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THE Post Office Electrical Engineers' Journal

THE METRIC SYSTEM FOR THE BRITISH EMPIRE.

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[A paper read before Centres of the Institution of Post Office Electrical Engineers at London on January 22nd, 1918; Shrewsbury on February 4th, 1918; Leeds on February 6th, 1918; Preston on February 11th, 1918.]

MY justification for bringing this subject before this Institution is that I am thoroughly convinced of the importance to the Empire of our adopting the reforms which I urge, and my recognition that the ingrained conservatism of our essentially progressive race demands that the most strenuous propaganda shall be instituted to secure application of any scheme, even when practical unanimity of most people concerned has been obtained. There are many able workers already in the field. I engage in the work only in the spirit that I hope many of my hearers will emulate; recognising that, not a few generals, but a host of recruiting sergeants must be forthcoming if the whole community is to be mobilised in the cause at this time, which is probably the most favourable that can ever occur.

I.—THE METRIC SYSTEM.

(*a*) I will not occupy your time by treating of the historical aspect of the metric system. Opponents to change often make much of the fact that the whole scheme formulated by the French scientists of the end of the eighteenth century is not in general use even now. Viewed from the proper angle, this is really a valuable argument for the present propaganda—we urge adoption, not of an untried academical scheme, but of a system that by practical use during over a hundred years has sifted out all non-essentials and is thereby even more simple than the original simple scheme.

Similarly, the objection that even in France the sou and the livre are still used in the market-place only shows that for an almost indefinite time the old terms can be retained when that is a matter of popular convenience.

We are, in fact, in a position now to adopt a proved-out system, the value of which has been uniformly recognised by a large majority of our best thinkers; the adoption of which has been recommended by Parliamentary Committees, by Chambers of Commerce, by Municipalities, by Trades Union Congress, by Trade Protection Societies, by the Institute of Chartered Accountants, by the General Medical Council, and by the Council of our own Institution of Electrical Engineers; and the use of which throughout Great Britain was legalised by Parliament twenty years ago.

Basis of the System.

(*b*) The whole system is based upon the metre—the measure. This title is given to the unit of length. It was intended that the length adopted should be one ten-millionth part of a quadrant of the earth's circumference—the quadrant was to be 100°, the degree 100′, the minute 100″, and the metre was to be $\frac{1}{10}$th of a second of arc. In practice *now* the metre is the distance between two marks on a certain rod of platinum inserted in a concrete block in Paris; and on certain copies of this which have been distributed over the world.

The unit of weight—the kilogram—is derived theoretically from the metre, as being the weight of 1 cubic decimetre of pure water at its maximum density. In practice, however, the *kilogram* is represented physically by a certain piece of platinum which is accepted as 1 kilogram when weighed at a certain temperature under a certain barometric pressure.

The unit of *capacity* is the litre, which is the volume at its maximum density of one kilogram of water.

The primary units adopted are the metre, the gramme, and the litre. Sub and multiple units are derived by ratios of tens—the sub units being designated by uniform Latin and the multiple units by uniform Greek prefixes. The prefixes and the values defined in relation to the units are:

milli.	centi.	deci.	Unit.	deka.	hecto.	kilo.
$\frac{1}{1000}$	$\frac{1}{100}$	$\frac{1}{10}$		10	100	1000

In practice quantities are expressed in one unit. For example, we do not write:

3 kg. 1 hg. 2 deg. 3 grm.

but

3·123 kg.

or

3123· grm.

or even

312300 cg.

That is, we are able to adopt the most convenient dimension or weight as our unit and express all quantities in that unit, with the realisation that they can be reduced to any other unit by merely changing the position of the decimal point.

This, however, by no means involves exclusion of convenient fractions. For instance, in retail transactions, the kilogram is the normal unit (it weighs 2·20462 lb.), and we should buy $\frac{1}{4}$ kilo. or $1\frac{1}{2}$ kilos. just as we do in lbs., and perhaps more frequently have a fraction on account of the greater weight of the kilo.

Comparison of Metric with English Weights and Measures.

(*c*) The strength and weakness of the English tables is the great diversity of ratios between the various units. In days when the knowledge of arithmetic was almost non-existent, small ratios were more or less essential and the possibility of simple division and sub-division by two was a great desideratum, but, as I have said, for such minor transactions, fractions of a unit are to us as good as units with low ratios.

When one sets out the English tables of length, weight, capacity, and square measure, taking only the units more or less commonly used and ignoring such special items as barleycorns and hands, it will be seen that there are seventeen different ratios for twenty-five items. In the metric system the only ratio is that of the ordinary notation—ten.

In addition, we have the same word meaning radically different things. Live men and live cattle are weighed by "stone," but 8 stone of man make a cwt., while it takes 14 stone of bullock to make a cwt.

The anomaly of calling 112 lb a hundredweight has induced the United States to decimalise that unit, and so a United States cwt. weighs only 100 lb. and a ton only 2000 lb. against our 112 lb. and 2240 lb. respectively.

In troy weight the only legal standard is now the ounce and decimals of an ounce. The ounce troy is defined as 480 grains, the grain being $\frac{1}{7000}$ of a pound avoirdupois. Thus this reform has practically eliminated the only vestige of connection between troy and avoirdupois weights.

Legally, corn is sold by weight, but by custom it is reckoned in bushels. The result is that certain standard weights of bushels are defined for various kinds of grain. They are—

38, 39, 40, 50, 52, 52½, 60, 62 lb.

It is said, however, that there must be 200 sizes of "bushel" in use. What scope for fraud still permitted in a community shielded by Weights and Measures Acts!

II.—Alternative Systems.

Those who object to the adoption of the metric system often refer to alternatives. They admit the need for a change from the British weights and measures, but they say we can do better than adopt the metric system.

Now, I submit that there are only two possible courses open to the British people in this twentieth century:

We can retain the English tables or we can adopt the metric tables.

In a paper read recently before the Institution of Electrical Engineers, Mr. L. B. Atkinson submitted an ingenious scheme for retaining a selection of our unit names, partially metricising their values and working to decimals, with a view to ultimate conversion to the metric system. I am convinced that *any* change that is worth making would, in the transition stage, be as inconvenient as any other, and therefore that one transition stage must be better than two. I submit that an absolute throwing over of our present system would be far more convenient than its adaptation, as there would be grave confusion in having the same name to represent different values in old and new contracts, and in subsequent references to documents and records. I also submit that such a change would add to our difficulties in foreign business rather than reduce them, and would probably precipitate adhesion of some of our Colonies to the metric system on their own initiative in despair of carrying us with them.

I urge that the clean cut between the old and the new would facilitate the enforcement of a square deal; so long as, for instance, *bushels* are a legal measure, there will always be some scope for sharp practice.

I urge that the only practical way to mend our present system is to end it, and that the only practical and efficient substitute is the Metric System.

III.—Advantages of the Metric System.

(*a*) *Scientific Basis.*—We electrical engineers are fortunate in having secured that our own special units should be international both in respect of names and values, and that they have a scientific basis—the centimetre-gramme second.

I think the advantage may be brought home by considering the physicist's "specific gravity." By universal consent all relations of weight are based upon the weight of a unit mass of pure water at its maximum density. Under the metric system the unit mass (1 cubic decimetre) of pure water at maximum density determines the weight of 1 kilogram. Thus the weight in kilos of a similar mass of any other material is represented by its specific gravity without calculation.

The English physicist, however, adopts a cubic foot as the unit mass and the lb. as unit weight. Hence our unit for specific gravity is 62.288 lb.

Similarly with other values dependent upon weight of water which are in constant use:

Pressure.

A head of 2·31 ft. gives 1 lb. per square inch.	A head of 1 dm. gives 1 kg. per square decimetre.

Weight.

