groups. In a good distribution the last assumption is always closely fulfilled.

Then, as already shown, there are $(x+1)$ mutually exclusive ways in which a caller may find the x trunks busy. However, to consider the case generally let S be the probability of any secondary sub-group having all y trunks busy and P_0, P_1, P_2,.........P_x, the respective probabilities that 0, 1, 2,.........x trunks in a primary

* The effect of incoming calls on the originating calls has been ignored, because the relations given in (1) and (2) require a priori that the number of subscribers' sub-group be unlimited. The present theory may be modified to include incoming calls but the size of the subscribers' groups would enter into an *exact* calculation of the case so that Erlang's formula would not apply.

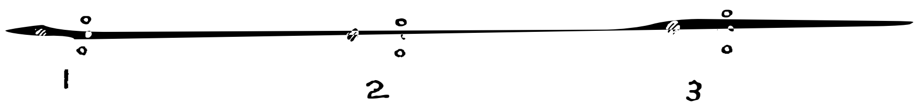
group are busy and using $\left(\dfrac{x}{r}\right)$ instead of $\dfrac{x!}{r!(x-r)!}$ then

$$
\left.
\begin{aligned}
P_0 &= \left\{\frac{1}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^x}{x!}}\right\}\left\{1-S\right\}^x \\
P_1 &= \left\{\frac{A}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^x}{x!}}\right\}\left\{1-S\right\}^x+\left\{\frac{1}{1+A+\dfrac{A^2}{2!}+\cdots\cdots\cdots\dfrac{A^{x-1}}{(x-1)!}}\right\}\binom{x}{1}S(1-S)^{x-1} \\
P_2 &= \left\{\frac{\dfrac{A^2}{2!}}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^x}{x!}}\right\}\left\{1-S\right\}^x+\left\{\frac{A}{1+A+\dfrac{A^2}{2!}+\cdots\cdots\cdots\dfrac{A^{x-1}}{(x-1)!}}\right\}\binom{x}{1}S(1-S)^{x-1} \\
&\qquad+\left\{\frac{1}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^{x-2}}{(x-2)!}}\right\}\binom{x}{2}S^2(1-S)^{x-2} \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
P_x &= \left\{\frac{\dfrac{A^x}{x!}}{1+A+\dfrac{A^2}{2!}+\cdots\cdots+\dfrac{A^x}{x!}}\right\}\left\{1-S\right\}^x+\left\{\frac{\dfrac{A^{x-1}}{(x-1)!}}{1+A+\dfrac{A^x}{2!}+\cdots\cdots+\dfrac{A^{x-1}}{(x-1)!}}\right\}\binom{x}{1}S(1-S)^{x-1} \\
&\qquad+\cdots\cdots\cdots\cdots\cdots\cdots+S^x
\end{aligned}
\right\}\cdots(3)
$$

Where the sum of all the probabilities is 1, or certainly as should be the case.

Under the assumptions made P_x will also represent the proportion of lost calls for one subscribers' group.

In calculating the *total* loss for trunking schemes, the general practice appears to be to take the sum of the losses at each connecting point, but this method is incorrect although it happens that same is nevertheless a very close approximation.



Let Fig. 1 represent a trunking scheme in which p_1, q_1; p_2 q_2; p_3 q_3 are the respective probabilities for loss and no loss at each connecting point. Then according to the usual method the total loss is :—

$$B = p_1 + p_2 + p_3$$

If the number of connecting points were indefinitely increased or p_1, p_2, etc., made comparatively large then the total loss would finally become $\geqq 1$, or in other words the total traffic would be lost, whereas, actually this could not be the case. The total loss is calculated from the usual rules of probability, and, as in the case under review the only combination involving no loss is the probability of no loss at all points, *i.e.*,

$q_1 \cdot q_2 \cdot q_3$, the total loss is therefore

$$B_T = \{1 - q_1 \cdot q_2 \cdot q_3\} \quad \ldots\ldots (4)$$

which in some cases gives an entirely different result to the usual method.

If $q_1 = q_2 = q_3 = Q$

then

$$B_T = 1 - Q^N \quad \ldots\ldots (5)$$

where N is the number of connecting points.

Let N be the number of main groups and n the number of sub-groups to a main group, there being a total of $N \cdot n = \phi$ sub-groups, then the loss in one main group is

$$B_M = 1 - \{1 - P_x\}^n \quad \ldots\ldots (6)$$

and the total loss for the exchange up to but not including the first selectors is

$$B_T = 1 - \{1 - B_M\}^N \quad \ldots\ldots (7)$$

If there was only one main group with the same total number of sub-groups then there would be ϕ sub-groups, so that the total loss up to the first selectors would be

$$B_t = 1 - \{1 - P_x\}^{\phi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

and in this case it can be very easily seen or proved that (7) and (8) are equal, so that we arrive at the important and perhaps unexpected result that provided the loss in each subscribers' group *remains constant* then the total loss up to the first selectors is independent of the trunking scheme adopted.

In actual cases it will generally be found that a cyclic distribution will be the most economical because whilst almost any number of switches can be arranged cyclically under certain conditions, an even division into groups will perhaps be impracticable.

In the relation given for P_x in (3) it is usually only the first four or five terms that are important, the remaining terms being so small (*i.e.*, the events they relate to being highly improbable) that they may be ignored.

A few examples have been worked out to illustrate the foregoing theory. The case considered is that of 1000 subscribers divided into 20 sub-groups of 50 lines each. In examples (1) to (5) the total traffic is 50 units or 2.5 units per sub-group and in examples (6) to (9) the total traffic is 60 units or 3 units per sub-group.

No.	No. of trunks serving each primary sub-group.	Total No. of primary trunks.	No. of secondary sub-groups.	No. of trunks serving each secondary sub-group.	Total No. of first selectors	Approximate LOSS. In calls per 1000 for ONE primary sub-group.	Approximate LOSS. In calls per 100 for 1000 subscribers.
1	10	200	Constant = 10	10	100	0.4	0.79
2	9	180		10	100	1.5	2.9
3	8	160		10	100	5.0	9.5
4	10	200		9	90	0.45	0.9
5	10	200		8	80	0.65	1.3
6	10	200		10	100	2.0	3.9
7	9	180		10	100	5.3	10.0
8	10	200		9	90	3.0	5.8
9	10	200		8	80	5.0	9.5

The above figures require no explanation, but the *false* economy in primary trunks revealed by examples (2), (3) and (7) is obvious. Examples (3) and (9) should be compared and the difference in the traffic not lost sight of.

In a recent paper by Mr. F. L. Baer, of the Automatic Electric Company, Chicago, entitled "The Computation of Quantities of Telephone Switching Equipment," empirical and arbitrary methods are therein demonstrated for the calculation of the quantities in question. Space does not permit of the article in question being here discussed, but Mr. Baer states, *inter alia*, that 100 selectors reached *viâ* primary and secondary line switches may be considered as having the effectiveness of a group of 85. Actually, however, the traffic which 100 selectors will carry for a given loss under different circumstances is a variable quantity.

It will now be seen that a most important point is to make liberal provision in the primary trunk groups, necessitated by the fact that congestion in a secondary sub-group reduces the available number of outlets from several of the subscribers' groups. Further, it will also be evident that the secondary sub-groups essentially only provide a means of economising in first selectors by bringing about a more efficient co-ordination between the latter switches and the primary line switches. Additional loss is entailed on account of the arrangement, but this is more than offset by the resultant economy in first selectors.

There is a limit below which the probability of lost calls cannot be decreased, and this limit may be approached by increasing the number of secondary sub-groups to such an extent that congestion in one of them is highly improbable. This would practically eliminate the "back-busying" feature on the primary trunks so that the loss could be calculated simply from the traffic to be carried by the subscribers' groups.

From observations of working exchanges, it is thought that a loss of one call/100 for each 1000 lines gives a high grade of service, and it has been noticed that the calculated loss has been six calls/100 with comparatively few swinging master switches.

Where rotary line switches are used the total number of primary and secondary sub-groups is reduced and the number of lines to a sub-group increased on account of larger trunk groups available.

The result gained is, therefore:—

(*a*) A lower overall loss for the total number of subscribers, or
(*b*) For a given total loss a greater amount of traffic may be carried, or
(*c*) For a given traffic and a given loss fewer first selectors will be required,

as against the case if plunger type equipment were installed.

If the traffic is not too great it may prove more economical with a suitable scheme of distribution to trunk direct to first selectors and thus dispense with the necessity for using the secondary groups.

This only applies, however, to exchanges where the lines connected are comparatively few or where the traffic is small enough to permit of this being done.

Taking now the case where the trunking is symmetrically arranged, which implies that the number of secondary sub-groups is a factor of the number of trunks in a primary sub-group, and let x and y have the same significance as before, and further, let θ be the number of trunks from one primary sub-group terminating on a secondary sub-group, then there are $\left(\frac{x}{\theta}+1\right)$ different ways in which a subscriber desiring to call may find x lines busy. (Note in large exchanges θ will be equal to 1). These may be tabulated as follows:—

(i.) x trunks engaged: 0 trunks busy.
(ii.) $(x-\theta)$ trunks engaged: θ trunks busied.
(iii.) $(x-2\theta)$,, ,, : 2θ ,, ,,
(iv.) $(x-3\theta)$,, ,, : 3θ ,, ,,
....
$\left(\frac{x}{\theta}+1\right)$ 0 ,, ,, x ,, ,,

and as before the probability of a subscriber finding all trunks "busy" is the sum of the probabilities for each of the $\left(\frac{x}{\theta}+1\right)$ enumerated cases.

Space does not permit of acutual comparisons between the two types concerned, but the reader who is so disposed can easily investigate any case.

Another arrangement is the one in which primary line switches of the plunger type are used in conjunction with secondary sub-groups of the rotary type. The number of primary sub-groups is not decreased, but the scheme is more efficient than the case where plunger type switces are solely used.

CONCLUSION.

In presenting the foregoing investigation, I have been actuated by a desire to place the subject treated on some kind of a common basis and to clear up a number of misconceptions in regard thereto. I have not so far encountered or know of any work thereon, with the exception of Mr. Baer's article already referred to. It appears to me that a number of the theoretical investigations carried out from time to time with regard to trunking in automatic exchanges are not entirely applicable to practical cases. For example, another subject I may touch on later is the almost general case encountered in trunking from selector levels; where the number of connecting circuits provided is greater than the number of bank contacts on a switch level. This problem is important as, apart from the question of trunk provision, the economics of traffic distributor schemes between selector levels and other groups of switches cannot be accurately discussed without a proper formulation of same.

KEYBOARD PERFORATORS.

A. C. BOOTH.

THE accompanying illustrations show the arrangement of the keys for Keyboard Perforators which has been adopted by the Post Office as a standard, so that operators will find practically no inconvenience in changing from one type of instrument to another, no matter whether the Keyboard Perforator works on any of the 5-unit equal letter alphabets or the well-known Morse code with its letters of varying length.

In all cases each key is arranged to provide two characters. These may be the same or quite different groups of perforations, determined by the use of the combined space and change keys marked "Figures" and "Letters."

BAUDOT MULTIPLEX KEYBOARD

FOR

PERFORATORS NO 25 & 30.

FOREIGN CIRCUITS

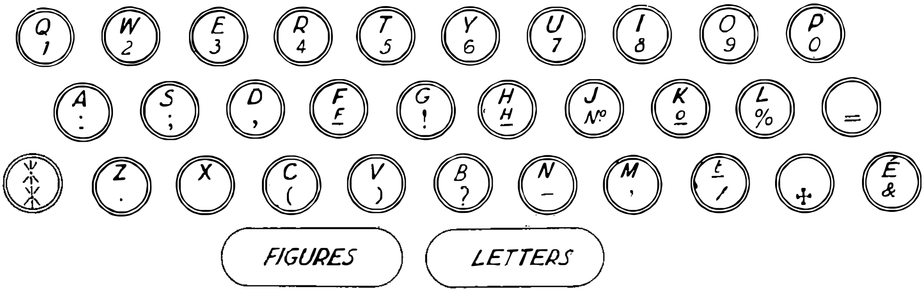


FIG. 1.

The first illustration shows the arrangement of the keys for foreign Baudot circuits in which the signals used for the Baudot type-wheel as used in France and on the Continent are provided, including the accented E.

BAUDOT MULTIPLEX KEYBOARD

INLAND CIRCUITS
FOR
PERFORATORS NO 24 & 31

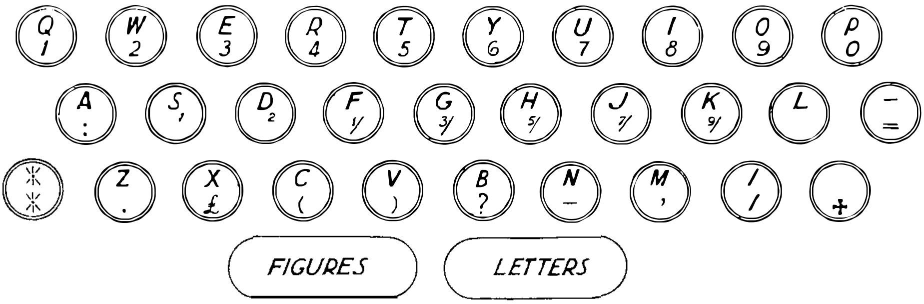


FIG. 2.

The second illustration shows the arrangement of the keys for use on British inland circuits where the Baudot Receivers are provided with type-wheels differing from the French Baudot type-wheel, mainly in the secondary characters, but also in one or two

MURRAY MULTIPLEX KEYBOARD

FOR
PERFORATOR NO 27

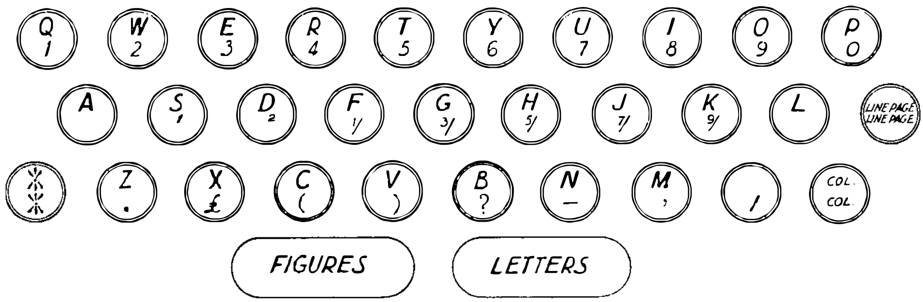


FIG. 3.

cases in the primary characters. The accented " E " and the small " t " are not required and have been replaced by a duplication of the hyphen and oblique stroke in order that such groups as C/O may be printed by three signals instead of five.

The third illustration shows the arrangement of the keys for future Murray Keyboard Perforators for use on the Murray Duplex Multiplex. They can also be used on inland Baudot circuits, as the only real differences are unimportant, being merely the duplication of the hyphen and oblique stroke on the primary side, and the secondary signal on Key A, which is not provided. The " Col " key is the same as the " + " signal used for the " End of Message " signal, while the " Line Page " signal is the same as the " Break " signal or " Double-hyphen." Both these signals are on the primary as well as the secondary keys in this case.

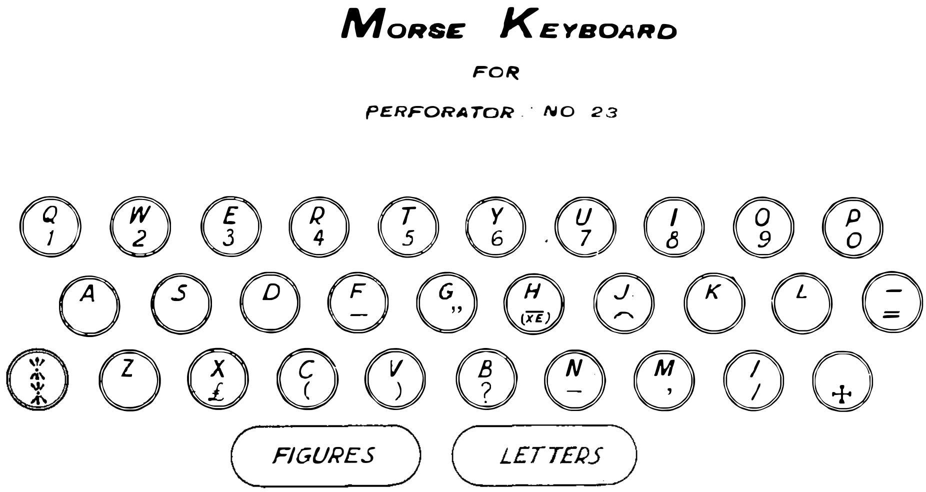


FIG. 4.