1 c. yd. weighs 15 cwt. 0 qr. 1·776 lb.	1 c. m. weighs 1 tonne.

Measure.

1 imp. gal. = 277·274 c. in.	1 litre = 1 c. dm.
1 U.S. ,, = 231 c. in.	

Simplification of Calculations.—The scientist or the engineer in these days addresses the whole world in his writings. When the English writer submits a mass of tabular work, it is only accessible to his foreign colleague by laborious calculations. Similarly, the English reader is barred from a clear understanding of foreign works far more in respect of the calculations than by the difficulties of language; whereas every foreign writer and reader of scientific literature in the principal countries of the world has the same language of figures however their spoken languages may differ.

If we, too, by adopting the metric system, thought and wrote in their language of figures, our work would be enormously simplified, and, at the same time, their work would become accessible to us, and comparable with our own work without translation.

In a paper on the "Steam Path of the Turbine" read by Dr. C. P. Steinmetz before the American Society of Mechanical Engineers, it was stated that where an investigation extends over several branches of science the "incongruous mixture of heterogeneous units called the English system" is so cumbrous that it is far simpler to translate the premises into the metric system and to carry out the work in the metric system, even if the results have to be expressed in English measures.

Under the head of simplification I think it is fair to put engineering drawings. What a mixture of dimensions we get now! Even where restricted to English measures we get feet, inches, and quarters, eighths, sixteenths, thirty-seconds, sixty-fourths, and mils.

$1\frac{3}{16}''$ is liable to be misread for $\frac{13}{16}''$,

$1'\ 1\frac{1}{4}''$ to be mistaken for $11\frac{1}{4}''$ or even $111\frac{1}{4}''$,

whereas under the metric system every dimension large or small can be expressed in millimetres and automatically translated when the higher unit needs to be expressed.

Even for home use in the simplest relations of life it must surely represent serious loss of brain force when, instead of uniformly recognising that the process of multiplying say 11 by 7 gives 77, we have to deduce a result according to various circumstances, and even to find that 7 × 11 does not necessarily give the same answer as 11 × 7, thus:

			£	*s.*	*d.*
11 articles	@	7*d.*	0	6	5
11 ,,	,,	7*s.*	3	17	0
11 pints	,,	7*d.* per quart	0	3	$2\frac{1}{2}$
11 yards	,,	7*d.* per foot	0	19	3
11 pounds	,,	£7 per cwt.	0	13	9
7 ,,	,,	£11 ,,	0	13	$3\frac{3}{4}$

Under a metric and decimal coinage system we should have correspondingly:

			£
11 articles	@	7 mils	·077
11 ,,	,,	7 fl.	7·7
11 litres	,,	7 mils per decilitre	·77
11 metres	,,	7 mils per centimetre	7·7
11 kilograms	,,	£7 per ton	·077
7 ,,	,,	£11 ,,	·077

In practice, however, we should actually have prices of litres, metres, and kilograms.

(*c*) *Calculating Machines.*—Those who have used mechanical calculators or slide rules appreciate the limitations introduced by our erratic tables. You need a special machine even for direct money calculations. What a marvel it will seem to the ordinary clerk to be able to find the cost by means of a slide rule of what is now (say) 3 cwt. 2 qr. 17 lb. of sugar at (say) £2 13*s.* 7*d.* per cwt., and to know that by the same machine he could ascertain the weight of what would now be 3 miles 270 yds. of 70-lb. wire!

(*d*) *Education.*—It has been stated that of 221 headmasters who reported upon the subject in 1903, 212 express unreserved support of the metric system, as its introduction was estimated greatly to economise school life:

161 masters	estimated	the saving	as	1	year.
30	,,	,,	,,	2	years.
6	,,	,,	,,	3	years.

That the views of educational authorities have not changed is indicated by a resolution last year of the L.C.C. Central Consultative Committee of Headmasters: "That the time is now ripe for the compulsory introduction of the Metric System." The Education Committee asked the Council to convey to the Government a recommendation to that effect.

(*e*) *The International Problem.*—There is never any serious doubt that the ordinary merchant engaged in foreign trade would generally welcome a change, although I have heard it urged that there would be serious objection to a change at this time as facilitating the entry of the German trader into British markets. But the *German* trader has penetrated what used to be British markets already to a very serious extent, and a great many observers hold that this is really largely due to the fact that the German merchant is quite keen to make and to sell goods to the measures and requirements of the buyer; that, in fact, he already uses our system where the buyer is accustomed to it, while the British merchant is all too prone to give the British system where the metric would be better appreciated—in fact, foreign trade after the war will have to be carried on under the dual system, with which the German is already perfectly familiar, or under the metric system, which we must learn and use either instead of, or in addition to, our own. If Great Britain adopts the metric system, it will become universal within a decade.

Hosts of our people during the war have become generally familiarised with the metric system to an extent never before experienced, and the general conditions ruling at present are extraordinarily favourable to a change.

IV. Objections to the Change.

(*a*) *Convenience of the Majority.*—The objection that the bulk of the population of these islands has no direct concern with high accounting or with foreign trade, but would be greatly disturbed by any change, has an attractive force by its implication of a considerateness that is lacking in the contention of the metricist.

Those who have travelled in foreign countries have noticed how easily they drop into the strange measures and money in simple transactions, even where the trader is unfamiliar with their difficulties. How much easier will it really be where the trader is himself in close sympathy with the difficulties and has been trained by explanation of the conversion tables that will be exhibited in every shop. For instance, housewives who know well the present price of sugar per lb. will at first only know that 66 mils per kilogram is a fair price by seeing on the table that 66 mils per kilogram is about the same as 6½*d.* per lb.

Further, there will always be the possibility of virtual retention of the old system—the trader would practically use the conversion table in the reverse sense.

(*b*) *English Measures in Foreign Trade.*—It is, of course, admitted that our measures are widely known and understood, and that at present a considerable proportion of our overseas trade is with our colonies and dependencies and with the United States, where the English measures are in use; but the variations made in the United States and the representations made by some Colonial Governments indicate that there is a very real tendency to break away from our system, whether we do so or not. It has been pointed out that our actually *foreign* trade is not by any means the most important branch of our trade. If that be so, it surely should suggest that here is a most promising field for enterprise in increasing our total overseas trade, which will be of the greatest possible importance after the war.

(*c*) *Cost of the Change.*—I can in this matter most conveniently quote in full from my paper before the Institution of Electrical Engineers.

(i) *General.*—The objection to the change that has to be taken most seriously is, perhaps, the matter of cost. Every opponent refers vaguely to the enormous cost involved in making the change.

There can be no doubt that the cost to the community in the aggregate will be considerable, but this should be kept in its right perspective. The cost would not be a charge in bulk. It would be borne in relatively small sums by businesses according to the turnover. The small business would have to disburse once for all a few shillings for a set of new weights.

Progressive retailers during the last few years have "scrapped" not only their weights but their scales in favour of direct-reading balances. Those balances could be corrected to the new weights for a relatively very small sum. The same would apply to butchers' steelyards, which (without any revolutionary change) a few years ago replaced other machines that had to be scrapped as a result of a Board of Trade order.

(ii) *Engineering Work.*—Similarly, with a big engineering firm, the cost of the change for templates, gauges, meters, dies, etc., will for the most part only precipitate normal renewal and will be a mere decimal point of the regular expenditure under many overhead charges, such as postage.

Probably, even in regard to a large proportion of specially expensive measuring instruments, the makers will be able to devise methods of altering rather than scrapping, while in other cases there will be little objection to, or inconvenience in, use of conversion tables.

(iii) *Estimates:* (A) *Taring of Railway Trucks.*—As an example of groundless fears, a great railway engineer recently explained how the comparatively simple process of re-taring all the railway trucks would cost about £400,000. But I understand that railway trucks are re-tared normally (where facilities exist) when they come into the shops for repair, and the General Manager of a great railway was good enough to give me the works' history of three representative trucks built in 1908, 1909, and 1910 respectively, which were each re-tared twice within five years of building.

(B) *Shipbuilding.*—In 1895, the President of the North-East Coast Institution of Engineers and Shipbuilders (one of our most progressive engineering institutions) when advising the then Prime Minister (Mr. Balfour) that his members were unanimously in favour of the change stated that at his own works, with a wages bill of £2500 a week, the cost of the change would be little over £100.

This "scrapping" idea is really fanciful in many cases. In regard to meters, for instance, people who can read a gas-meter in cubic feet and check the account at x per 1000 c. ft. would not seriously object to having to convert their reading into the corresponding metric measure. It would be no worse than a certain water company whose meters registered cubic feet while the charge was per 1000 gallons.

(*d*) *Transition Stage* (*Habit*).—So much for cost sterling; but how about that valuable asset of mental and manual facility which we call habit? Here we have to visualise the difference between the existing conditions, with every English-speaking person using to some extent the awkward English measures, and all who have foreign business using, in addition, another system, and, on the other hand, the metric system alone being used by all for thought and word and work.

If the issue were clear cut between the two conditions, I should expect a unanimous voice in favour of the metric system alone. The real difficulty is that there must necessarily be a transition stage, during which the conditions will be more complicated for great numbers than the present dual system is for a few. Admitting all this, I urge that the nation that is cheerfully acquiescing in passing through the horrors of this great war as the transition stage between the *Armed Truce* that we thought was PEACE and the INTERNATIONAL PEACE that is to bless our children, is not a people whose breadth of vision and generosity of purpose is to be baulked by minor considerations of habit and of temporary convenience. Let our legislators boldly adopt the best course, and our people will willingly run in it.

(*e*) *Dual Stocks, etc.*—The transition stage would cause some trouble in respect of need for double stocks, but such consideration is not preventing the Engineering Standards Committee from seeking for an international screw-thread even at the possible cost of the highly-standardised Whitworth thread.

In fact, standards in so essentially progressive an art as engineering are not, and ought not to be, unchangeable—where an improvement can be secured it must be secured.

(*f*) *Drawings and Ordnance Maps.*—It is on record that the Baldwin Locomotive Works of United States of America undertook to make twenty locomotives within six months for a *French* company.

Present.		Proposed.		
Scale and denomination.	Ratio.	Denomination.	Ratio.	Equivalent.
Miles to inch	1 to	mm. to km.	1 to	Inches to mile
15·782	1,000,000	1	1,000,100	0·06336
10	633,600	2	500,000	0·12672
4	253,440	4	250,000	0·25344
2	126,720			
		10	100,000	0·6336
		20	50,000	0·2672
Inches to mile		40	25,000	2·5344
1	63,360			
6	10,560	100	10,000	6,336
25,344	2,500	200	5,000	12,672
50,688	1,250	400	2,500	25,344
		1,000	1,000	63,363

The railway company supplied 500 drawings to scale dimensioned in millimetres. Nineteen thousand workmen were engaged upon the work and there was not a single error due to the familiar measure. There need be no fear that use of the familiar dimensions of existing drawings will lead to mistakes where such drawings are used later on.

In regard to Ordnance maps, adoption of the "natural scale," that is, a scale that is a fraction of full size as in an ordinary drawing is obviously in favour—three out of our eight standard sizes are to natural scale. I have set out the present standards side by side with a regular series to natural scale with ratios 1, 2, 4, in units, tens, and hundreds, and one scale of the thousands series. This would include our present 15·782 miles to inch and our present 25,344 inch.

to miles; and, for our present 1″ and 6″ maps, would give us scales equivalent to a little over $1\frac{1}{4}$″ and $6\frac{1}{4}$″ to the mile respectively. The vast improvement presented by the latter series of scales ten years after adoption, when few maps of the present scales would exist, is, I think, self-evident.*

V. Influence on the Work of the Post Office Engineer.

When I first thought of taking up this subject, I contemplated that this section would be of very considerable proportions. Two facts have materially qualified this idea. In the first place, I have been impressed that it is the general propaganda work that has been neglected rather than the engineering; and, in the second place, I feel that the Post Office engineer's characteristic work will be relatively little affected. The arguments for and against in regard to the bulk of his work are the same as for the work of other people engaged in business and accounting matters. Perhaps, for instance, we shall regret that a forty-eight hour week does not work quite so well into a decimal as into a duodecimal system of coinage, but there will be compensating facilities in such connection and advantages of other kinds.

Treatment of our special conditions lead naturally to emphasising of the fact that the compulsory adoption of the metric system contemplated in the Bill drafted by the Association of Chambers of Commerce is restricted to commercial transactions and provides that "nothing in this Act shall affect the manufacture or use of any machinery, tool pattern, sieve, template, or other article made by measures other than metric measures," that is to say, that while in all transactions where measures are the basis of the *charges*, such measures must be expressed metrically, other measures and dimensions convenient for manufacturing purposes can be altered or not, as the makers or users may decide. Thus, for instance, although we should have to buy copper-wire by tonne and kilogram, we could continue to describe it as "100 lb. per mile" as long as we liked, and still be acting legally.

I think that in some things we should be bound to find it convenient to retain both systems current for some considerable time, and that this would cause little or no confusion. This necessity would no doubt apply particularly to standard mileage and similar records. On the other hand, the change would present a useful opportunity for reviewing some of our practice, such as the standard sizes of wire.

In other cases we should print both systems side by side during the transition stage.

* The Director-General of Ordnance Surveys advises me that it would take twenty years to effect a complete change economically.

Taking as an easy example Table I of our "Technical Instructions on Aerial Lines—where, at present, our pole lengths advance by steps of 2 to 40 ft., and then by 5 to 85 ft.—we could go from 5 to 12 metres, by 1 metre and then by 1½ to 25½ metres, the mnemonic being almost as simple.

TABLE I.—*Length of Poles.*

Standard length.	Equivalent.	Previous standard.
Metres.	Feet.	Feet.
5	16·40	16
		18
6	19·68	20
7	22·97	
		24
8	26·25	26
		28
9	29·53	30
		32
10	32·81	34
11	36·09	36
		38
12	39·37	40
13½	44·29	45
15	49·21	50
16½	54·13	55
18	59·06	60
19½	63·98	65
21	68·90	70
22½	73·82	75
24	78·74	80
25½	83·66	85

Similarly, where joinery or such-like approximate dimensions were concerned, tables showing inches and usual fractions, with actual and nominal equivalents in millimetres, would facilitate the easy transition from one to the other. This is set out in the table on the following page.

So, too, other dimensions would be converted to round numbers —heights of wires, for example:

Minimum height of wire above ground surface—
(12 ft.) 3½ metres = 11·48 ft.

Road and railway crossing—
minimum (20 ft.) 6 metres = 19·68 ft.
normal (22 ft.) 7 ,, = 22·97 ft.

Trolley crossing—
(28 ft.) 8½ metres = 27·89 ft.

Again, for strength of materials:

1 ton is practically equivalent to 1000 kilograms.
1 cwt. ,, ,, 50 ,,

There are also other approximations between the two systems that would be useful if memorised:

1 kilometre	=	about	$\frac{5}{8}$ mile.
1 metre	=	,,	$1\frac{1}{10}$ yd.
1 centimetre	=	,,	$\frac{2}{5}$,,
1 millimetre	=	,,	$\frac{1}{25}$,,

Equivalent Dimensions for Conversion from Inches to Millimetres (Actual and Nominal).