The fourth illustration shows the arrangement of the keys for the Morse or Wheatstone Keyboard Perforators, from which it will be seen that the difference between the arrangement and that of the Baudot Keyboard lies in the secondary characters of the second row, where provision has to be made for the " Underline," " Inverted commas," " Horizontal fraction bar " and the " Tie-bar " between whole numbers and fractions. These differences are not of great importance from the operating point of view.

THE SHUNTED CONDENSER.

THE following notes are based upon an investigation carried out by Mr. A. B. Morice on behalf of the Telegraph Section and dealt with in Research Section's Report, No. 1747:—

The experiments were made for the purpose of obtaining a record of the effect on the current curve of the inductance of a Wheatstone receiver, and of its rectification by means of a shunted condenser.

Four separate conditions were dealt with:—

(1) Reversals of a current of 8 ma.'s through the receiver coils in series without a shunted condenser in circuit.

(2) Conditions as in (1) but with a shunted condenser included having values for K and R necessary to annul the inductance of the receiver.

(3) Coils of the receiver joined in parallel with reversals of 16 ma.'s (8 ma.'s in each coil) without shunted condenser in circuit.

(4) Conditions as in (3) but with the shunted condenser included.

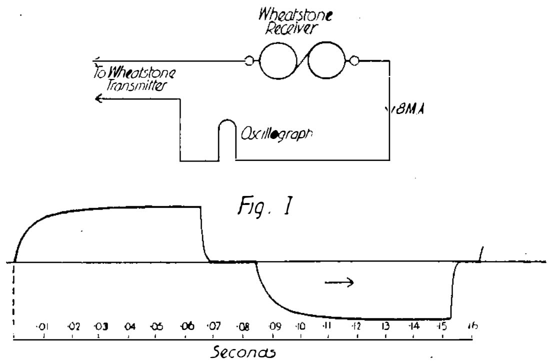


Fig. **1** shows the circuit arrangement and the current curve for the condition laid down in (1). The curve has the well-known characteristic shape for the rise of a current in an inductive circuit, and the value of the latter may be readily estimated at any particular stage of its duration by means of the subjoined time-scale.

In Fig. **2** the Wheatstone Receiver has been replaced by an equivalent non-inductive resistance of 200 ohms. The slight departure from the true rectangular form is due to the combined effects of the inertia of the mirror system and the movement of the oscillograph drum. An interval of .002 second has to be allowed for these combined effects, and must accordingly be deducted from the curves.

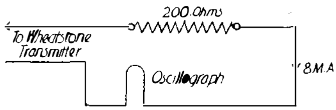
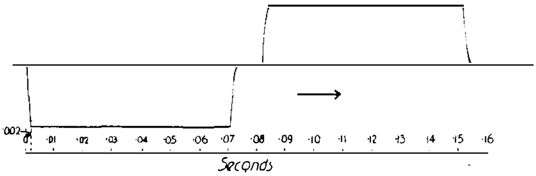


Fig. II



In Fig. **3** the nullifying effect of the condenser is clearly shown. The small time-interval of lag, after allowing for instrumental error, is due to a slight deficiency in the value of the shunting capacity.

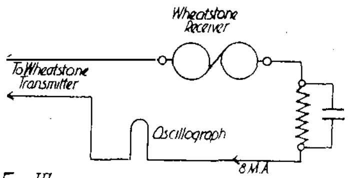
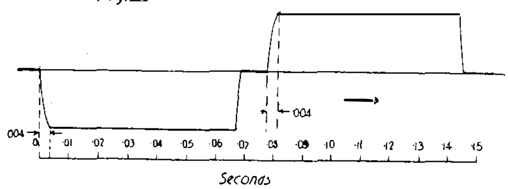


Fig. III



The curve was obtained with 1000 ohms in the rheostat and 1.5 microfarads in the condenser. Similar curves were obtained with values of 1500 ohms and .75 mf.; 2500 ohms and .25 mf.; and 500 ohms and 6 microfarads, the best result being given by the high resistance and small capacity.

Corresponding characteristics were observed in the series of curves taken with the coils joined in parallel and with the following values in the rheostat and condenser:—

R.	K.
1000	.75 mf.
1500	.25 ,,
500	2.25 ,,
1000	1.[illegible] ,,

In all cases the effect of the shunted condenser was to reduce the time taken by the current to reach its so-called maximum, to that of the non-inductive circuit.

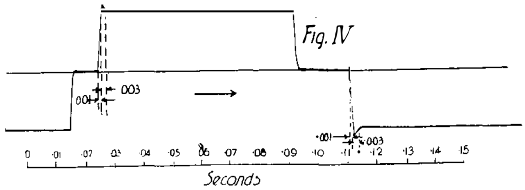


Fig. 4 shows the effect of increasing the shunting capacity slightly in excess of that required to produce neutralisation. In this case the coils were in parallel, and the shunted condenser had a resistance of 1000 ohms and a capacity of 1 mf.

A further series of curves is being prepared with more extensive values of capacity and resistance required to produce a rectified curve. The results obtained will be dealt with in a subsequent article.

A. F

THE INSULATION OF A LINE.

By J. G. HILL.

INSULATION tests are everyday occurrences, and one might imagine that their correct interpretation would be a commonplace fact, beyond all possibility of doubt. A correct knowledge is not, however, sufficiently widespread to enable one to say that the main facts concerning such tests are sufficiently well known. It is here proposed to briefly discuss some important points in connection with them. Direct current tests will be dealt with, and the current loss at the insulators in a long uniform aerial line will first be analysed. It will be assumed that the steady state has been reached, *i.e.*, that the current has had time to rise to its state of steady flow. Finally, formulæ for lines of any length will be given and illustrated by examples.

We define the conductor resistance of the line as the direct current resistance of the line wire at a given temperature, and it will generally be convenient to express it in terms of ohms per mile. Similarly, the insulation resistance per mile will be the resistance of the insulators in this length joined from the line wire to earth, and it will be assumed that the insulation resistance is uniformly and equally distributed along the line.

It is evident that the measurement of the apparent resistance at the sending end of the line, with the distant end either open or closed, is the measurement of the combined conductor and insulation resistance, with different terminal conditions. If the line is electrically short and the distant end open we practically measure the insulation resistance only, as we shall see later, and if the distant end of a short line is closed the sending end resistance is similarly the conductor resistance of the line. As a line increases in length, however, the conductor resistance increases and the total insulation resistance decreases; the combined effect being that if the line is sufficiently long there is no difference between the apparent conductor resistance and insulation resistance, as measured from the sending end of the line. The reasonableness of this statement will perhaps be appreciated if we remember that as the line is indefinitely lengthened, more and more current is lost at the insulators, and if the line were long enough the received current would be negligibly small, even with the receiving end of the line closed. It could then make no difference at the sending end whether the line were open or closed, and the apparent conductor resistance and insulation resistance would be the same. This constant resistance is called the characteristic resistance, and the conception of it is important in the development of a correct theory. The phenomenon described may, however, be observed in practice on very long lines in wet weather.

Analysis of the Current loss in a long Aerial Line.

Suppose that each insulator in a 100-lbs. single wire copper line has the same insulation resistance R_1 and that the line is long enough to have a constant characteristic resistance R_0 as measured from any point. In such a case the same proportion of the line current I arriving at the insulator, will be lost through the insulator to earth. The current I_1 through each insulator will be in fact by ohms law:

$$I_1 = I \frac{R_0}{R_1+R_0} \qquad \text{.......................................(1)}$$

when R_0 and R_1 are constant resistances.

Let the line described have 30 insulators to the mile and suppose that one ten-thousandth part (0·0001) of the current is lost at every insulator. (It will be seen later that this is equivalent to an insulation resistance of 1 megohm per mile). What would be the effect of this insulation loss on a current observed on this indefinitely long line at a point 200 miles from the sending end?

Suppose that the current has a value 1 at the beginning of the line. On arrival at the first insulator 0·0001 of this current is lost and 1 – 0·0001 transmitted; this latter current arrives at the second insulator and 0·0001 of it is lost; the current passing on is again 1 – 0·0001 or 0·9999 of the current which arrived there, or (1 – 0·0001) of (1 – 0·0001) or $(1 - 0{\cdot}0001)^2 = (0{\cdot}9999)^2$. The current passing onwards from the third insulator would be $(0{\cdot}9999)^3$, and reasoning in this way the current arriving at the end of 200 miles is $(0{\cdot}9999)^{6000}$. (6000 is the number of insulators in 200 miles). Now $(0{\cdot}9999)^{6000} = 0{\cdot}54935$, *i.e.*, a little more than half the sent current.

It should be noticed that the received current has been found from a knowledge of the current loss per insulator, and the knowledge that the resistance R_0 of the line is constant. Now the latter quantity R_0, and the loss of current per unit length, are quantities which enter into all formulæ for the accurate determination of the sending end resistance with the distant end open or closed, and also the received current, in lines of any length. Formulæ of *general* application have been developed for these quantities and these lead to the same results as those already obtained, as will now be shown. Proofs may be found in transmission manuals. The percentage loss of current per unit length is called the attenuation constant and is denoted by the symbol β. The formula for β is

$$\beta = \sqrt{RG} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where G is the reciprocal of the insulation per mile and R the conductor resistance per mile.

In the case of the 100 lbs. circuit already described, we have $\beta = \sqrt{9 \times 10^{-6}} = 3 \times 10^{-3} = 0{\cdot}003$, which is the equivalent of the value previously found, for there are 30 insulators per mile and a loss of 0·0001 per insulator. So that we have a current loss of $30 \times 0{\cdot}0001 = 0{\cdot}003$ per mile.

A further formula which has been developed in the transmission theory, when the sent current is 1, is

$$e^{-\beta l} = I_R \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where e is the base of the natural logarithms, l the circuit length and I_R the received current. Applying the data of the 100 lbs. circuit at a point 200 miles from the sending end to this case we have $e^{-0 \cdot 003 \times 200} = I_R$ or $e^{-0 \cdot 6} = I_R = 0{\cdot}54582$.

The value previously found by the preceding investigation is 0·54935 or a difference of only about one tenth of one per cent. in the two cases.

The characteristic resistance may be obtained from the formula

$$R_0 = \sqrt{\frac{R}{G}} \quad \ldots\ldots (4)$$

In the case already taken this becomes $R_0 = \sqrt{\frac{9}{10^{-6}}} = 3 \times 10^3$ $= 3000$. Further, from formula (1) the loss of current in one insulator is $I \frac{R_0}{R_1 + R_0}$, where R_1 is the insulation resistance of one insulator or $10^6 \times 30$ ohms, so that (1) becomes $I \frac{3000}{30 \times 10^6 + 3000}$ $= \frac{3000}{30{,}003{,}000} = \frac{1}{10001} = 0{\cdot}0001$ nearly. The quantity 0·0001 is the loss per insulator previously assumed. It may be deduced from the well-known form of (3) that the current is attenuated in accordance with the compound interest law, and as the attenuation is due to the loss through the insulators, the current through them falls off from the sending end in accordance with the compound interest law.

Having found that the standard formulæ apply to the case of long aerial lines and that their application is not difficult, we will now consider the question of short lines.

Formulæ for Finite Lines.

In the case of finite lines, or lines of any definite length short of those long enough to be regarded as having a fixed resistance R_0, there may be considerable variation of the apparent sending end resistance with length, and this complicates the problem very much.

The apparent resistance Z of a uniform line of any length measured from the sending end with the distant end open is:—

$$Z = R_0 \coth \beta l \quad \ldots\ldots (5)$$

If the distant end is closed the sending end resistance Z_1 is:—

$$Z_1 = R_0 \tanh \beta l \quad \ldots\ldots (6)$$

The received current I_R is obtained from the formula:—

$$I_R = \frac{E}{R_0 \sinh \beta l} \quad \ldots\ldots (7)$$

Here R_0 and βl have the meaning already given and E is the applied constant voltage at the sending end of the line. Sinh βl, tanh βl, and coth βl are the hyperbolic sine, tangent and cotangent of the angle βl. The introduction of hyperbolic functions of course complicates the matter; but if a correct result is required for all lengths it is difficult to see how their use can be avoided.

The formulæ are, however, no more complex than the physical facts which they symbolize. It will be seen later that the usual approximate formulæ are not sufficiently accurate. Moreover, in the direct current case all the required hyperbolic function values may be read directly from tables, so that the calculations are not very complicated. To show this, let us find the sending end resistance of the 100 lbs. circuit already dealt with, and let the circuit length be 400 miles with the distant end open. In that case formulæ (5) applies, and we have $Z = 3000 \times \coth\ (0{\cdot}003 \times 400) = 3000 \times \coth\ 1{\cdot}2$. Now coth 1·2 by reference to a suitable set of tables—for example the Smithsonian tables of Hyperbolic Functions, page 129 —is 1·1995, so that we have $Z = 3000 \times 1{\cdot}1995 = 3{,}599{\cdot}5$ ohms.

Next compare this with the result obtained from the formula which has hitherto been most commonly used in the Post Office for calculation of the sending end resistance with the distant end open. This formula is based on the assumption that if the insulation resistance of all the insulators in parallel is placed as a shunt in the middle of the line resistance, with the distant end open, the apparent resistance at the sending end is found.

The formula is—

$$Z = \frac{Rl}{2} + \frac{R_2}{l} \qquad \text{(8)}$$

Rl is the total conductor resistance of the line and $\frac{R_2}{l}$ is the insulator resistance per mile divided by the number of miles. In the case of the 100 lbs. conductor dealt with, we have:—

$Z = 1800 + 2500 = 4300$, as compared with 3599·5 (say 3600) found by formula (5), an error of nearly 20%. If the line were much longer the error would be greater. If, however, the line were relatively short the error would be much less; for example, a 100 lbs. line with 1 megohm insulation per mile has an error of only 1·5%, and for all shorter lengths it is less.

Fig. 1 shows in the ordinate y the ratio between the results obtained by calculation by formulæ (5) and (8). Thus, when the line angle βl is 1·2, we find this figure on the horizontal line, and tracing vertically up to the graph it is seen that the corresponding figure on the ordinate or vertical line at the left of the graph is nearly 1·2, or an error of nearly 20%, as already found. Similarly, when βl is 0·3 the error is 1·5%, etc. The error is readily obtained by the formula $(y - 1)\ 100 =$ percentage error. This graph relates to lines of any length, and any gauge and material of wire, open or underground. It is, moreover, evident that formulæ (5) and (8) only agree when the lines are electrically short, or in other words when βl is very small; for in that case only the ratio approaches 1. If a table of hyperbolic functions is not available, Z may be calcu-

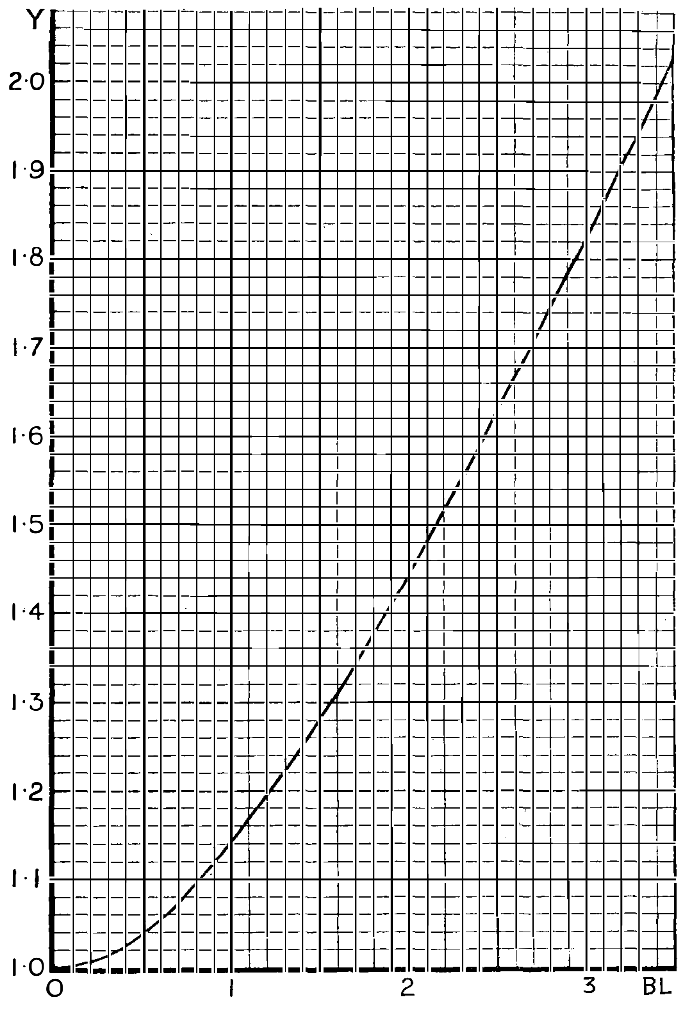


FIG. 1.

lated from (8) and the value as calculated from (5) may be deduced from Fig. 1.