Inches.	Equivalent in millimetres.		
	Actual.	Nominal.	
			Alternative.
			5
$\frac{1}{4}$	6·35	$6\frac{1}{4}$	
			10
$\frac{1}{2}$	12·70	$12\frac{1}{2}$	
			15
$\frac{3}{4}$	19·05	$18\frac{3}{4}$	
			20
1	25·4	25	
2	50·8	50	
3	76·2	75	
4	101·6	100	
5	127·0	125	
6	152·4	150	
7	177·8	175	
8	203·2	200	
9	228·6	225	
10	254·0	254	
11	279·4	275	
12	304·8	300	

NOTE.—Alternative quarters of inch: Adopt next higher or next lower multiple of 5 as may be convenient.

Also

1 sq. metre	=	,,	$1\frac{1}{5}$ sq. yd.
1 litre	=	,,	$1\frac{3}{4}$ pints.
1 kilogram	=	,,	$2\frac{1}{5}$ lb.

Poles per Mile compared with Poles per Kilometre.

Per mile.			Per kilometre.		
No.	Span.	Nominal span.	No.	Nominal span.	Actual in yard.
	Yards.	Yards.		Metres.	Yards.
			14	70	78
22	80	80	15	66	73
24	73·3	73	16	62	68
25	70	70	17	59	64
28	62·8	63	18	56	60
30	58·7	60	19	53	57
33	53·3	53	20	50	55

VI. Compulsion.

I fancy our constitutional objection to anything that smacks of limitation of our personal freedom is at the bottom of much of the opposition to the introduction of the metric system. We have been legally free to use the system for twenty years.

We are asked: "If it is so good as the Decimal Association says, why have not some of the advocates themselves adopted it in all that time?" Surely no fair-minded opponent of normal intelligence can be excused for asking such a question. Take even such a huge and influential undertaking as the Post Office. Assume that it decides to adopt the metric system (as it has already been obliged to do in regard to international mails). It promulgates its new postal rates, and immediately all people concerned in sending parcels or letters that need weighing must get metric weights and a metre measure for one use only. This results in great inconvenience and appreciable expense to the public, and no conceivable benefit to the Post Office. But wait—these parcels, etc., that have been weighed at the counter by metric weights must be weighed to the railway carriers by British weights, and even if this could be avoided, there would have to be some adjustment of the sort at some stage of accounting.

But, even so, although some compromise with the railway companies might be possible in regard to mails, it would not be applicable (say) to engineering stores. Therefore, the transactions handled and expressed by the Stores Department in metric measures would have to be expressed also in English measures in respect of all freight charges.

So it is demonstrable that the Legislature in putting a permissive Act on the Statute Book drafted what was practically essentially a dead letter. The interactions of modern life render it impossible to secure any considerable reform on permissive terms—it is not practicable for one or more districts, for one or more trades, or for one or more utilities or administrations to adopt *any* reform in weights and measures unless and until the whole community is compelled to do so.

But for the war we should probably have waited for years for Daylight Saving, in deference to the fool-logic that: "If people want to get up an hour earlier in summer, let them, without altering our clocks to pretend that it isn't an hour earlier."

The war has opened our eyes to many things—there is no room for doubt that if our weights and measures are ever to be reformed NOW is the best time that ever has been, or ever will be. Not that delay will by any possibility prevent the reform—it can only postpone it to a less convenient season. The concensus of the opinion of all the high authorities in commerce to which I have referred compel one to the conclusion that the best interests of the community demand early compulsory adoption of the metric system by the British Government.

VII. Decimal Coinage.

Since some authorities advocate a decimal system of coinage as a step to the introduction of the metric system, while others urge adoption of the metric system as a step towards decimal coinage, and as in both cases the advocates ask for first turn, I think the logical outcome should be simultaneous adoption of both. This would slightly increase the inconvenience of the transition stage, but it would give us one transition stage instead of two.

Last year the Institute of Bankers adopted the report of a Special Committee, which formulated a clear scheme of decimal coinage. Adhesion to this scheme was later on notified by the Associated Chambers of Commerce and by the Decimal Associations. It provides for the present £ as the unit, the florin as £$\frac{1}{10}$, and the *mil* as the smallest sub-unit.

The complete schedule of coins is as follows :

	Coins.	Value in £	Value in mils.	Value in present currency.
Gold (or notes)	**Sovereign**	**1·000**	**1000**	20*s*.
	Half-sovereign	·500	500	10*s*.
Silver	Double florin	·200	200	4*s*.
	Florin	**·100**	**100**	2*s*.
	Half-florin	·050	50	1*s*.
	Quarter-florin	·025	25	6*d*.
Nickel (with scalloped edge)	**10-mil piece**	**·010**	**10**	2·4d.
	5 „ „	·005	5	1·2*d*.
Bronze	4-mil piece	·004	4	·96*d*.
	3 „ „	·003	3	·72*d*.
	2 „ „	·002	2	·48*d*.
	1-mil piece	**.001**	**1**	·24*d*.

The advantages of this scheme are well expressed in a short pamphlet issued by the Decimal Association :

> "The £ sterling is universally recognised in the settlement of international transactions throughout the world and any abandonment, even in name only, of its use as our standard monetary unit would be a voluntary surrender of its acknowledged international goodwill.
>
> "The advantage of this choice is, moreover, confirmed by the two facts that whereas on the one hand the war has made it all the more necessary for us to maintain the integrity of our £ sterling it has equally, on the other hand, demonstrated the failure of our penny coinage to meet fluctuations in currency values and necessary changes in the prices of small articles and services.

"By way of illustrating the latter point it will be noted that while the *cost* of many daily necessaries may have been increased by, say 20 per cent., it has been necessary to raise the *prices* of halfpenny goods and services by 100 per cent. to a penny, and of the penny ones by 50 per cent. to three halfpence, *because of our lack of coins to represent intermediate values.* The rare use of the farthing coin shows that it does not meet the practical requirements in this direction. THE UNSUITABLY STEEP GRADING OF OUR PRESENT COINS HAS, IN FACT, PROVED A SOURCE OF HARDSHIP, ESPECIALLY TO THOSE WHO ARE OBLIGED TO PURCHASE FOOD AND OTHER DAILY NECESSARIES IN SMALL QUANTITIES, and the proposed 'mil' coinage referred to would therefore fulfil the demand for a system of coinage which would facilitate the adjustment of prices for goods or services in finely-graded steps to correspond more closely with fluctuations in cost."

We could never get odd farthing prices—a $\frac{3}{4}$*d.* evening paper for instance—without farthings; but under this ingenious scheme we could have odd mils without ever needing a mil coin, and even a 3 mil newspaper would be practicable.

Notwithstanding this enlarged range of low-value coins the *total* number of different coins minted would be the same as at present.

(*b*) *Imperial Coinage.*—Internationalisation of coinage is neither feasible nor desirable, but uniformity of coinage in the British Empire is probably both feasible and desirable. Silver and lower value coins should be legal tender only in the country of issue, and gold coins should be current throughout the Empire. In my paper before the Institution of Electrical Engineers, I suggested that the present *sovereign* might well be re-named the "Imperial" on its general adoption—an impressive symbol of Imperial unity.

VIII. When shall Great Britain lead?

I should like to reply "Now," but such an answer is necessarily qualified by several considerations.

Unless the present Government felt that it had some kind of "mandate" it would probably feel unable to carry through such a change. It should, however, be able to appoint an Imperial Commission with representatives of all the principal Colonies and Dependencies, with instructions to report at once.

If the report were favourable, that should be mandate enough.

Then there would be needed time for manufacture of weights and measures; design and production of conversion tables for issue to all the various classes of traders; the revision of scales of charges, freight tables, etc.; and the (comparatively simple) provision of a scheme of working the revised currency. The smoothness with which the great change could be effected would be largely dependent upon the level-headedness and prevision with which the mass of detail preparatory to the change was handled. But it could be done and done for all time.

Why not do it now?