If the line is very short, the sending end resistance with the distant end open measures very nearly the true insulation resistance.

For example, suppose the circuit already taken is only 1 mile in length we then have:—

$Z = R_0 \coth \beta l = 3000 \coth 0{\cdot}003 = 3000 \times 333{\cdot}33 = 999{,}990$. We know, of course, that the true value is one million or an error of 1 in 100,000.

If it is desired to find the true insulation resistance for lines of moderate length, methods are shown in transmission manuals to which the reader is referred. I have no space to give them here. Generally, however, the measurement of the sending end resistance suffices in cases where only the comparative insulation value on different dates is required for maintenance purposes. Care should, however, be exercised in drawing conclusions as to insulation resistance from such tests.

The Insulation of Underground Cable Wires.

In these cases, owing to the high standard of insulation resistance which is required, the line angle βl as measured by direct current is very small, and formula (5) gives the true insulation resistance with sufficient accuracy, and therefore also the measured sending end resistance with the distant end open gives the true insulation resistance.

There are, however, one or two more or less self-evident points which may be overlooked when testing. The first of these points is that the insulation resistance depends to some extent on the applied voltage. Ohms law does not, of course, apply in this case. Given a sufficient voltage the insulation of any cable may be broken down. The same voltage should, therefore, be used for maintenance tests on each occasion. If a megger is used the best results will be obtained if the handle is rotated at a uniform speed and in a regular way. A motor is sometimes used for this purpose. The second point is that the readings should always be taken after the voltage has been applied to the cable for a sufficient length of time to ensure that the capacity current is negligible.

This is by no means all that could be said, but I have already exceeded the Editor's limit of space.

WIRELESS

ENGLAND TO AUSTRALIA BY WIRELESS.

TRIALS have been carried out recently between Leafield Wireless Station and the Department's corresponding Wireless Station at Abu Zabal, Egypt.

Leafield transmitted on the following wave-lengths: 8,750, 9,200, 13,000 and 15,500 metres.

The results obtained in reception of these signals at Abu Zabal were such as to leave no doubt as to the possibility of maintaining the satisfactory 24 hours per day service with Egypt as soon as the Abu Zabal Station is completed.

The effectiveness of the Leafield Station has been further demonstrated in a striking manner. Leafield transmits press messages at noon, 8 p.m. and midnight, G.M.T.

Official reports received from India state that Leafield's signals are good at 8 p.m. and midnight. These results are presumably obtained with receiving apparatus of ordinary pattern and not specially designed for the purpose.

Still more interesting are the results obtained in Australia. Reports have been received from the Australian Post Office authorities to the effect that Leafield's 8 p.m. press message can always be received at Perth, Western Australia, provided atmospheric disturbance is not immoderate. For example, on the 4th December last 448 words sent out at 8 p.m. was received at Perth strength six and the message was handed to the Australian Press for publication.

NORTHOLT WIRELESS STATION.

E. H. SHAUGHNESSY, O.B.E., M.I.E.E.

A POST OFFICE wireless station for communication with stations up to 1500 miles away, and which is classed as a medium power station, is in course of erection at Northolt. The site of the station is situated to the South of Harrow and is within easy access of London by the Metropolitan Railway; South Harrow Station is about half a mile distant.

The site of the station and the lay-out of the masts and buildings on the site are shown in Fig. 1.

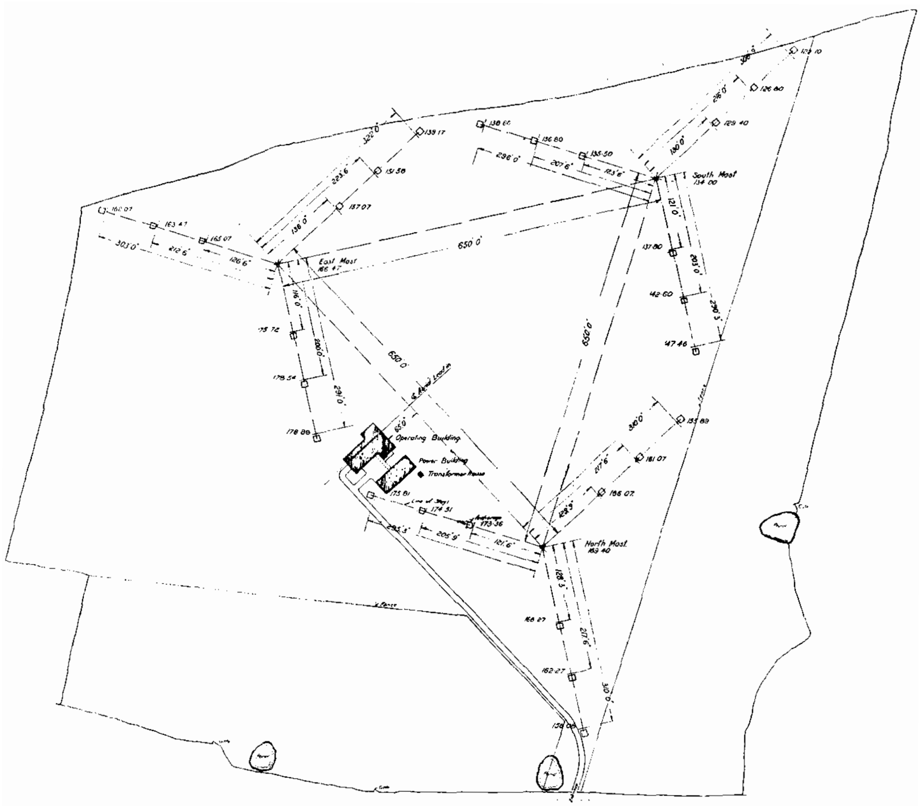


FIG. 1.

The site is approximately 21 acres in extent, and the buildings have been so disposed to the aerial system as to allow of expansions. It is contemplated that the station will ultimately be utilised for several simultaneous transmissions; the corresponding services would then be performed at a separate receiving station, which latter station would be the actual operating station; the transmitters at Northolt would be operated by remote control from the receiving station.

Power is taken from the Uxbridge and District Electric Supply Co., Ltd., and is led by underground cable to the transformer house in which the Company's transformer is housed. The supply is 3-phase, 6600-volts, 50 periodicity, and is transformed down to 400 volts for power and 110 volts for lighting. A prime mover, an oil engine, is provided for stand-by purposes in the event of failure of the power supply.

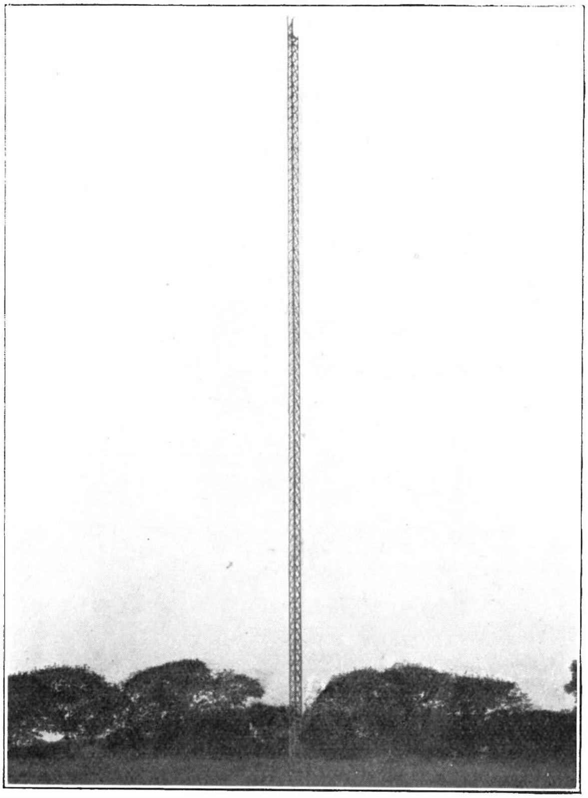


FIG. 2.

The 400-volts supply will drive induction motors direct-coupled to D. C. generators for furnishing direct current to the wireless continuous wave generators. The latter consist of Arc generators in duplicate, each capable of giving a current of 50 amperes in the aerial system with a wave-length of 5000 metres.

The whole of the equipment, masts, aerials, earths, power plant and wireles generators are being supplied by Messrs. Elwells, Ltd., and the work of constructing the mast, aerial and earth systems has been completed. The building work has advanced to the stage when the installing of the power plant can be commenced, and before this description is in print it is contemplated that the work of installing will be well forward.

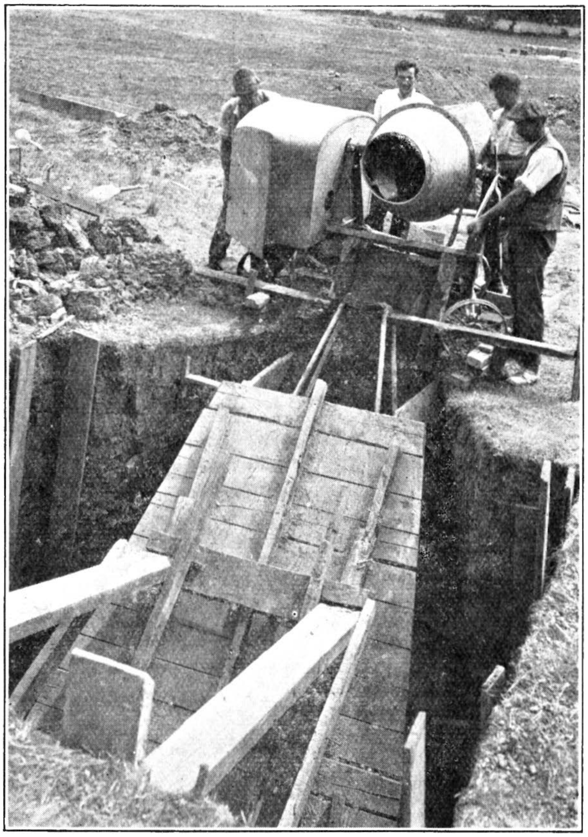


FIG. 3.

The masts are a prominent feature on the landscape for some miles round the neighbourhood of Harrow. As a foreword to a complete description of the station, which it is hoped to furnish on the completion of the station, some details of the mast, aerial and earth system are given.

The masts are three in number, 446 feet high, of triangular wooden lattice construction. A view of one mast nearing completion is shown in Fig. **2**. The mast is stayed at seven points approximately equidistant along the mast; three sets of stays are provided, the attachments of which are at the apices of the triangular structure. There are three anchorage points for each set of stays, the two anchorages nearest the mast carrying two stays and that furthest

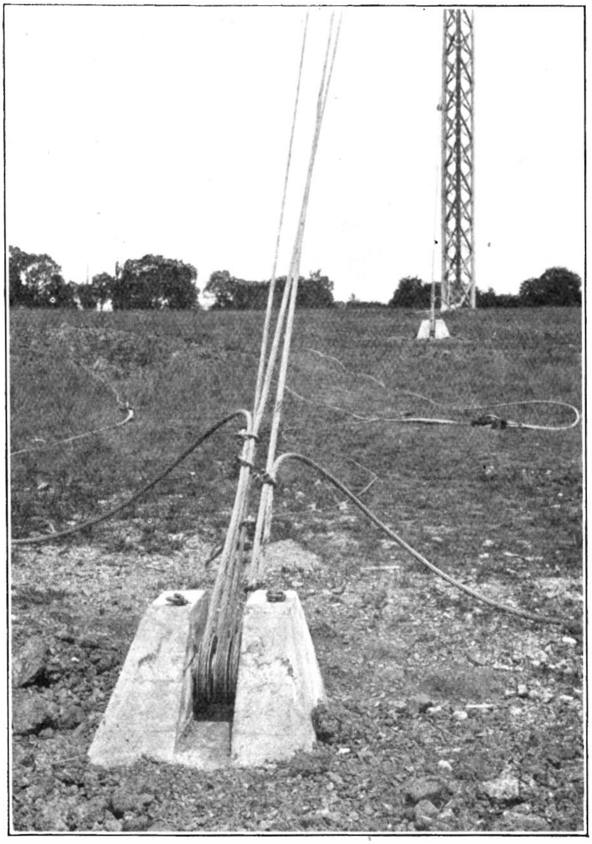


FIG. **4**.

from the mast three stays; in addition, this last anchorage carries a back stay to take the pull of antennae.

The method of making one such anchorage is shown in Fig. **3**; the completed anchorage with the stays in situ is shown in Fig. **4**. The method of fixing the stays by bull-dog grips after they have been drawn up is shown in this figure.

The method of building the mast can be gathered from Figs. **5** and **6**. The lowest vertical members are unequal in length, being 8, 12, and 20 feet respectively. These are first erected upon the foundations and the diagonal brace frames and horizontal tie-rods fitted. A working platform is then placed in position and a jib is fixed to the tallest member by bolts through the holes prepared to receive the tie-rods. A column is then hauled up and placed upon

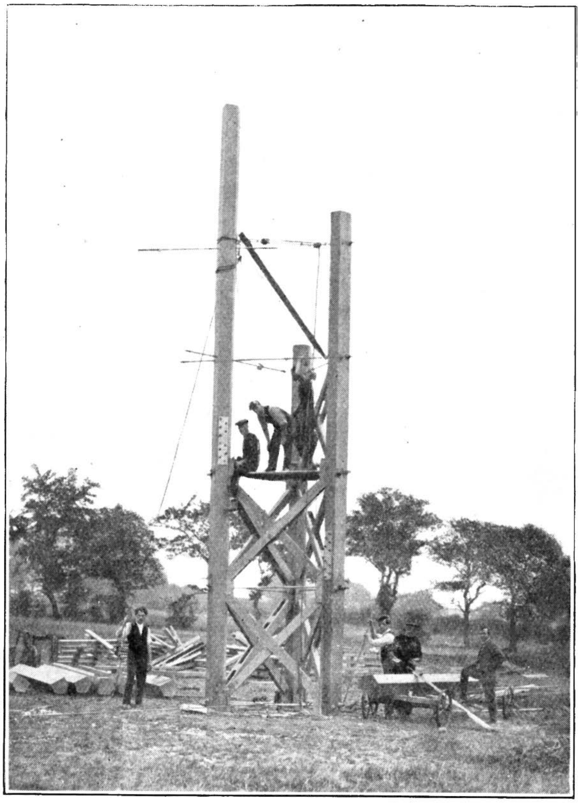


FIG. 5.

the shorter member; brace framing is fitted, the platform moved, and the jib fastened to the new member, which now becomes the tallest. Building then proceeds in the same manner, all subsequent members being of equal length, viz., 18 feet, except the top three members which are graded to make the heights of the three vertical columns the same.

The earth system of the station consists of a number of copper strips radiating from the central earth connection in the wireless building and buried a small depth below the surface of the ground. Approximately, one strip for each stay anchorage and mast foundation is provided and is buried beneath the anchorage or foundation and extended thereafter to the extremity of the site. In addition a copper strip electrically connects all the mast foundations and stay anchorages earth points.