Since it was first seriously considered, we have not only renewed footrules and scales, templates, jigs, gauges, and weighbridges—we have rebuilt stores and factories, works and railway stations; we have re-equipped them "lock, stock, and barrel" time after time; and in that same time, we have wasted and cheerfully paid for literally millions of years of school-boy life in learning and practising the great English system of weights and measures.

The German Empire provided for, and carried through, the adoption of the French system at the victorious end of their war against the French; let us prepare NOW to adopt the same system of our gallant Allies at the victorious end of our great war against the Germans.

APPENDIX.

CHRONOLOGY.

(Abridged from the 'Electrical Review.')

1824. On discussion of decimal coinage in the House of Commons a "pound and mil" system was recommended.

1841. After the destruction by fire of the Houses of Parliament, the Commission for the Restoration of the Standards of Weights and Measures reported in favour of the decimal system.

1843.
1853. } Further favourable reports.

1859. A Select Committee of the House reported against a change in the coinage pending reform of the weights and measures.

1862. A Select Committee reported in favour of the adoption of the metric system.

1892. The Conference of the Chambers of Commerce of the Empire resolved that introduction of the decimal system was urgently needed. (Similar resolutions were passed also in 1900, 1903, and 1912.)

1893. Trades Union Congress advocated the reform.

1897. Metric system made legal, but the enactment did not provide for any compulsion.

1902. Sixty municipalities petitioned for the adoption of the metric system throughout the Empire. Two hundred and ninety-two Members of Parliament expressed their approval. Adoption was urged by the Imperial Conference.

1902. 1903. 1904. The Associated Chambers of Commerce and the Association of Trade Protection Societies advocated compulsory introduction of the metric system and of decimal coinage.

1903. The Council of the Institute of Chartered Accountants passed a Resolution in a similar sense.

1904. The General Medical Council resolved that the metric system should be the only legal system for use in dispensing drugs. The Chambers of Commerce of Australia urged that the British Government should adopt the metric system.

Second reading of a Bill for the purpose passed the House of Lords.

1907. The House of Commons rejected, by the narrow majority of 32, a Bill providing for the compulsory introduction of the metric system.

1910. The Australian House of Representatives, by 35 votes for and 2 against, resolved that the metric system be adopted as soon as it became compulsory in Great Britain.

1914. The metric carat became the only legal standard for the weighing of gems, etc.

Barometer readings recorded in units of pressure founded on the metre-gramme-second system. Rainfall recorded in millimetres.

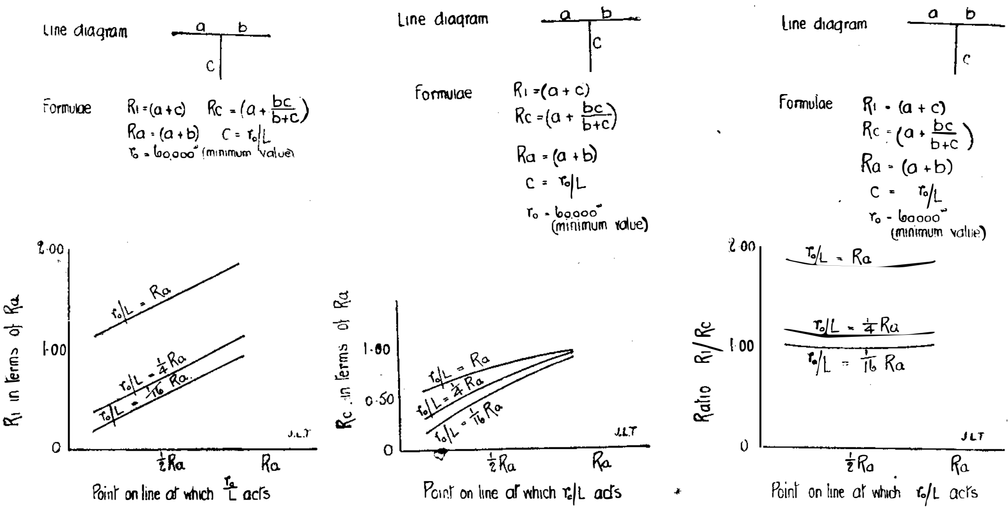
In the new edition of the ' British Pharmacopœia ' weights and measures are given in the metric system " in the expectation that in the near future the system will be generally adopted by British prescribers."

At each Centre, after reading and discussion of the Paper, the following Resolution was unanimously adopted :

" That this Meeting of this Centre of the Institution of Post Office Electrical Engineers views with favour the compulsory adoption of the metric weights and measures and a decimal coinage in this country after a suitable time to prepare for the change, and urges the Council of the Institution to identify itself with the Decimal Association in urging this important and necessary reform."

OVERHEAD TELEGRAPHS: THE LEAKAGE CONDUCTANCE THEORY.

IN the issue of July, 1917, of this JOURNAL the writer arrived at formulæ representing limiting line mileages for different types of telegraph circuits by assuming uniformly distributed leakage, in order that the insulation resistance might be regarded as a resultant earth fault at the centre of the line resistance. The following notes are intended to supplement those in the previous article, and the schedules and figures have been numbered consecutively with those in the notes referred to.



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Two questions will doubtless have occurred to many readers, viz.:

(1) What effect has leakage upon the line constants when the weather losses are not uniformly distributed, and

(2) To what extent can the leakage conductance theory be made applicable to overhead lines the lengths of which fall well within the limiting distances imposed by the formulæ, and also to conditions other than those obtaining in this country?

Although no complete statement can readily be given of the actual changes that occur in an overhead telegraph line, some idea of the effects of non-uniformly distributed leakage can be obtained by assuming values for different leakage paths, and by working out the figures for each leakage path when the latter is acting at different distances from the sending end.

In **9** is shown how the measured insulation resistance (R_1) varies with the point on the line at which the leakage path is acting. **10** indicates the corresponding variation of the measured conductor resistance (Rc). In **11** the ratio R_1 Rc is shown, and it will be observed that although both R_1 and Rc may fall to a very low value, the ratio of R_1 to Rc remains, for all practical purposes, constant.

Algebraically this may be expressed in the following form :

$$R_1 = (a + c)$$

$$Rc = \left(a + \frac{bc}{b + c}\right)$$

$$\frac{R_1}{Rc} = \frac{\frac{ab}{c} + c + Ra}{\frac{ab}{c} + Ra}.$$

From this it will be clear that R_1 cannot be less than Rc, and also that when c = infinity, R_1 will be infinity and Rc will equal Ra.

Working out from the formula the values of the ratios for different values of the leakage resistance path (c), the results shown on Schedule 8 are obtained.

SCHEDULE 8.