Between the mast heads of the two masts nearest the station buildings a triatic is fixed. The aerial system is supported between the triatic and the third mast. The wires are spaced along the triatic with the widest spaces in the centre portion of the triatic, closing

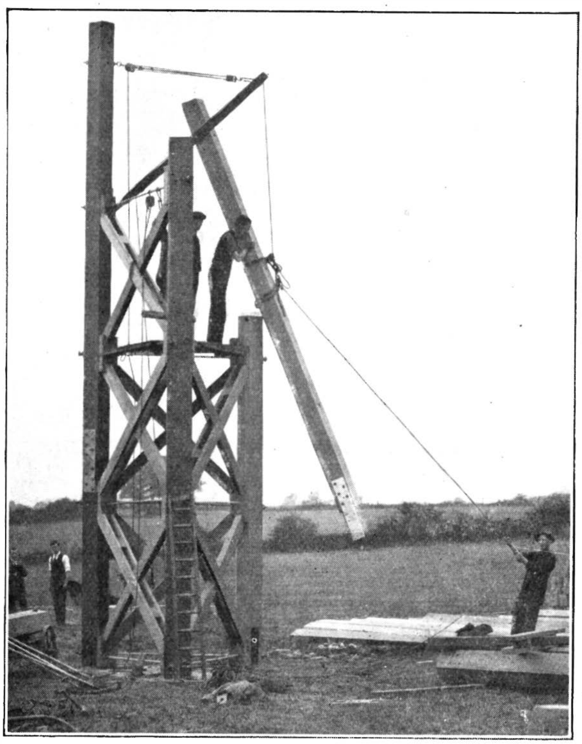


FIG. 6.

up towards the ends. The wires terminate at an insulator attached to the third mast, thus forming a triangular carpet of wires in the space formed by the three mast heads. Each wire is taken downward from the triatic to a point about 100 ft. below the middle of the triatic, where the whole are bunched together and attached to a down lead formed of a cage of wires of about three feet in diameter. This down lead is anchored to posts fixed in the ground and carrying insulators. A connection from the lower end forms a

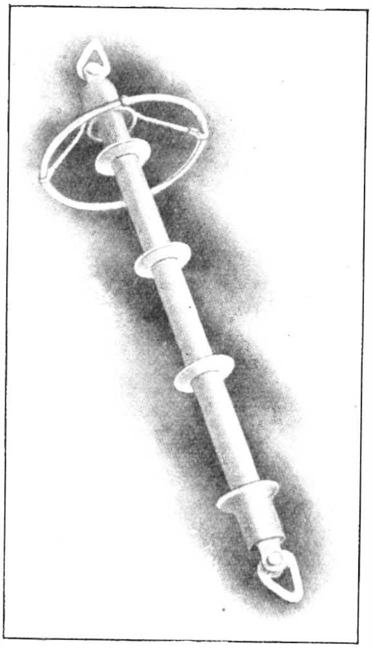


FIG. 7.

short lead into the station. Fig. 7 gives a view of the insulators used for insulating the aerial from the masts and earth.

RADIO CENTRAL—WORLD'S GREATEST STATION.

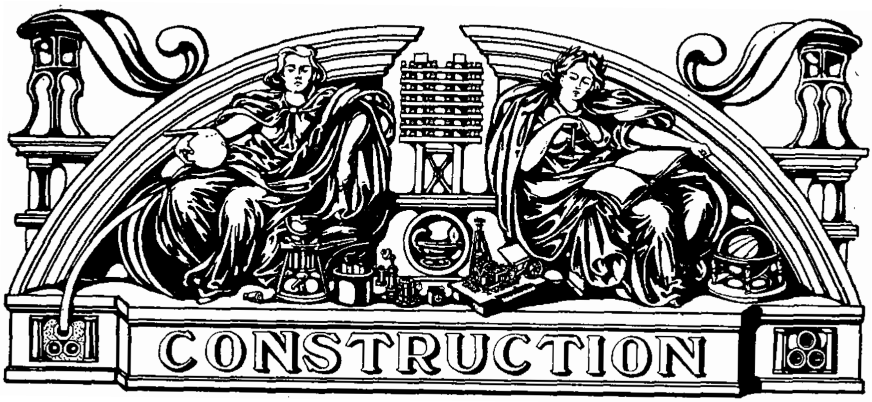
THE following description of the great new American station is taken from the *Telegraph and Telephone Age* (New York) of the 16th November:—

Radio Central station is designed for world-wide wireless communication, which includes Europe, South America and the Far East. This super-station is situated at Rocky Point (seven miles east of Port Jefferson) on the northern shore of Long Island, seventy miles from New York City. The station site covers 6,400 acres, or 10 square miles. The construction of Radio Central began July, 1920, and the first test signals were sent in October, 1921, or a little more than a year; a record in itself, when one considers the great amount of work accomplished. 1,800 tons of structural steel were used to erect the first twelve towers, each tower employing approximately 150 tons. Each tower is 410 feet in overall height and the cross arm or bridge supporting the antenna wires at the top is 150 feet long. 8,200 tons of concrete were employed for the foundations of twelve towers, the base of each tower leg being sunk nine feet below the ground, with a total base area of 360 square feet.

The distance between two adjacent towers is 1,250 feet, or nearly three miles from the first to the twelfth tower. Each antenna consists of sixteen silicon bronze cables, $\frac{3}{8}$ inch in diameter, stretched horizontally from tower to tower. In all, fifty miles of this cable has been used for the first two antenna systems. The ground system for both antenna consist of 450 miles of copper wire buried in the ground of the entire antenna system in starfish and grid-iron fashion. The first power house section covers a space of 130 feet by 60 feet, and accommodates two 200 K.W. high frequency transmitting alternators with auxiliaries and equipment. A sending speed of 100 words per minute is at present possible with the use of each transmitting unit at Radio Central. This means a combined sending capacity of 200 words per minute for the two completed units. The erection of additional antenna units forming the spokes of the huge wheel and further improvements, which are being made, will correspondingly increase the transmitting capacity of the big station. The transmitting range of Radio Central is practically world wide, as demonstrated by preliminary tests when the station was heard in all parts of Europe, as well as Australia, South America and Japan.

The cooling pond for cooling the water after it has circulated through the high speed alternators covers a ground space of 64 feet by 42 feet, and is 7 feet deep. The pond is equipped with four spray heads which, when operating, present a beautiful and ornamental appearance. The community house for the staff is a low one-story building closely resembling an exclusive country club. It contains sixteen single rooms, an official suite, a large living room and dining room as well as quarters for servants. The engineer in charge, with a staff of fifteen assistants, comprises the personnel necessary to maintain the huge station in operation at present. The maufacture and installation of the high frequency alternators and their auxiliaries, switchboards, tuning coils, etc., were accomplished by the General Electric Company. The construction contract for Radio Central was executed by the J. G. White Engineering Corporation of New York, under the direction of the engineers of the Radio Corporation of America. The 23,000-volt transmission line was built from Port Jefferson to the station, a distance of seven miles, by the Long Island Lighting Company; the electrical power being generated at that company's Northport plant. There are no radio operators at Radio Central; the actual transmission taking place by remote control from the Central Traffic Office at 64, Broad Street, New York City. The receiving station working in conjunction with Radio Central, is located at Riverhead, L. I., sixteen miles away. No operators are located here, for the distant signals are first received by radio, automatically transferred to wire lines and received at audible tones at the Central Traffic Office, New York City. The action is simultaneous from the time the signals are transmitted abroad, picked up by the aerial, to the moment of actual transcribing by the receiving operators in New York.

The final installation at Radio Central will comprise twelve antenna units supported by 72 towers, forming, so to speak, the spokes of a giant wheel nearly three miles in diameter. Ten high frequency alternators will be employed which in total will give a power output of 2.000 kilowatts, or 2,700 horsepower. The electrical force thus brought into play at Radio Central permits the realisation of the vision of communication engineers to transmit messages to all points of the world from a single centrally located source. The accomplishment of the Radio Corporation of America has been made possible through the financial, commercial, technical, engineering and research support of the following organisations: General Electric Company, American Telephone and Telegraph Company, Western Electric Company, United Fruit Company, Westinghouse Electrical and Manufacturing Company, and the Radio Corporation of America.



AN UNDERGROUND WAY IN ANCIENT LONDON.

BY A. O. GIBBON, M.I.E.E.

THE congestion in the City of London, so far as vehicular traffic is concerned, is regarded as unique, and the same remark may perhaps be applied to the crowded condition of affairs underground when one considers the enormous amount of excavation and tunnelling that has been undertaken in the metropolis during the last twenty-five years. The Post Office Engineering Department has had occasion to lay considerable nests of ducts recently in connection with the establishment of new City Exchanges. This has been particularly noticeable during the past few months, when such thoroughfares as Holborn and Ludgate Hill have been opened up in order to lay a large number of ducts in connection with the New Toll Exchange, besides providing new routes for junction cables from East to West of the metropolis. One of the most interesting sections of congested duct work has recently been constructed between St. Paul's Cathedral and Fleet Street, *via* Ludgate Hill.

When the original layout of main duct routes was undertaken in the City of London between 1900 and 1902 it was not considered necessary to provide a route down Ludgate Hill. It may be that the enormous volume of vehicular traffic in this thoroughfare, together with the knowledge of obstructions underneath, may have had something to do with the avoidance of this street for main underground networks. On the other hand there was not the same necessity as exists to-day for the concentration of junction and short distance trunks in a separate exchange, and this factor has been partly responsible for the development of the Ludgate Hill route.

As an indication of the congestion in the vicinity of the Trunk, City, and Central Exchanges, Fig. 1, showing the duct-ways which have been provided for present requirements and also for development, will be of interest. The solid lines represent existing routes and the dotted lines indicate the routes which have just been completed. It will be seen that the number of duct-ways provided in each section is considerable. The marvel is that room has been found for such quantities of plant underground, when one remembers the enormous volume of mains, tubes, etc., belonging to other

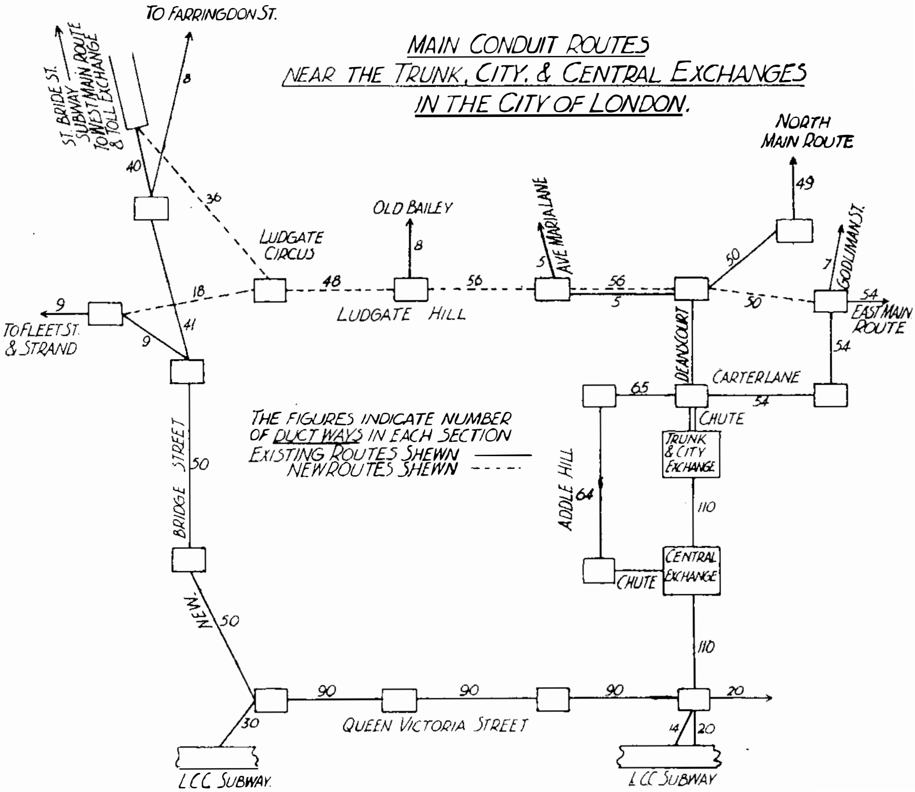


FIG. 1.

public and private authorities; also that the Post Office was generally a "late comer." The new network between the Trunk Exchange and Fleet Street, *viâ* Ludgate Hill, represents a saving of approximately 250 yards of duct route as compared with the Queen Victoria Street route. A nest varying from 56 to 48 octagonal ducts has been laid between St. Paul's Churchyard, from Godliman Street on the south-east side of the Cathedral, to Ludgate Circus, St. Bride's Street and Fleet Street.

The traffic conditions outside the Cathedral were of such a character that ordinary trench work was not permitted and a tunnel 61 feet long had, therefore, to be driven across St. Paul's Churchyard at a depth of 11 ft. 6 in. As the subsoil is of a very light, unstable character at this point, heavy timbering was resorted to in order to minimise to the fullest extent any possibility of movement resulting from heavy vehicular traffic above the excavation.

The usual practice in London when tunnelling at abnormal depths is resorted to is to fill in the headings with concrete, after the conduits have been laid, without breaking down from the surface. The traffic conditions near St. Paul's are so abnormal, however, that it was decided to break in the ground in short sections to the depth of the conduits after the ducts had been laid. The ground was then carefully filled in and punned solid, the permanent reinstatement of the concrete and wood surfaces being finally undertaken.

Excavating at abnormal depths near St. Paul's Cathedral may perhaps be regarded as a unique experience, because one feels instinctively that the history of centuries is very closely associated with this neighbourhood, and it did not occasion surprise when the foundations of some of the ecclesiastical buildings of Old St. Paul's were uncovered and had to be cut through. Stone work characteristic of an old Roman Bath was unearthed near Queen Anne's statue. There is a legend extant which tells of the demolition by the Romans during the Diocletian persecution of a Church which originally stood on the site of the present Cathedral. It is also said that on the same site there had existed a temple to Diana, and earlier still, a temple to an ancient British deity. The value of the legend is discounted to some extent, as it is understood that Sir Christopher Wren's excavations for the present edifice did not confirm the story. Archeologists have been greatly interested in the trench excavations at this point, and during the progress of the work the probability of the uncovered stone work having formed part of the site of Diana's Temple, or, alternatively, that it was part of the foundations of the old Churches of St. Faith or St. Gregory, were subjects of discussion amongst experts.

After these interesting obstructions had been disposed of, the crown of a main sewer 5 ft. 6 in. by 4 ft. in diameter was uncovered, and beyond this sewer the heavy power system belonging to the Postmaster General was disclosed; both obstructions crossing at right angles. The Engineer to the City of London who, apart from his official oversight of the work, was greatly interested in the Department's operations, was approached and agreed to alter the level of the sewer and by this means to provide sufficient clearance for the nest of 56 ducts to cross over the crown of the outfall. The formation of the ducts at this point is indicated in Fig. **2**.

From this point down Ludgate Hill, between St. Paul's Churchyard and the Old Bailey, the contractors had the remarkable

FIG. 2.—ST. PAUL'S CHURCHYARD. FORMATION OF NEW DUCT LINE.

experience of dislodging virgin soil within 10 feet of the surface in certain sections. A matter of interest to archæologists was disclosed at a point near the Old Bailey, where brickwork was cut through which is supposed to have formed either the foundations of old houses which stood in the present roadway or else a portion

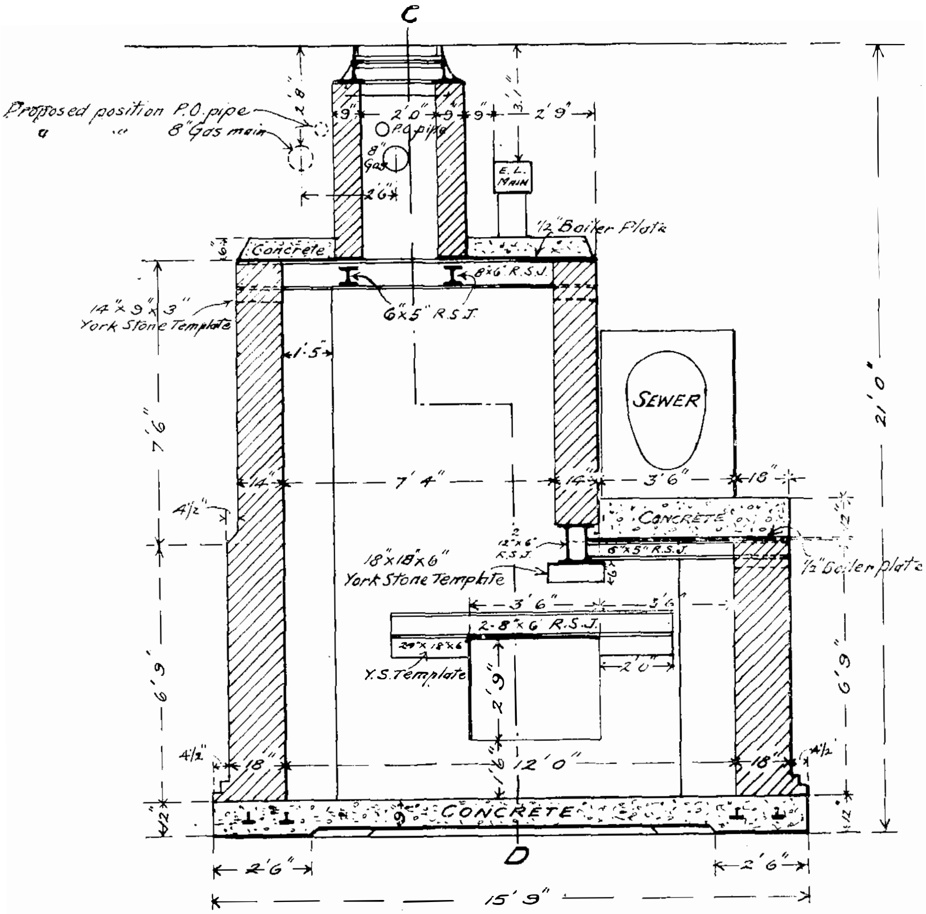


FIG. 3.—SECTION OF LUDGATE CIRCUS MANHOLE, SHOWING METHOD OF SUPPORTING MAIN SEWER.

of the foundations of the old Lud Gate which spanned the road near this spot.