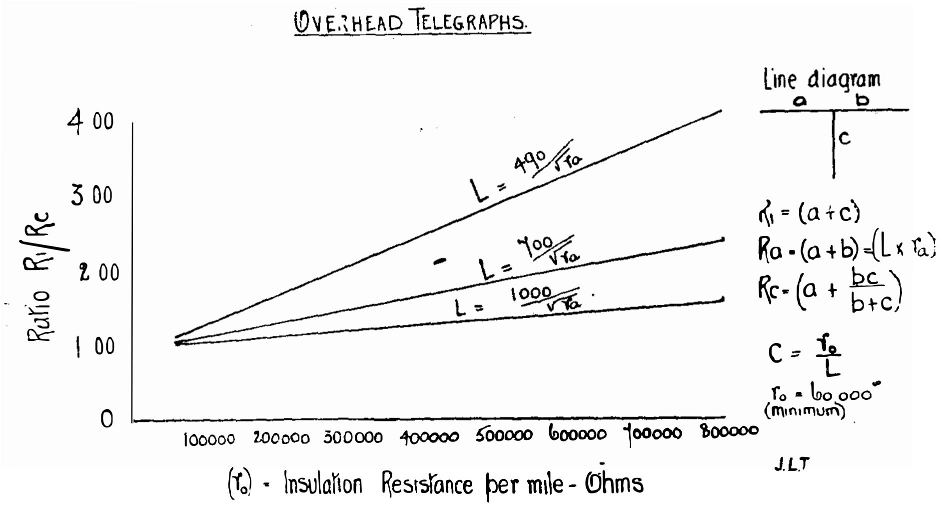
Showing the Values of the Ratios obtained from the Formula :

$$\frac{R_1}{Rc} = \frac{\frac{ab}{c} + c + Ra}{\frac{ab}{c} + Ra}.$$

Values of a	b	c	Ratio R_1/Rc.
$\frac{1}{4}$ Ra	$\frac{3}{4}$ Ra	$\frac{1}{16}$ Ra	1·015
$\frac{1}{2}$,,	$\frac{1}{2}$,,	,,	1·012
$\frac{3}{4}$,,	$\frac{1}{4}$,,	,,	1·015
$\frac{1}{4}$,,	$\frac{3}{4}$,,	$\frac{1}{8}$ Ra	1·05
$\frac{1}{2}$,,	$\frac{1}{2}$,,	,,	1·04
$\frac{3}{4}$,,	$\frac{1}{4}$,,	,,	1·05
$\frac{1}{4}$,,	$\frac{3}{4}$,,	$\frac{1}{4}$ Ra	1·142
$\frac{1}{2}$,,	$\frac{1}{2}$,,	,,	1·125
$\frac{3}{4}$,,	$\frac{1}{4}$,,	,,	1·142
$\frac{1}{4}$,,	$\frac{3}{4}$,,	Ra	1·84
$\frac{1}{2}$,,	$\frac{1}{2}$,,	,,	1·80
$\frac{3}{4}$,,	$\frac{1}{4}$,,	,,	1·84
$\frac{1}{4}$,,	$\frac{3}{4}$,,	2 Ra	2·82
$\frac{1}{2}$,,	$\frac{1}{2}$,,	,,	2·77
$\frac{3}{4}$,,	$\frac{1}{4}$,,	,,	2·82
$\frac{1}{4}$,,	$\frac{3}{4}$,,	3 Ra	3·804
$\frac{1}{2}$,,	$\frac{1}{2}$,,	,,	3·769
$\frac{3}{4}$,,	$\frac{1}{4}$,,	,,	3·804

The formula for fast-speed telegraphs (viz. $L = 700 | \sqrt{r_a}$) is based on a minimum value of $r \mid L = \frac{1}{8}Ra$. Hence the inference to be drawn from Schedule 8 is that, when the ratio $\frac{R_1}{Rc}$ falls below the value of 1·04, fast-speed telegraphy will be carried on with difficulty. The same reasoning applies to the other formulæ.

In order, therefore, to arrive at the working value of any given aerial line, it is only necessary to make from one end two tests of the whole length of the wire—that is, an insulation resistance test giving the reading R_1, and a conductor resistance test giving the reading Rc. If the tests follow each other in rapid succession, it is unlikely



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that the line conditions will have changed to such an extent as to render the result valueless.

In **12** is shown the relationship between the insulation resistance per mile (r_0) and the ratio $R_1 | Rc$ for the three cases of

(1) $L = 490 | \sqrt{r_a}$; (2) $L = 700 | \sqrt{r_a}$; and (3) $L = 1000 | \sqrt{r_a}$.

It should be noticed that the resistance of the leakage path decreases as the length (L) of the circuit increases, and, from Schedule 8, it will be apparent that the ratio $R_1 | Rc$ increases as the value of the leakage path resistance increases. This, taken in conjunction with the fact that the various formulæ are based on different minimum values of the ratio $R_1 | Rc$ when the value of the insulation resistance per mile (r_0) has fallen to a fixed minimum, will explain the disparity between the rise in the ratio $R_1 | Rc$ for the different formulæ (**12**).

Another point arises in this connection. Consider Schedule 9.

Schedule 9.

r_a (ohms)	26·6	13·3	8·78	5·85
$L = 700 \mid \sqrt{r_a}$ miles	136	191	236	290
Ra ohms	3617	2541	2072	1697
200,000 | L ohms	1470	1047	847	689
Rc ohms	2619	1844	1502	1229
R_1	3278	2317	1883	1537
Ratio $R_1 \mid Rc$	1·251	1·256	1·253	1·250

When the ratio equals 1·25 the wire has an insulation resistance represented by the maintenance standard of 200,000 ohms per mile.

Ratios obtained by this means are shown for different formulæ in Schedule 10.

The value $L \times Ra$, shown in column 3, may be regarded as the real limiting factor for overhead telegraphs, since the KR law is not applicable.

$L \times Ra$ is derived as follows:

$$L = \frac{X}{\sqrt{r_a}} \text{ squaring both sides}$$

$$\therefore \ X^2 = L \times Ra.$$

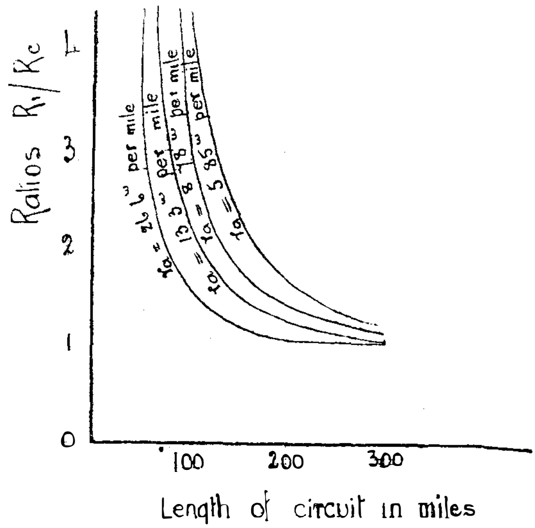
Schedule 10.

Values of $R_1 \mid Rc$ *for Different Formula and also* $L \times Ra$ *Values.*

Formulæ.	Type of circuit.	$L \times Ra$ value.	Ratio $R_1 \mid Rc$. Minimum value.	Ratio $R_1 \mid Rc$. Maintenance standard.
$L = \frac{1000}{\sqrt{r_a}}$	Key D.C. Morse	1,000,000	1·01	1·088
$L = \frac{700}{\sqrt{r_a}}$	Fast-speed telegraphs	490,000	1·04	1·250
$L = \frac{490}{\sqrt{r_a}}$	Quadruplex with 40 and 120 volts	240,000	1·125	1·640
$L = \frac{316}{\sqrt{r_a}}$	C.B.S. special head-office sets	99,856	1·33	2·770
$L = \frac{223}{\sqrt{r_a}}$	C.B.S. ordinary H.O. sets (*a*) Quadruplex 24 and 80 volts (*b*) C.B.X. with relay at out-office (*c*)	49,729	1·8	4·820
$L = \frac{141}{\sqrt{r_a}}$	C.B.X. with polarised sounder at out-office	19,881	3·10	11·070

In order that a fast-speed telegraph circuit may work satisfactorily, the ratio R_1 Rc should not fall below the value of 1·04. At the maintenance standard the ratio will be 1·25, provided the length L of the wire is equal to $700 \sqrt{r_a}$. From **13** it will be seen that a 200 lb. galvanised iron wire of 100 miles in length will give a ratio of 1·6 at the maintenance standard; a wire 400 lb. G.I. will show a ratio of 2·25 under the same conditions, whilst the corresponding ratios for 100 and 150 lb. copper are approximately 3 and 4 respectively.

For wires that have a length less than that obtained from the relevant formula, therefore, less difficulty will be experienced in maintaining good working conditions than in the case of lines that approximate to the limiting mileages. The value of the maintenance standard, in teams of the ratio R_1/Rc, obtained from the formula for the particular type of circuit under consideration, as shown in Schedule 8, would seem to provide a uniform standard of maintenance.