Between the Old Bailey and Ludgate Circus the difficulties of securing a straight route were greatly increased. Many obstructions of different kinds were met with, necessitating a gradual increase in the depth of trench towards the Circus, and at the latter point a depth of trench of nearly 19 feet was reached. The Ludgate

Hill sewer empties itself into the Fleet River at the Circus. The duct route was carried alongside but at a lower depth than the sewer, and a reference to Fig. **3** indicates the method adopted of carrying the sewer over the manhole by means of a specially strengthened roof. It is of interest to observe the method adopted in carrying the main sewer outside this manhole. The relief steel work consists of two 8 feet × 6 inch girders placed over the recessed ducts, in order to relieve the conduits of the weight of the super-

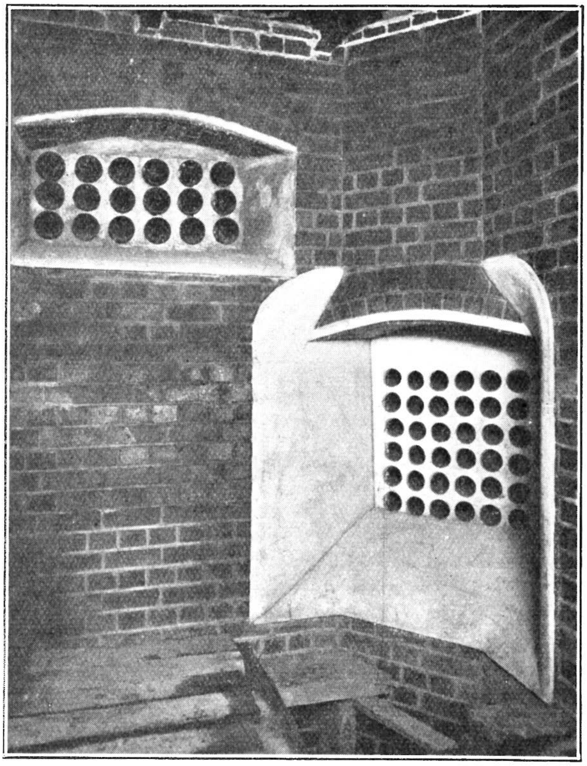


FIG. **4**.—VIEW OF A PORTION OF THE LUDGATE CIRCUS MANHOLE, SHOWING "SPLAYED" CORNER AND RECESSED CONDUITS.

structure and to throw the stresses on to the side of the walls. A specially designed manhole had to be constructed, and it is interesting to note that this manhole is the first to be built in the City of London on the American method of "splayed" corners. Cabling and jointing operations have subsequently been undertaken in this manhole and the "splayed" corners have proved of value in placing the cables in an orderly manner round the walls. **Fig. 4** represents a portion of the completed manhole at Ludgate Circus.

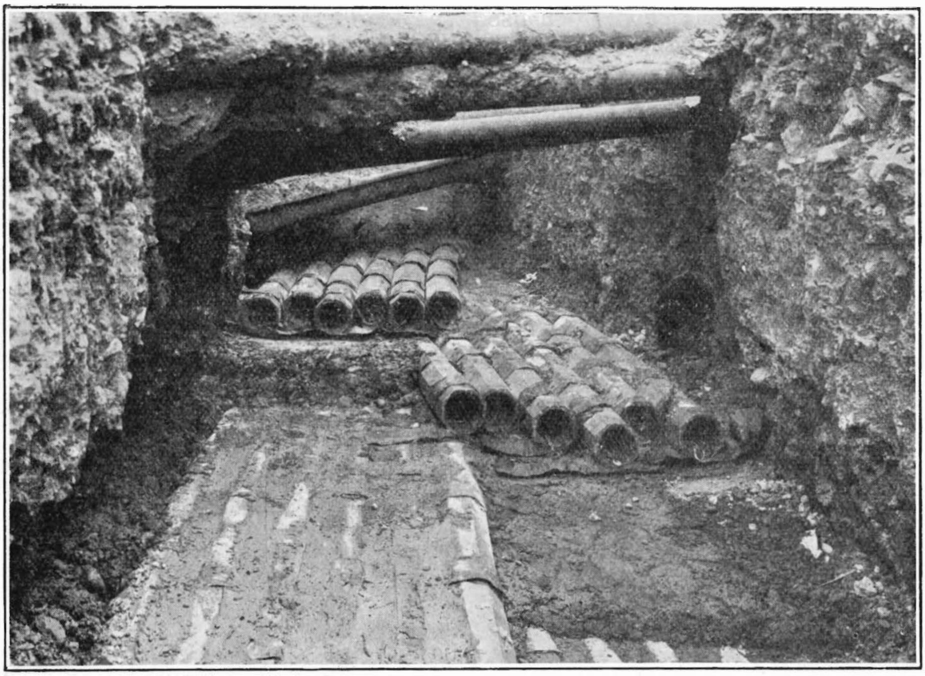


FIG. 5.—CHANGING FORMATION OF DUCT ROUTE AT LUDGATE CIRCUS.

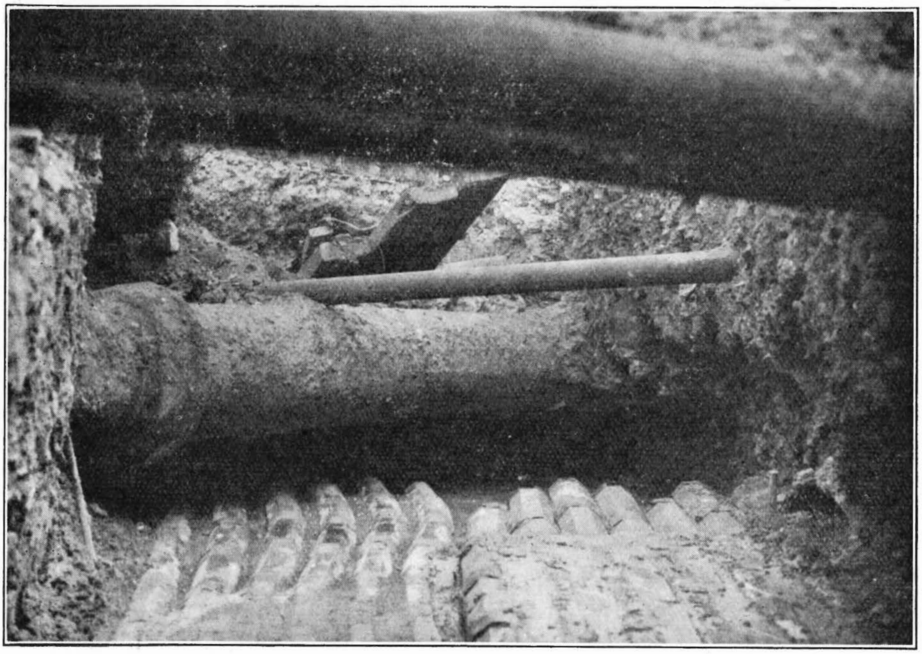


FIG. 6.—A CONGESTED SECTION OF DUCT ROUTE CROSSING LUDGATE CIRCUS.

The Fleet River, which used, in olden times, to meander down Farringdon Street is now enclosed in a culvert. At Ludgate Circus the presence of this culvert made the problem of laying ducts even more complicated, especially in view of the fact that the crown of the Fleet culvert is only 3 feet below the surface of the roadway and the culvert itself is approximately 24 feet deep. In order to cross Ludgate Circus at this point it was decided to lay steel pipes, and the section across the Circus to Fleet Street,

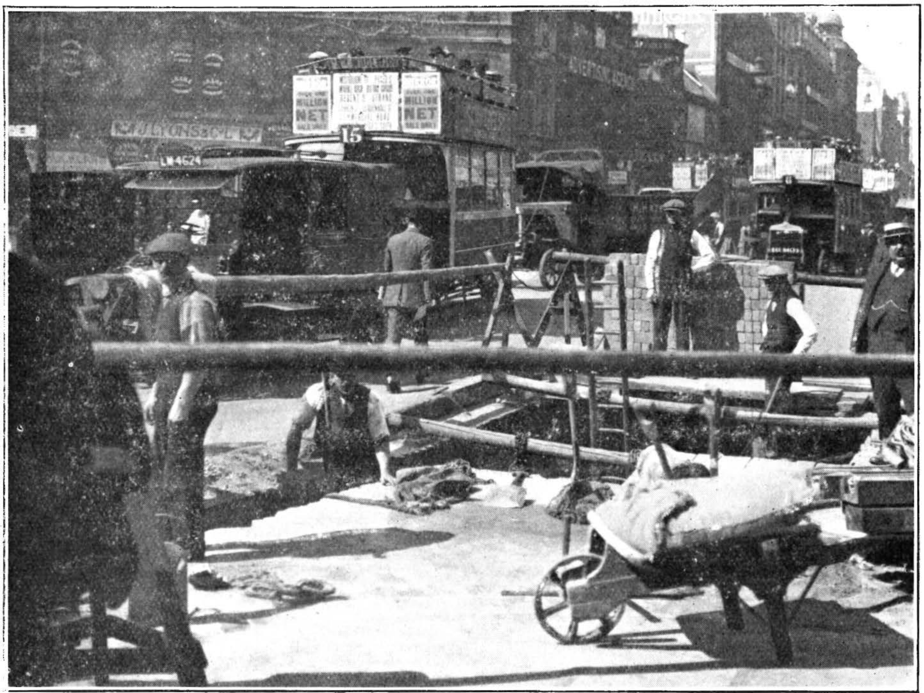


FIG. 7.—TRAFFIC CONGESTION AT LUDGATE CIRCUS. NEW MANHOLE IN COURSE OF CONSTRUCTION IN FOREGROUND.

although short, was fraught with several obstructions,—conduits, culverts, and other complications underground,—added to which, the vehicular traffic at the Ludgate Circus junction, probably one of the most congested points in the City, made trenching operations difficult in the extreme. Fig. **5** shews the method adopted in changing the formation of the ducts, and Fig. **6** indicates the small amount of space available at one point for the conduits. A typical street scene is reproduced in Fig. **7**. It is unfortunate that one of the great "Controllers of Traffic,"—a London policeman on point duty,—is not in the picture!

The work, which must be regarded as a notable achievement in the annals of the London Engineering District, was carried out under the control of Mr. J. A. Hunt, M.I.E.E., Sectional Engineer, and Mr. H. C. Stone, A.M.I.E.E., Assistant Engineer. The writer is greatly indebted to Mr. Stone for a mass of valuable information incorporated in this review. The contractors were Messrs. John Mowlem and Co., Ltd., who have been responsible for the execution of many difficult works for the Post Office Engineering Department in the City of London.

This article cannot be closed without expressing appreciation of the assistance rendered by the engineering staff of the City of London Corporation, also the engineers of the Electric Lighting, Gas, and Water authorities, whose plant was uncovered and in some cases diverted, in order to provide a satisfactory route for the Department's conduits.

WHEATSTONE BRIDGE FOR LINEMEN.

A. C. BOOTH.

A SIMPLIFIED pattern of Wheatstone Bridge has been designed for use by Linemen for locating the distance of earth faults and contacts, or for measuring resistances of lines or apparatus.

With a view to reducing the possibility of error to a minimum the external connections have been reduced to three, viz., two for "Line" connections and one for an "Earth."

The galvanometer is connected permanently and is not too sensitive; further, it has a variable shunt to reduce its sensitivity when only approximate measurements are required. If the pointer moves to the left the resistance in the dials should be decreased, and if to the right it should be increased. Instructions to this effect are engraved at each end of the galvanometer scale. The battery consists of six dry cells permanently connected in the base of the case.

There is only one key to depress, which closes the battery circuit first and then the galvanometer circuit. There are no pegs to be lost or to make more or less doubtful connections, as the Bridge arms are equal and are fixed in value at 200 ohms. The rheostat consists of three dial resistances reading up to a total of 999 ohms, with an "Infinity" position on the last stud of the "Hundreds" dial.

The three chief tests for which it will be used are (1) Loop Test, (2) Positive to Earth Test and (3) Single Line resistance Test. The alterations of the connections for these Tests are made by a three-position telephone key suitably labelled. A description of the tests with a numerical example is pasted in the lid of the case and is given in full at the end of this article.

The instrument is not intended to compete, either in accuracy or range, with the standard Post Office Wheatstone Bridge, but has been designed to be a fairly safe and moderately accurate instru-

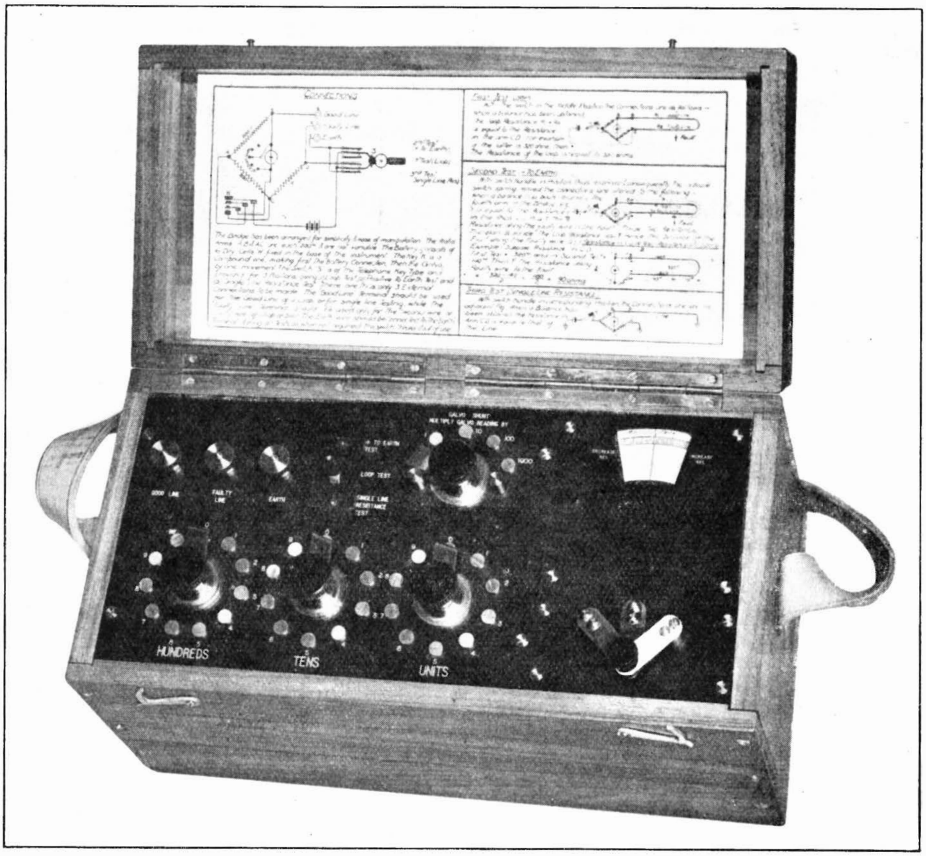


FIG. 1.

ment for measuring resistance from 1 to 999 ohms, and to be used by those who have not sufficient opportunity to become familiar with the many connections and various arrangements of the more elaborate apparatus.

It is considered that the new instrument will be most useful at intervals probably of 20 miles or thereabouts along main lines, allowing each man to compile at suitable opportunities the resistance values of lines in his section, and to confirm with the adjacent lineman the approximate position of faults. The instrument is portable and ready for immediate use on the road, but should seldom be required for that purpose.

Six instruments have been made for trial, as practice may show that some modifications may be necessary.

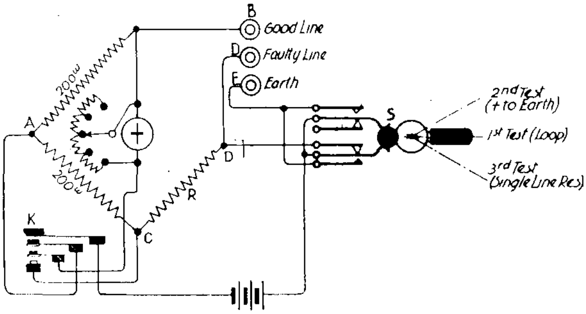


FIG. 2.

The key " K " is a compound one, which makes first the battery and then galvanometer connections by one movement. The switch " S " is of the telephone key type and has three positions, giving (1) Loop Test, (2) Positive to Earth Test and (3) Single Line Resistance Test. There are thus only three external connections to be made. The " Good Line " terminal should be connected to the good line of the loop under test; the " Faulty Line " terminal should be used only for the second or faulty wire of the loop or pair. The Earth wire should be connected to the Earth terminal during all tests, as the switch throws it out of use when not required.

First Test (Loop). With the switch in the middle position, the connections are as follows :—

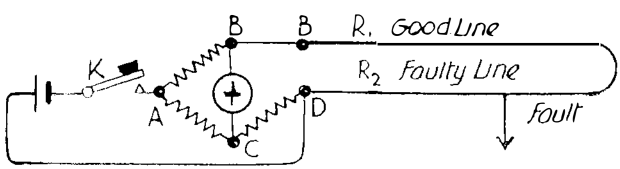


FIG. 3.

When a balance has been obtained, the loop resistance, R_1+R_2, is equal to the resistance in the arm C D. For example, if the latter be 320 ohms, the resistance of the loop is 320 ohms.

Second Test (Positive to Earth). With switch handle in position thus marked and consequently the opposite or lower long spring of the switch pushed outwards into contact with the bottom spring, the connections are altered to the following:—

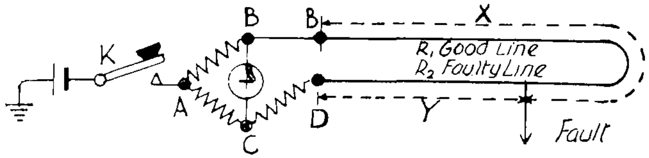


FIG. 4.

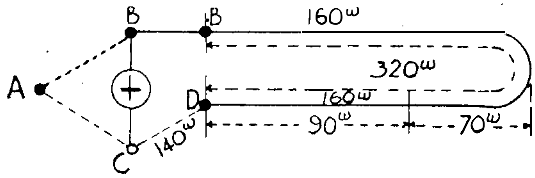


FIG. 5.

When a balance has been obtained the fourth arm of the bridge, viz., X in the diagram, is equal to the resistance in the rheostat C D plus Y—the resistance along the faulty wire to the Fault. These two resistances therefore balance the loop resistances minus Y. Hence the resistance of the fault along the faulty wire equals:—

Resistance in C D (1st Test)—Resistance in C D (2nd Test).

Example.—Suppose resistance in C D (1st Test) = 320 ohms, and in second test = 140 ohms; the resistance along the faulty wire to the Fault = $\frac{320 - 140}{2}$ = 90 ohms.

Third Test (Single Line Resistance). With the switch handle in the corresponding position, the connections are as in figure below:—

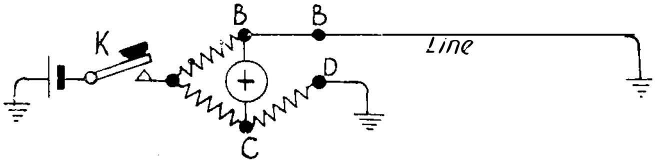


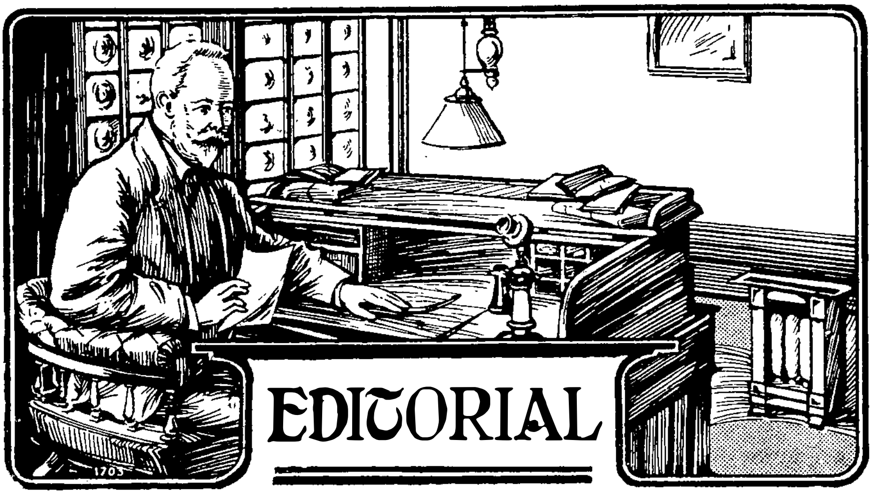
FIG. 6.

When a balance has been obtained the resistance in the arm C D is equal to that of the line.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

MILEAGES AND TELEPHONE STATIONS FOR EACH ENGINEERING DISTRICT AS AT 30TH SEPTEMBER, 1921.

Telephone Stations.	Overhead Wires: Mileages.				Engineering District.	Underground Wires: Mileages.				Submarine (Land miles).
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.	
313,492	565	2,192	52,380	195	London	17,114	17,277	1,178,037	15,844	
48,128	2,781	15,336	41,910	2,687	S.E.	2,228	8,675	148,086	16,236	Telegraphs
40,045	4,773	19,672	36,300	1,722	S.W.	12,287	1,690	75,188	1,400	18,281
31,780	9,700	25,997	33,110	4,001	E.	15,478	21,884	43,255	14,438	(Includes 3997
54,789	9,691	36,783	39,694	2,539	N. Mid.	7,758	13,636	94,674	63,167	Atlantic Cable'
43,612	5,418	24,482	45,080	4,679	S. Mid.	6,550	7,311	109,783	83,313	3667 Ex.D.U.S.)
37,388	5,527	24,036	35,399	3,125	S. Wales	4,781	9,639	61,817	18,625	Trunks
51,183	9,379	20,805	34,545	5,789	N. Wales	11,742	16,424	94,286	10,184	1,497
94,450	3,204	16,060	43,793	3,319	S. Lancs.	9,584	31,953	231,550	30,394	
46,484	6,773	24,410	34,465	1,917	N.E.	4,545	12,211	104,931	23,609	Exchanges
46,736	4,364	26,098	38,447	2,779	N.W.	9,432	15,460	100,447	14,205	(Prov.)
30,879	3,011	13,974	21,285	2,326	N.	3,121	4,966	51,660	6,071	380
31,441	23,014	11,133	25,882	883	Ireland	838	100	52,864	489	
41,099	6,010	18,969	27,774	2,696	Scot. E.	1,375	4,886	75,379	3,539	Spares
61,072	7,443	21,095	39,154	376	Scot. W.	11,442	11,837	168,310	19,163	1,251
972,578	101,653	301,042	549,218	39,033	Total.	118,275	177,949	2,590,267	320,677	
966,659	151,471	308,289	552,339	38,504	Figures on 30th June, 1921.	116,942	175,986	2,559,650	282,977	



EDITORIAL NOTES AND COMMENTS.

IN the course of the great war this country suffered severely from the lack of co-operation in pre-war days between those engaged in the investigation and pursuit of natural science and the authorities responsible for war equipment. The British expeditionary force which left for France in the early autumn of 1914 was composed individually of the finest fighting material in the world, but it was equipped on its electrical side with apparatus woefully behind the knowledge and usage of latter-day science. It is true that nobody, save perhaps M. Bloch, anticipated that the war would quickly lose its mobile character and settle down into a long struggle across earthworks extending half across Europe, but any telephone man engaged in research work could have foretold that telephones fitted with buzzers, working on single lines and operated from 4-line field exchanges with common earths, were dangerous things to use in the field in any circumstances against a scientifically trained army like that of Germany. The disastrous finish at Tannenberg of the Russian advance into East Prussia in the early days of the war was due almost entirely to German superiority in wireless work, and it is not going too far to say that our failures at Neuve Chapelle, Festubert, Loos and elsewhere can be attributed to the lack of appreciation of what the Germans were doing behind their lines in the way of picking-up and reading our signal communications. Colonel Cusins, in his paper before the parent institution, tells how the Germans were acquainted with our movements—the taking-over of a section of the line by a fresh battalion being heralded by the playing of the unit's regimental march on a German cornet, and so on. Now, the methods used were quite as well known in this country as in Germany; in fact, a Lieben-Reiz valve had been tested and reported upon in the spring of 1914 by the Research Section of the P.O. Engineering Department.

It is not our intention, however, to gird at the Army for its dilatoriness in the application of methods embodying the latest practice in electrical science; it made ample amends later when by the end of 1916 and in 1917 and '18 the equipment of our armies was in almost every respect ahead of that of our enemies. Due credit has already been given to the Engineering Department for its services in that connection. The point we wish to emphasise is the supreme importance of co-ordinating the work of the laboratory and that of the factory; the fullest advantage should be taken of the results obtained by the patient investigations of the physicists, chemists and metallurgists. The work of Thomson and Richardson, Soddy and Rutherford is revolutionising our ideas of matter and of electricity, and we appear to be approaching rapidly the moment when the energy of the atom will be released and controlled for the service of man.

The labours of the front rank men are reconnoitring expeditions into the unknown; behind them come the pioneers and engineers whose duty it is to consolidate the ground won and to apply the information obtained to practical purpose. Most engineering firms of repute and standing now recognise the necessity and importance of research work, and their overhead charges on the actual costs of production include a percentage to cover their laboratory and experimental work. It pays to do so; no house jealous of its name for sound material and good workmanship can afford to risk its reputation and its sales by the use of faulty or unsuitable material, or by the adoption of a "half-baked" scheme or design.

Cribbed, cabined and confined in the old experimental room and basement workshop of the G.P.O. West the Research Section of the Post Office Engineering Department has been handicapped for years in the work it had to undertake. But we consider it has justified amply its existence and cost. Its work in connection with the production of the Tucker microphone for gun-spotting purposes during the war, and the successful scheme for balancing long lengths of paper core cable which it evolved are but two examples of the valuable services rendered to the State by this section. Now that a start has been made in the new laboratories at Dollis Hill it has been given the opportunity to pursue investigations on a larger scale and to build up an organisation equal to the demands of what is, after all, one of the biggest engineering businesses in the country. Unfortunately the moment coincides with the slump in trade, and for some time at any rate the work of the section will be limited by causes not within its own control. There is an old proverb about the casting of bread upon the waters which aptly covers the case of research work; the reply of the Treasury would be no doubt that the present price of the loaf is prohibitive.

Those of us who were in close touch with Mr. A. J. Stubbs before his retirement were convinced that his energies were too great to permit his settling down into a placid existence, void of enterprise and of worry. His entry into partnership with Sir Charles Bright, Lieut.-Col. Woodall, and Mr. Seabrook is a matter for congratulation, and although our notice is rather late we can assure Mr. Stubbs he has the best wishes of all his old colleagues for the success of the venture. The firm will practise at 146, Bishopsgate, E.C.2, as consulting engineers under the name of Sir Charles Bright and Partners. The special point of the business that is likely to appeal is the wide range of engineering that the new firm will cover and the scope for co-ordination of the electricity and gas interests. We understand Col. Woodall was the first gas manager to install electric light in his gasworks.

HEADQUARTERS NOTES.

EXCHANGE DEVELOPMENTS.

Orders have been placed for the following new Exchanges.

Exchange.	Type.	No. of Lines.
Chorlton-cum-Hardy ...	Manual C.B.	1100
Hull Toll	Manual C.B.	115
Birmingham Victoria ..	Manual C.B.	560
St. Albans	Manual C.B.	980
Dunfermline	Manual C.B.	660
Broughty Ferry	Automatic	550
Aldershot . .	Manual C.B.	680

Orders have been placed for extending the equipment at the following existing Exchanges:—

Exchange.	Type.	No. of Lines
Bournemouth	Manual C.B.	1100
Romford	Manual C.B.	280

AUTOMATIC EXCHANGES OF THE VILLAGE TYPE.

Two small C.B.S. exchanges have been converted recently to automatic working—one at Ramsey, Hunts., in the Peterborough Section, and one at Hurley, Bucks, in the Reading Section. The fitted capacity of these exchanges is 40 subscribers' and 10 junction lines.

Ramsey opened automatic on the 24th October with 31 subscribers and 5 junctions, 4 of the latter working both way to Peterborough and one to Warboys. Trunk connections, originated and incoming, are dealt with at Peterborough.

The exchange at Hurley was transferred to automatic working on the 20th December. The number of lines at present connected is 20 subscribers and 5 junctions, 3 of the latter working to Maidenhead and 2 to Marlow.

LONDON DISTRICT NOTES.

Telephone Lines and Stations.—During the thirteen weeks ended September 27th, 1921, 3,873 exchange lines, 4,683 internal extensions and 487 external extensions were provided. In the same period 2,672 exchange lines, 4,280 internal extensions and 354 external extensions were recovered, making nett increases of 1,201 exchange lines, 403 internal extensions and 133 external extensions.

INTERNAL CONSTRUCTION.

Hendon.—A temporary exchange, installed in an Army hut on the site of the permanent Hendon Exchange, was opened on the 2nd of November with 142 subscribers and 54 junctions.

This No. 9 C.B. type switchboard of 500 lines comprises 5 " A " and 2 " B " positions, and the exchange will be the means of affording relief to the Finchley and Kingsbury Exchanges. The plant was installed by the District staff.

Clerkenwell.—The permanent Clerkenwell Exchange in Ironmonger Row, Lever Street, E.C., is a 40-volt C. B. No. 1 equipment provided by the Peel Conner Co. The temporary exchange is installed in the same building. The new exchange is of 10,000-line capacity with an initial provision for 7,120 calling equipments and a multiple of 7,100 on both A and B boards, that on the A side being 9-panel. The outgoing junction multiple is for 1,100 lines. 88 " A " positions, 35 " B " positions, and 7 positions for jack-ended junctions, testing operator and plugging-up purposes are at present equipped.

A pneumatic house tube system has been installed which has some features of interest. Owing to the number of despatching and receiving terminals to be provided for, eight in all, it was considered that to work all these stations on one "loop" would not be an efficient arrangement. It was therefore decided to divide the tube into two sections of equal load. The tubes, which are of brass, 1½ inches in diameter, and have a total length of 190 yards, are jointed into a collateral Y at the upper end of a 2½-inch service pipe, 32 yards in length, connected to a Roots blower, .07 type. The power is supplied from a ½-H.P. single-phase motor and the displacement of air per minute is about 30 cubic feet. The blower is situated in the basement of the building, and the tube provides service between the Supervisor and Testing Telephonist on the 3rd floor and between the latter and the Test Desk on the 2nd floor.

The exchange was opened on the 26th November with 1,610 subscribers' lines and 783 junctions, 72 of the latter being new lines. The temporary Clerkenwell switchboard will subsequently be opened as a temporary Bishopsgate Exchange to relieve London Wall, Central and Avenue of the subscribers proper to the Bishopsgate Exchange Area.

Stratford:—The Western Electric Company is making progress in the installation of the new Stratford Exchange, but it is not expected that the exchange will be opened before the next issue of this Journal.

Extensions of the following exchanges are in the hands of contractors:—Avenue, East, Lee Green, Streatham and Willesden.

Conversion of incoming junctions for keyless ringing is well advanced at Hampstead and Gerrard, the former being carried out by the District staff.

The provision of meters for all multiple circuits in London exchanges is approaching completion.

Valve Amplifiers.—Two applications of Valve Amplifiers are being made in the London District. Ten Repeater sets—Repeaters, Telephonic No. 5A—for insertion in the music lines at the Electrophone Exchange are being installed by the Department. These will provide means for meeting abnormal demands for a particular entertainment conveniently and expeditiously without having to provide additional music lines.

A telephonic cord circuit repeater station is to be installed at the London Trunk Exchange. Two trunk positions are to be fitted with equipment for 10 repeater cord circuits and 120 trunk and balancing circuits. The repeaters will be used in connection with long-distance calls of a difficult character passing over certain Continental and Inland Trunk routes. The Trunk circuits will be worked at their normal positions until they are required for the purpose of effecting calls at the repeater positions, and when they are taken up at the latter they will be automatically disconnected from the positions on which they are normally worked.

Central Telegraph Office.—Reference was made in the October issue of the Journal to the installation of Murray Keyboard perforators and Murray transmitters on the Belfast circuit. The arrangement is in substitution of the ordinary Baudot Keyboards.

The triple duplex Baudot mentioned in the same issue as about to be installed on a Brussels circuit has also been completed. This supersedes two duplex Hughes circuits and the new installation will meet the whole of the Brussels traffic, providing thereby two additional channels and throwing one wire into reserve.