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The question of the terminal resistances at the end of an overhead telegraph wire and the effect on the received current can, perhaps, best be considered by taking the formula for fast-speed telegraphs, viz. $L = 700\sqrt{r_a}$, and ascertaining the effect of adding resistance at each end of the aerial wire. Apart from the terminal resistances the algebraic expression representing the received current is:

$$Cr = \frac{E}{a + \frac{bc}{b + c}} \times \frac{c}{b + c}.$$

Where Cr, E, a b, and c have the significance already assigned to them,

$$\text{multiplying out } Cr = \frac{E}{\frac{ab}{c} + Ra.}$$

Clearly when $c =$ infinity $\frac{ab}{c} = o$ and $Cr = \frac{E}{Ra} =$ the perfect current ($Cp.$); also when $a = b$ the value of Cr is a minimum.

With the use of a 400-lb. G.I. wire the length of underground at each end may be as much as 35 miles before the KR value of the circuit approaches such a figure as will result in the line speed being less than the apparatus speed, and until this limiting value of the KR is reached the sum of the resistances of the underground and the apparatus may be regarded, for the purpose of calculation, as resistances, since the leakage of paper-core cable does not appreciably affect the value of the received current.

Call the terminal resistances r_1 and r_2 and let it be assumed that r_1 and r_2 are each equal to the value of the leakage path resistance (c) when the latter has reached the minimum value of $60{,}000 | L$, then:

$$\text{the current } C = \frac{E}{c + a + \frac{c(b + c)}{2c + b}}$$

$$= \frac{E\,(2c + b)}{3c^2 + 2ac + 2bc + ab}$$

and the received current

$$Cr = \frac{E\,(2c + b)}{3c^2 + 2ac + 2bc + ab} \times \frac{c}{(2c + b)}$$

$$= \frac{E}{\frac{3c^2 + ab}{c} + 2Ra.}$$

When $L = 700\sqrt{r_a}$ the value of $c = \frac{1}{8}Ra$. Substituting this value in the equation gives:

$$Cr = \frac{E}{4{\cdot}375Ra} \text{ when } a = b.$$

When $r_1 = r_2 = 2c$ the formula for the received current becomes:

$$Cr = \frac{E}{\frac{8c^2 + ab}{c} + 3Ra}$$

and with $c = \frac{1}{8}Ra$ this reduces to—

$$Cr = \frac{E}{6Ra}.$$

Working out values for $r_1 = r_2 = 3c$ and $r_1 = r_2 = 4c$ and tabulating, gives the results shown in Schedule 11.

It has already been shown that, apart from terminal resistances, the value of the minimum received current on an aerial telegraph wire is one-third the perfect current when the resistance of the leakage path is equal to $\frac{1}{8}Ra$. On Schedule 12 is shown the effect

SCHEDULE II.

Showing the Effect on the Received Current of Adding Terminal Resistances to an Overhead Telegraph Wire of Length L $= 700 / \sqrt{r_a}$ *Miles.*

Value of leakage path resistance (c).	Value of terminal resistances $r_1 = r_2$.	Value of minimum received current Cr.	Ratio of min. received current to perfect current Cr / Cp.
$\frac{1}{8}Ra$	c	$\frac{E}{4{\cdot}375Ra}$	0·228
,,	$2c$	$\frac{E}{6Ra}$	0·166
,,	$3c$	$\frac{E}{7{\cdot}88Ra}$	0·126
,,	$4c$	$\frac{E}{10Ra}$	0·100

of adding to the overhead wire terminal resistances, each of which is equal to $2c$ (*i. e.* $\frac{1}{4}Ra$).

It has been assumed that Wheatstone apparatus is in use and that the terminal resistances at each end are the same.

From columns 1 and 2 it will be seen the speed obtained with good insulation conditions is determined by the KR value of the circuit, whilst the speed with minimum insulation depends upon the value of the received current. In the cases shown under columns 3 and 4 the line speeds are greater than the apparatus speeds under good insulation conditions, but a reduction of speed is necessary when the received current falls below 17 ma. The maximum speed of the Wheatstone apparatus has been taken as 300 words per minute. In practice it is found that the traffic requirements are satisfied with a maximum speed of 200 words per minute. Further, where the Wheatstone receiver is joined up to the locals of a relay standard G or B, the fast-speed formula will also require slight modification; and the following are offered tentatively as approximations appropriate to these conditions:

(*a*) Wheatstone receiver on locals of relay standard B: Limiting distance miles, $L = 818 / \sqrt{r_a}$. Ratio $R_1 / Rc = 1{\cdot}024$; Ratio $Cr / Cp = 0{\cdot}263$.

(*b*) Wheatstone receiver on locals of relay standard G: Limiting distance miles, $L = 916 / \sqrt{r_a}$. Ratio $R_1 / Rc = 1{\cdot}013$; Ratio $Cr / Cp = 2 / 9$.

(*c*) Wheatstone receiver direct on line: $L = 734 / \sqrt{r_a}$. Ratio $R_1 / Rc = 1{\cdot}035$; ratio $Cr / Cp = 0{\cdot}3$.

These values may require modification with experience.

SCHEDULE 12.

Showing the Effect of adding Terminal Resistances each equal to (2c) (*where* c *equals the Minimum Resistance of the Leakage Path*) *on Overhead Lines within the Mileage Limits imposed by the Formula* $L = 700\sqrt{r_a}$.

	(1)	(2)	(3)	(4)
Conductor resistance per mile r_a ohms	26·6	13·3	8·78	5·85
Length L miles $= 700 \div \sqrt{r_a}$	136	191	236	290
Calculated conductor res. $Ra = L \times r_a$	3617	2541	2072	1697
Resistance of leakage path $c = 60000 \div L$	440	314	254	207
Value of $2c$	880	628	508	414
$(2c - 250^{\omega})$ (250^{ω} = apparatus resistance)	630	370	258	164
Equivalent of $(2c - 250^{\omega})$ in miles of 100 C. Cable	70	41	28	18
Total length of aerial plus underground	276	273	292	326
K.R. value of line	78032	36091	23654	16000
Total resistance of circuit	5377	3797	3088	2525
E.M.F. volts	120	120	120	120
Perfect current ma.	22·3	31·5	38·8	47·5
Minimum received current ma.	3·7	5·23	6·4	7·8
Approx. words per minute with Wheatstone working with perfect insulation	115	250	300	300
Approx. words per minute with Wheatstone working with $r_0 = 60000^{\omega}$	25	78	120	150

The "received" and "sent" current values for different conditions of overhead lines are shown in **14**. It will be observed that when the resultant leakage path is acting at a point close up to the sending end, the value of the "sent" current will be high. If, in addition to this condition, the circuit arrangement is such that the terminal resistance at the receiving end is large as compared with that at the sending end, the circuit will be unsymmetrical. Two examples will make this clear:

(1) Let the terminal resistance at the sending end $r_1 = 300^{\omega}$.
Terminal resistance at the receiving end $r_2 = 300^{\omega}$;

$a = b = 900^{\omega}$; length miles $L = 200$;

$r = 9^{\omega}$ per mile.