Fleet Street Power Scheme (Telegraphs).—A scheme of telegraph power distribution to the Newspaper Offices in the Fleet Street area has been carried into effect and is now completed. For some years past about forty of the Fleet Street circuits have received power from the C.T.O. on individual leads. This, for reasons at once apparent, was not a very flexible arrangement, but was nevertheless a step in the right direction. The present system was, therefore, designed with the purpose of superseding the individual power leads, and the large number of primary batteries still in use—comprising about 6,000 dry cells, and thereby effecting considerable economies in maintenance. Now main leads from the telegraph secondary battery installation at the C.T.O. are taken to the very doors of the Newspaper offices.

Voltages of 40, 80, and 120, positive and negative, are supplied from the existing main telegraph batteries, which have ample capacity to meet the extra load. Six 7/16 V.I.R. cores in one cable carry the current from the main distributing board in the battery room through 15-ampere fuses to Ludgate Circus B.O. Here the six voltages are branched through fuses, one branch serving the north and another the south side of Fleet Street, the distant ends meeting near the Law Courts to form a complete loop. A third branch feeds Shoe Lane on one side and Tudor Street on the other. Intermediately there are six distributing points, three on each side of the street. These facilitate testing and fault localisation. The newspaper offices are served either by teeing into the main cable in the footway box, terminating the cable in the basement of the building in a small iron jointing box, or by looping the cable into the basement through a similar jointing box. Tail ends of single 40lb. conductors extend the power leads to a 6/6 cut-out, 1-ampere fuses. Single 20lb. lead-covered leads carry the power to the protective resistance coils or lamps provided on the instrument tables.

EXTERNAL CONSTRUCTION.

During the three months ended 31st October, 1921, the following changes have taken place in the single wire mileages.

Telegraphs.—Nett increase of 98 miles, being a decrease of 1 mile open wire and an increase of 99 miles underground.

Telephones (Exchange).—Nett increase of 1,301 miles, being 124 miles increase in open wire, 43 miles decrease in Aerial Cable and 1,220 miles increase in underground.

Telephones (Trunks).—Nett increase of 356 miles, being 5 miles open and 351 miles underground.

Pole Line.—Nett increase of 33 miles, the total now being 2,938 miles.

Pipe Line.—Nett increase of 6 miles, the total now being 3,982 miles.

The nett increase of underground cable was 34 miles, making the total to date 7,937 miles.

The total single-wire mileages, exclusive of wires on Railways maintained by Companies, at the end of the period under review were:—

Telegraphs	17,699
Telephones (Exchange)	1,230,352
Telephones (Trunks)	19,359
Spare Wires	16,071

The smaller increases recorded in pipe, cable, and telephone (Exchange) wire mileages, as compared with the figures for three months ended 31st July last, are due to a recent alteration in method, whereby particulars are now posted from completed works, instead of, as formerly, from monthly progress reports.

The large amount of development work in hand in the District involves not only the placing of new plant in position, but also the recovery of old plant, mostly overhead.

The following figures will give some indication of the amount of plant being displaced. The quantities represent recoveries made during a period of three months.

Poles—531, Aerial Cable—41 miles.
Leads—58,328, Wire—819 miles.
Underground cable—20 miles.

UNLOADING HEAVY CABLE DRUMS FROM HIGH-DECKED LORRIES.

The following describes the method pursued by Messrs. Godwin Bros., Cable Haulage Specialists, of North Woolwich.

The lorry is a steamer of the Sentinel type. It carries as auxilliary equipment:—

Two rolled steel joists, 8in. by 4in. and 12 feet long or thereabouts, which, when in position for unloading, form a gradient of about 30 degrees. The top ends are hooked and the lower ends bevelled to give a base of about twelve inches on the ground.

A strong chain with a ring at both ends and another in the middle; a cable drum spindle; a long $4\frac{1}{2}$-in. rope; 2 or 3 crowbars.

A stout board slotted at both ends, the distance between the bottom of the slots giving a width slightly greater than the width of the cable drum.

The usual wooden blocks for skotching purposes.

The framing of the deck of the lorry is of steel and the deck itself of timber. A gap of about $1\frac{1}{2}$ inches between the deck and the frame is left at the rear, and into this gap the lips of the hooked ends of the rolled steel joists are inserted. At the fore end of the deck is a stout tube about $2\frac{1}{2}$ inches in diameter, parallel with the fore end and raised above and secured to the deck by two brackets, giving a clearance between the tube and the deck of about 6 inches.

The unloading team consists of three men:—No. 1, the driver of the lorry; No. 2, his mate; No. 3, a man from the cabling gang.

Procedure.—The lorry being in position the joists are attached to the rear, the spindle is passed through the drum and the chain attached by passing the end rings one over each end of the spindle.

The rope is next threaded through the middle ring up to half its length and the two ends of it given three turns around the fixed tube. No. 2 now mounts the roof of the engine cab and pulls up both rope ends until the trace is taut and the slack is on the roof.

Nos. 1 and 3 then shepherd the drum to the tail of the lorry, No. 2 paying out cautiously. The slotted board is then inserted between the two branches of the chain to prevent its fouling with the edges of the drum.

No 3 joins No. 2 on the roof of the cab and they take a rope end each. No. 1 from the ground gives the requisite impetus to the drum; it takes to the joists and under the absolute control of the men on the roof rolls slowly and steadily to the ground.

Time, under 20 minutes; Weight of drum, 2 tons; Burden of lorry, 2 drums.

RETIREMENT OF MR. G. W. CONNELL.

BY the retirement of Mr. G. W. Connell, on the 30th August, the headquarters buildings of the General Post Office, London, lose a well-known figure. Mr. Connell entered the service of the General Post Office in September, 1883, when he was 19 years of age. He was early transferred to the engineering staff at the Central Telegraph Office and has been intimately associated with the General Post Office Headquarters during practically the whole of his 38 years service.

In the early period of his career the Central Telegraph Office naturally loomed considerably larger on the horizon of the engineering officers of the Department than it does to-day, when the telephones absorb so much of their energy and thought. He was on the old linemen's staff in those early days, and was quick to realise the advantages of some theoretical training to supplement the practical experience which came to him in his occupation. Mr. (now Sir William) Slingo organised the classes where tuition in technical telegraphy was available to the staff of the Central Telegraph Office, and, to use the old T.S. phrase, Mr. Connell "took Slingo." This early theoretical and practical experience, combined with a generous share of natural ability, brought its reward, and he was one of the men selected for promotion to the Sub-Engineers grade, when that now defunct class was formed. He was subsequently promoted to 2nd Class Engineer and Assistant Engineer. These promotions did not entail his removal to other sections of the Engineering Department, and he had the experience, which fall to the lot of few men of his rank and length of service, of commencing, continuing (with one short break), and ending his service at the same headquarters.

A brief reference only can be made to a few of the outstanding events with which he was associated:—

Enlargement of Central Telegraph Office by adding the fourth floor to the G.P.O. (West Building) and encroachment of the C.T.O. on other floors of the building due to the growth of the telegraphs following the introduction of the sixpenny tariff.

Building of the G.P.O. North.

Transfer of the old Submarine Telegraph Company to the Post Office (the formation of T.S.F.).

Transfer of the telephone trunk line to the Post Office (in the early days the Trunk Exchange was housed in the C.T.O.).

Early experiments in Wireless Telegraphy. Mr. Connell frequently spoke of Sir William Preece's experiments and lectures, at which he helped as demonstrator.

Conversion of telegraphs from independent primary to universal secondary cell working. He supervised this conversion in the C.T.O.

Transfer of the Trunk Exchange from the C.T.O. to G.P.O. (South). This transfer took the trunks off his hands.

Provision of intercommunication switching to telegraphs in the Metropolitan area, by the introduction to telegraphs of a multiple switchboard of a modified common battery telephone type.

Commencement of local telephone exchange facilities by the

Post Office. Mr. Connell was selected to supervise the erection of the first Central Exchange in the G.P.O. South and this work constituted his longest absence from the Central Telegraph Office.

Introduction of the automatic telephone exchange. The official switch was installed in the G.P.O. West building and came under his supervision.

Side by side with these changes, which extended over many years, there was a continual improvement in telegraph apparatus. He might be said to have seen the evolution of telegraphy from the single needle to the present complicated machines of the type-printing and keyboard systems.

During the last year or so his health and vigour noticeably declined, and it was apparent to those associated with him that he would have difficulty in keeping in harness during the remaining two years required to cover the span of life official. After a severe illness, which impaired his vigour, it was decided to superannuate him.

His many friends in the C.T.O. Engineering Section and Traffic Department, who were familiar with his burly figure and general good nature, contributed to give their old colleague a parting token of their esteem and good wishes, and a handsome chiming clock and egg cruet were presented to him.

Holidays to him meant a visit to a quaint but delightful corner of the delectable Duchy, and he always said he should retire there. He has had the good fortune to realise this dream of years, and has already settled down to spend the evening of his days far from the madding crowd. The change seems to have already cheered him up and he speaks of fishing experiences on the Cornish Coast. Long may the pollock bite!

H.S

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

COUNCIL NOTES.

A MEETING of the Council was held at the Institution of Electrical Engineers, Victoria Embankment, S.W., on October 11th, 1921.

Reorganisation.—The Secretary reported that the Council's proposals respecting the new Constitution, having been endorsed by the membership, were duly adopted and brought into operation. The increased subscriptions called for had been readily paid, and consequently the financial position of the Institution was much more satisfactory.

Technical Periodicals.—Arrangements had been made for the circulation of technical periodicals, which had been temporarily suspended, to be resumed, and supplies of English journals would be issued immediately. Some delay was anticipated in connection with the American journals.

Central Lending Library.—The Librarian reported that 70 sets of Lantern Slides are now available for the use of Local Centres or individual members. These sets had been scheduled and a list of the subjects dealt with had been prepared and could be obtained on application.

Papers to be printed.—The following papers have been recommended for printing and will be issued in due course:—

"Secondary Cells," by R. G. De Wardt.

"Four Wire Telephone Repeater Systems," by Messrs. C. Robinson and R. M. Chamney.

"Relay System of Auto-Switching," by H. W. Dipple.

"Influence of Traffic on Auto-Exchange Design," by G. F. Odell.

Membership.—The Secretary reported that there had been a satisfactory increase in the number of Clerical Members, and although a serious loss of Associate Members had been experienced at the beginning of the year the position had been greatly improved. It was confidently expected that the Inspectors would realise that the change in the Constitution is in the interest of all concerned and renew their support of an organisation which is peculiarly adapted to serve their interests.

T. SMERDON, *Secretary.*

LOCAL CENTRE NOTES.

LONDON CENTRE.

THE first meeting of the present session took place on the 18th October. The occasion was interesting for two reasons. In the first place, we found ourselves again at the Institution of Electrical Engineers, after a lengthy absence due to the building having been occupied by the Air Ministry. It was interesting to observe how little the fabric had been adversely affected by this "alien" occupation. In passing, we desire to place upon record our appreciation of the hospitality accorded the Centre by the Royal Society of Arts during the period when Savoy Place was not available.

Nothing could exceed the consideration and courtesy accorded us by all the officers of the Royal Society.

Secondly, the meeting of the 16th October was notable from the fact that we had the pleasure of listening to the reading of a paper on "Method of Accounting in Engineering Department of the Post Office," by Mr. R. McIlroy, who had just recently been appointed Superintending Engineer on the London District, in succession to Mr. Moir. In his paper, which Mr. McIlroy explained had previously been read at a meeting of the South Wales Centre, the author set out to demonstrate the desirability for the accurate preparation of the "Primary Voucher," as having a most important bearing upon all the Cash Accounting of the Department. He was careful to point out that the accounting of the Department was carried out in accordance with the requirements of the Public Accounts Committee of the House of Commons, and that, although there might be the view that the system was not all that could be desired, yet, as a Department, we had to conform to what was required by the Committee in question. It followed therefore that the "Primary Voucher" was an all-important document, and we were treated to a lucid explanation as to its place in the accounting system, and the different phases of that system. For the purposes of his paper Mr. McIlroy assumed that the Engineering Department was a "Spending" Department. We do not quarrel with this description, having regard to the sense in which it was used. We respectfully suggest, however, that viewed in the light of true economics the Department is a "Revenue Earning" one, inasmuch as upon its efficiency depends to a considerable extent the revenue received from the various public services with which it is connected.

An interesting discussion followed the reading of the paper, in which many members, including Sir William Noble, took part, and in which several difficulties encountered by the staff were disclosed. In his reply the author incidentally touched upon a very important matter. He expressed his surprise at what was the comparatively high cost of London Maintenance. He said he had examined several explanations, but had been forced to reject each of them as inadequate. He advanced an opinion of his own in respect to the way in which the original telephoning of London was undertaken. We shall be very glad to learn whether Mr. McIlroy still holds to this opinion when he has had the advantage of a closer acquaintance with the problem. Without wishing to provoke a discussion, we confess we are far from being impressed with the comparisons which are formed by the critics of London Telephone administration in support of their criticisms. The provision of an adequate and efficient telephone service for the Metropolis is a unique problem without parallel anywhere. It is, of course, obvious to say that we should not be above learning from other people, but we suggest that it is equally true to say that it would be fatal to attempt wholly to learn by mere comparison where, to be guilty of a paradox, no suitable comparison exists.

To return to the paper, a perusal of its contents should prove invaluable to all those engaged in the preparation of the Department's accounts. It only remains to say that Mr. McIlroy had an audience worthy of the occasion, and that the ovation he received at the end was indicative of the appreciation called for by the reading of the paper.

At the second meeting of the Centre, held on the 8th November, Mr. A. B. Eason gave a paper on "Capacity of Batteries in C.B. Telephone Exchanges." It is regretted that the audience was a poor one, in view of the fact that the paper was of a very highly interesting character. We have much pleasure in saying that the author deserves great credit for the work involved in collecting the material for the paper—the title is fully indicative of its contents—and for the manner in which the data were presented. Of course, a very old question is raised in new clothes; that is, at what point should arrangements to meet an emergency be considered adequate. It emerged during the subsequent discussion that complete breakdowns took place at rare intervals, and then only for brief periods. The palm for breakdowns must be awarded to the ancient town of Norwich. Some years ago a breakdown lasting for three days took place. But then an inundation was responsible, which deprived Norwich of all its many services and isolated the Cathedral City from the outside world.

Mr. J. Stuart Jones, Telegraph Traffic Branch, read a valuable paper at the third meeting of the Centre, held on the 13th ult. The subject was "Telegraph Mechanical Aids from a Traffic Point of View." The author went over in detail the various appliances which had been tried, and discussed their usefulness from the traffic side. A spirited discussion followed. W.G.O.

NORTH WESTERN CENTRE.

The opening meeting of the 1921-22 Session was held in the Lecture Hall of the Preston Scientific Society on Monday, 5th December, when a paper of exceptional interest, entitled "Carrier-Current Multiplex Telephony," was read by Mr. W. J. Rolfe, A.M.I.E.E.

The Superintending Engineer (Mr. T. E. P. Stretche, M.I.E.E.) presided over a good attendance, and the paper was illustrated by an excellent set of lantern slides.

The lecture was in four parts, opening with a definition of "carrier-current," and a comparison of the carrier-current system with other methods of superposition. The lecturer went on to speak of recent inventions and developments—notably of the thermionic valve—which had made carrier-current telephony a practical proposition, afterwards dealing with the economics of the system, and the conditions in which it may successfully be developed in this country.

In part II., Mr. Rolfe outlined the history and development of the valve, explaining the theory of the emission of electrons and describing the behaviour of the valve as a rectifier of high frequency alternating currents. The action of the grid was next described, and the functions of the valve as an amplifier of weak oscillatory currents, and as a generator of high frequency oscillations were explained.

Part III. dealt with carrier-current circuits, leading from diagrams of single one-way transmitting and receiving ends up to multiplex working with five or more channels on one pair of wires. Diagrams showing the modulation of the carrier current to the voice frequencies, and the method of separating and demodulating the various currents at the receiving end were exceptionally clear. The method of signalling over carrier channels was also explained.

In part IV. Mr. Rolfe dealt with line characteristics, showing the variation of impedance and leakage at high frequencies, and the general effect of these upon telephone transmission. A simple method of measuring the impedance of a line at high frequencies was shown on the screen and described. The paper concluded with a consideration of the conditions under which world telephony will become a practical proposition, and emphasized the necessity for the introduction of a cable with extremely low dielectric losses.

A discussion folowed, when many queries were raised, to which Mr. Rolfe suitably replied.

The proceedings terminated with hearty congratulations to Mr. Rolfe on the production of so interesting and valuable a paper, and an expression of satisfaction that the North Western Centre should be first in the field with a paper on such an up-to-date subject as carrier-current telephony.

D. BARRATT, Hon. Secretary.

NORTHERN CENTRE.

THE Session opened on October 12th with a paper from Mr. C. Whillis, entitled, "An Engineer's Preliminary Work in Connection with a New Post Office."

Mr. A. C. Greening's paper, "Some Notes and Views upon

Telephone Fitting Work," was discussed on November 9th. The subject proved to be very popular, and a well sustained discussion followed the opening remarks of Mr. H. Kitchen. Mr. F. G. C. Baldwin's views upon the wiring of large buildings were aptly illustrated by lantern slides.

At the invitation of the North East Coast Institution of Engineers and Shipbuilders, Mr. C. Whillis read a paper on "A Modern System of Telephone Working," before that Institution on the 11th November. The meeting was well attended by I.P.O.E.E. members, and the discussion was opened by Mr. Elliott, who, in the course of his remarks, outlined the extent of the local schemes for the development of the Telephone Service.

The paper was read again on the 25th November before the Middlesbro' Centre of the Institution, there being an attendance of about 300 members, who were intensely interested in the subject.

The Centre was also well represented at the meeting of the Institution of Electrical Engineers held on 14th November, when Mr. E. S. Byng read a paper on "Telephone Line Work in America," and several of the members participated in the discussion.

A varied and interesting programme of six papers has been arranged for the Session.

Several new members have been enrolled this year.

Arrangements have again been made for the provision of light refreshments after the meetings of the Centre.

The officers for the present Session are:—

Chairman.—J. R. M. Elliott, Esq.

Vice-Chairman.—F. G. C. Baldwin, Esq.

Hon. Secretary.—Mr. A. C. Smith.

Hon. Librarian.—Mr. F. Johnson.

Committee.—Messrs. H. Kitchen, J. Peel, J. Friar, G. Bailey.

NORTH WALES CENTRE.

The first meeting of the current Session in connection with the North Wales Centre was held in the Technical School, Shrewsbury, on 18th October, 1921, under the chairmanship of Mr. T. Plummer. The attendance numbered 60.

Mr. J. H. Whitehead read a paper on "Some Aspects of the New System of Accounting," in which he outlined the changes which had been brought about by the introduction of the system. He described the relation between "Classes of Work" and "Units," and indicated typical errors and their results. The discussion centred on the practical application of the system and many points of difficulty were raised.

Mr. Whitehead, replying to questions as they arose, was in a position to give explanations on most of the difficulties which were being experienced, or to offer suggestions how such difficulties might be overcome.

It was pointed out that, whilst the system may not effect any saving of time in the Engineering Department, time would be saved in the A.G.D.

On the occasion of the second meeting of the Session it was decided as an experiment in the interests of economy to divide the meeting, and Mr. H. P. Lloyd's paper on "Faults on Lead-Covered Cable Sheaths" was accordingly read by him at Shrewsbury on 29th November, and at Birmingham on 6th December. Members in the Birmingham area attended on the latter date, whilst members from other parts of the District were present at the Shrewsbury meeting.

Mr. Lloyd described the composition of the cable sheath and the effect of electrolysis, mechanical injuries, chemical decomposition, vibration and crystalisation.

The difficulty in dealing with stray currents from power circuits, etc., was dealt with, and the method of testing for such currents explained.

Mr. Lloyd drew from his own experience many illustrations of cable faults, and described a number which presented peculiar features.

The paper, which was of a practical character, was well received at both meetings and led to good discussions.

The membership of the Centre this Session numbers 97 and interest is well maintained. The generosity of Members, etc., has enabled the Committee to offer book prizes to the students in Telegraphy and Telephony at the Birmingham, Shrewsbury, Hanley, and Llandudno Technical Schools. It is hoped to preserve this feature of the work of the Centre in future Sessions.

A.J.W.D.

SOUTH LANCASHIRE CENTRE.

The work of the Institution has proceeded smoothly since the re-organisation, and there is every prospect of a successful Session. Apart from the Inspectors, who, it is regretted, considered it desirable to withdraw after the Re-organisation proposals were brought into operation, the membership is very satisfactory. The number of new entrants has practically balanced the withdrawals so far as this Centre is concerned.

Three meetings have been held up to the time of writing:—

On the 10th October, the Chairman, Mr. W. J. Medlyn, read a paper on "Progress and Development in the Engineering Department," in which he reviewed the progress made during the preceding year, and gave in a simplified form figures and other data indicating the activities of the Engineering Department in its various branches.

On the 7th November, Mr. T. E. Matthews read a paper, the subject being "The New Accounting System and Unit Construction Costs." The lecturer contrived to make his subject very interesting, and humourously contrasted present-day practice with the methods in vogue say 20 years ago. He also made an appeal for an open mind in considering the merits of new methods, such as those dealt with in his paper.

The last meeting to date was held on the 5th December, when Mr. Magnall gave a lecture entitled "Pages from an Engineer's Notebook." The lecturer gave extracts from his "imaginary" notebook in his usual breezy way. He related some interesting experiences of the past, and brought to the notice of the meeting some valuable data. The lecture was illustrated by lantern slides, and was much appreciated.

The attendance at the meetings has been excellent, and the discussions which followed the last two lectures indicated that a lively interest had been taken in the proceedings.

BOOK REVIEWS.

"Appareils et Installations Télégraphiques." E. Montoriol. J. B. Bailliere.

We have received a copy of a very comprehensive work on telegraphic apparatus and installations by E. Montoriol, Inspecteur des Postes et Télégraphes, Professeur à l'Ecole supérieure des Postes et Télégraphes. The book forms part of an Encyclopædia of Industrial Electricity published under the direction of M. A. Blondel, Membre de l'Institute, Professeur à l'Ecole Nationale des Ponts et Chaussées.

The work occupies 625 pages with 449 illustrations and is priced at 40 francs, whilst a more costly copy can be obtained at 50 francs.

The illustrations are good and show very clearly the details of the apparatus, from the early "ABC" type of instrument worked on the principle known as the step-by-step method, to the modern complex page-printing receivers.

The Hughes Printing Telegraph instrument, which for years was the chief means of communication on the Continent and is still in considerable use, is very fully described, but quite naturally the Baudot system invented in France occupies a much greater portion of the work. There are many diagrams and illustrations dealing with the system as developed in France during some 40 years, but we find no diagrams nor illustrations of the British development of the Baudot duplex, which has in recent years made such a vast extension in the use of the Baudot system, and of the other systems which are founded on the general principles of the Duplex Baudot.

The matter is divided into sections as follows:—

1.	Apparatus with simple transmission	121	pages.
2.	Arrangements to increase the output of Lines	86	,,
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	Appendix:—Output of Operators, Lines, General classification, Comparison of systems ...	20	,,
	Conclusion:—Favouring the Baudot system for long lines, and Morse Sounder or Inker for short lines	3	,,

An ample index is given with references to other works on the subject or particular item described.

The Morse system developed to the extent that we know it has not been dealt with sufficiently from our standpoint, nor do we concur with some of the criticisms made in regard to other systems, more particularly with reference to the alleged disadvantages of Duplex Multiplex working; but we confidently recommend the book as being an excellent work of reference, particularly from the French point of view, and it will, we feel sure, take its place in the first rank with other notable works on this complex but very attractive industry.

"Principles of Radio Communication." By J. H. Morecroft (Columbia University), 1921. Chapman & Hall Ltd. (935 pages, 45/- net).

This book deals with the theory and practice of Radio telegraphy and Radio telephony. Chapter I. adopts the electron theory to explain the fundamental ideas of electric fields and currents, and proceeds to deal clearly and rapidly with the effects of resonance, decrement, and coupled circuits, etc. Chapter II. deals with resistance, inductance, and capacity. Chapter III. deals with electromagnetic waves, propagation, different types of waves, receiving attenuation, and freak transmission. Chapter IV. covers the laws of oscillating circuits. Chapter V. deals with the various types of spark telegraphy. Chapter VI. deals very fully with the important matter of vacuum tubes and their operations in typical circuits. Chapter VII. covers the various methods of generating continuous waves, the Poulsen Arc, Alexanderson and Goldschmidt Alternators, frequency changers and Marconi's timed spark, the methods of signalling on these systems and the reception of continuous wave signals.

Chapter VIII., on Radio telephony, gives various transmitting circuits and methods of modulation, the effects of decrement on the quality of speech and the method of reception. Chapter IX. deals effectively with the law of radiation from various types of antenna, the field at a distance from an antenna radiation resistance, counterpoises, antenna resistance, current and voltage, distribution along an antenna and loading. Direction finders are also included. Chapter X. is on wavemeters and their use. Chapter XI. deals with triode amplifiers for high and low frequencies, filters, the stability of amplifiers, etc. The last chapter describes a series of experiments which should prove useful to the engineer studying the subject. The work is most comprehensive, and deals very fully with a wide field of theory and applied science, both mathematically and descriptively. The book is profusely illustrated with clear diagrams, and the sequence of the subjects is well arranged. We welcome the book as a most valuable and up-to-date addition to the literature on the Radio art, and recommend its perusal to all those desirous of extending their knowledge of high frequency phenomena.

E. H. SHAUGHNESSY.

"The Diagnosing of Troubles in Electrical Machines." By Miles Walker, M.A., D.Sc., M.I.E.E. pp. 450 + xi. (Messrs. Longmans, Green & Co., London. 32/- net).

Dr. Miles Walker's earlier contribution to electrical literature in "The Specification and Design of Dynamo Electric Machinery" was sufficient to raise expectations that the present work would be one of more than ordinary interest. These expectations have been realized and it is thought that the present volume will prove as valuable a work of reference as Dr. Miles Walker's previous work.

The volume under consideration is one of Messrs. Longman's Electrical Engineering Series edited by Charles P. Sparkes, M.I.C.E., M.I.E.E. It contains 450 pages and 332 illustrations and diagrams.

As the author observes, it is impossible to deal with all the troubles that can occur in dynamos. As development and design advances new troubles are encountered, the causes of which have to be diagnosed before remedies can be applied. One is reminded of this by the recent example of the failures of the two alternators at Kilmarnock owing to mechanical resonance of the rotor bolts.

A work of this character should prove of great assistance to the designer, the testing engineer and also the engineer called on to maintain plant in operation.

Chapter I. naturally deals with the breakdown of insulation. The subject is dealt with very thoroughly and the various methods of determining the position of the fault are fully described, not only in the case of ordinary windings but in the case of the more complex re-entrant multiplex windings.

Chapter II. is devoted to overheating. The various methods of measuring temperature are described and criticised. The various causes of overheating are enumerated, and methods of calculating the probable temperature rise of a winding are explained. The desirability of having a large space factor and the exclusion of air pockets in windings is emphasised.

Chapter III. deals with low efficiency and the separation of losses by various methods. The chapter includes a useful section on the measurement of the losses in large machines by air-heating methods.

Miscellaneous troubles are grouped in Chapter IV., which contains a useful section on want of balance in running machines. The change of the directions of deflection about the critical speed is carefully explained. This point is not always clearly understood and the subject is dealt with more fully than we recollect seeing elsewhere. Some useful practical hints on balancing are included.

The use of vector diagrams often affords a simple method of attacking problems in alternating current circuits. The subject of these diagrams is very fully dealt with in Chapter V. as a preparation for Chapter VI., which deals with defects special to alternating current generators.

Chapters VII. and VIII. are devoted to direct current generators of various types.

Chapters IX. and X. deal with commutation and allied subjects. Some useful notes on brush gear are included.

A short chapter follows on the troubles special to direct current motors of various types.

Synchronous Converters and their defects are given consideration in Chapters XII., XIII. and XIV., and the question of sparking at the brushes on these machines is fully dealt with.

Two short chapters, XV. and XVI., are allotted respectively to induction motors and the use of the oscillograph.

A comprehensive index completes the work.

The volume is essentially of a practical character throughout, and the author has rendered it more valuable by the inclusion of actual numerical examples and curves taken from actual machines.

The majority of troubles which are described are naturally those more prevalent on large machines because defects which pass unnoticed on a small machine assume a more serious character on large high-speed machines. Nevertheless, we think the work will be of interest and value to all engineers concerned with electrical power plant, even if such plant is of comparatively small output, and the book is confidently recommended to their notice.

A. J. GILL.

"Common Battery Telephony Simplified." By Walter Atkins. Fourth Edition. (Benn Brothers, 8*s.* 6*d.*).

The fourth edition contains many new diagrams and the letter press has been revised. Written with the object of straightening out and simplifying the more intricate circuits used in connection with C.B. exchanges, the letterpress deals with junctions, P.B.X.'s, desk equipments, and testing and observation arrangements, and 157 diagrams are given. The book is a useful one for those engaged in exchange construction and maintenance, and will be handy also for reference to those who have not time to study wiring schemes. The cross-references are not always correct, however; for instance, on page 42 the figures referred to are quoted wrongly.

"Questions and Solutions in Magnetism and Electricity." By William J. White. Second Edition. 2*s.* 6*d.* (S. Rentell & Co., London).

A useful little book for students desirous of obtaining the City and Guilds of London Institute's certificate in Magnetism and Electricity.

The book contains the whole of the question sets during the period 1907-1921 with the appropriate solutions for the great majority of these questions. It is suggested that in future editions the author should refer the student back to a particular answer rather than forward, *e.g.*, in Questions 6 and 7, page 7, it would be better to deal with the questions fully at this stage and to refer the student back from pages 42 and 22 respectively.

Pages 48 and 71. It might be well to explain the meaning of "multiple arc" or to drop the term altogether.

Page 88. Fig. 60 shows the Varley single needle coils and not the G.P.O. single current galvanometer; the difference, however, is not great, being only in the arrangement of the magnets.

H.W.

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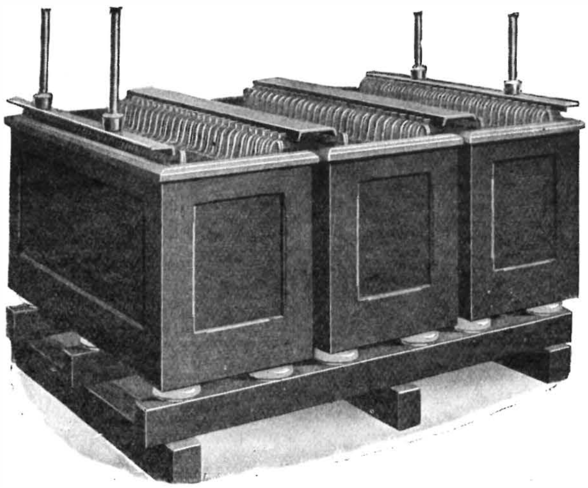

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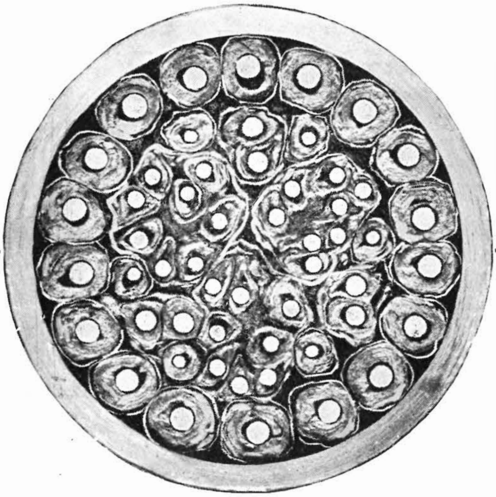
1837  **1921**

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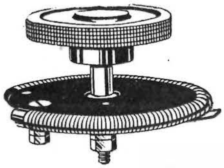

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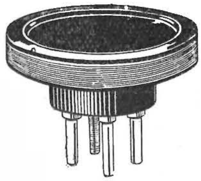

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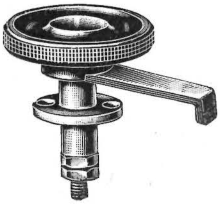

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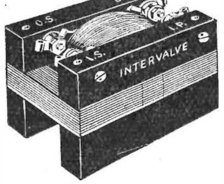

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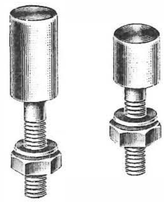

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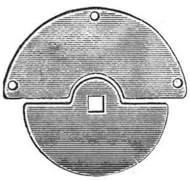

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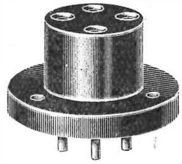

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