The minimum value of the resultant leakage path

$$\frac{r_a}{L} = \frac{60000}{200} = 300^{\omega}.$$

The measured conductor resistance Rc including the terminal resistances

$$Rc = r_1 + a + \frac{c(b + r_2)}{b + r_2 + c} = 1200 + \frac{1200 \times 300}{1500} = 1440^{\omega}.$$

With E.M.F. = 80 volts the sent current

$$Cs = \frac{80}{1440} = 55{\cdot}5 \text{ ma}.$$

(2) If a length of underground wire having a resistance of 700^{ω} be

added at the receiving end, and if the leakage path is acting at a point on the line represented by a distance from the sending end equivalent to $\frac{1}{18}Ra$, the value of Rc will be

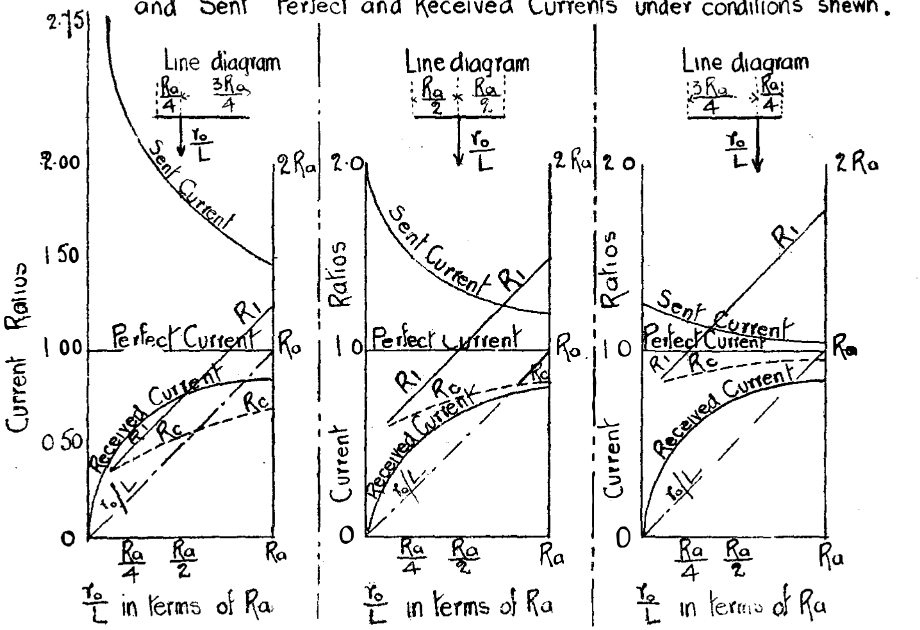
$$Rc = 400 + \frac{300 + 2700}{3000} = 670^{\omega}$$

and the sent current will be 119·4 ma.

In the event of a partial earth fault the high value of the sent current will be further accentuated. Hence a circuit symmetrically arranged is preferable.

In the great majority of cases that arise in practice the mileage

Graphs showing the relations existing between Measured Insulation Resistance (Ri), Measured Conductor Resistance (Rc), Calculated Conductor Resistance (Ra) and "Sent" "Perfect" and "Received" Currents under conditions shewn.



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length will fall well within the limits imposed by the relevant formula. For double current morse working the circuit value of any aerial wire can readily be arrived at by dividing the minimum value of r_0 (viz. $60{,}000^{\omega}$) by the length L in miles. If the figure obtained in this way is not less than $\frac{1}{4}Ra$, then the minimum received current will be not less than 0·49 of the "perfect" current. For ordinary key working, therefore, the usual practice of providing a perfect current of 15 ma. will be ample to meet such cases, whilst 30 ma. will provide for fast-speed working.

When more definite figures are required, it is a simple matter to arrive at the ratio of the minimum "received" current to the "sent" current. For example, let the terminal resistances $r_1 = r_2 = 400^\omega$ and let $a = b = 600$, also $L = 200$ miles.

$$\text{The value } \frac{r_0}{L} = \frac{60000}{200} = 300^\omega.$$

$$\text{Perfect current } Cp = \frac{E}{2000}.$$

$$\left.\begin{array}{l}\text{Sent current } Cs \text{ when} \\ r_0 = 60{,}000^\omega\end{array}\right\} = \frac{E}{1000 + \frac{300 \times 1000}{1300}} = \frac{E}{1230}.$$

$$\left.\begin{array}{l}\text{Received current } Cr \\ \text{when } r_0 = 60{,}000^\omega\end{array}\right\} = \frac{E}{1230} \times \frac{300}{1300} = \frac{E}{5330}.$$

$$\text{Ratio } \frac{Cr}{Cp} = \frac{E}{5330} \times \frac{2000}{E} = 0{\cdot}37.$$

Hence $Cr = 0{\cdot}37\ Cp$.

If key working only is required, the perfect current $Cp = \frac{8 \text{ ma.}}{0{\cdot}37}$ $= 22$ ma. with a minimum received current of 8 ma. and the E.M.F. $= CR = 0{\cdot}022 \times 2000 = 44$ volts.

For Wheatstone working at 300 wpm. $Cp = \frac{17}{0{\cdot}37} = 46$ ma. and E.M.F. $= CR = 0{\cdot}046 \times 2000 = 92$ volts.

In the case of telegraph circuits superposed on telephone trunks the conditions are somewhat different. Considering each wire separately, the minimum value of the leakage path will be $60{,}000/L$. Hence the resistance of the derived leakage circuit on the telephone loop will be $2 \times 60{,}000/L = 120{,}000/L$. With a telegraph circuit superposed on such a loop the minimum value of the leakage path resistance will be $60{,}000/2L$. The effect of leakage on the superposed telegraph circuit is therefore four times that on the telephone loop, ignoring for the moment the question of the relationship between leakance and frequency. So far as the superposed telegraph circuit is concerned, if Ra be the resistance of each wire of the loop, then $\frac{1}{2}Ra$ will represent the joint resistance of the two wires. Hence the joint resistance to a point represented by $\frac{1}{2}L$ will be $\frac{1}{4}Ra$. The standard arrangement for superposing a telegraph circuit on a trunk telephone loop provides for the insertion of a coil resistance 1000^ω between the transformer and the telegraph apparatus, and the circuit may be regarded as one in which the terminal resistances r_1 and r_2 are 1300^ω, and the line resistance is equal to $(\frac{1}{4}Ra + \frac{1}{4}Ra)$. The value of $\frac{1}{4}Ra$ will be small as compared with that of the terminal resistances, and an approximation to the conditions may be arrived at by considering the circuit as two resistances of 1500^ω with an earthed leak of the value of $60{,}000/2L$.

When the length L of the loop is 60 miles, the resistance of the resultant leakage path will be $60{,}000/2L = 500^\omega$.

Therefore the value of $Rc = 1500 + \frac{500 \times 1500}{2000} = 1875^{\omega}$.

With an E.M.F. of 120 volts the sent current

$$Cs = \frac{120}{1875} = 64 \text{ ma.}$$

and the minimum received current

$$Cr = \frac{500}{2000} \times 64 = 16 \text{ ma.}$$

This will provide conditions which will permit of Wheatstone working at 300 words per minute. Each case can be worked out on the relevant data.

In connection with telegraph sets worked from telegraph lamp signalling concentrator switchboards it is occasionally necessary to join up double current Morse apparatus to universal connections, as shown in Circular E. 15, in order to form a D.C. omnibus circuit· The following notes mav prove of assistance in making calculations in order to provide for voltages and equalising resistances necessary in connection with this class of circuit. The resistance of the resultant leakage path of each spur or section of overhead wire is obtained by dividing 60,000 by the length L of the spur or section. If the value of the joint resistance of the several leakage resistance paths is as low as $\frac{1}{8}$ of the sum of the calculated conductor resistances of each spur or section, a current of 20 ma. per receiving office should be provided. The subsequent calculations of joint resistance values (which should include the apparatus and other terminal resistances) should be made on the assumption that the insulation resistance of the circuit is infinity. Where 20 ma. is allowed per receiving office the total current required will be equal to $20\,(N - 1)$ ma. where N is the number of offices on the D.C. omnibus circuit.

The balancing resistances should be joined up between the key and the relay in order that when the key switch is at "send" the added balancing resistance may be cut out of circuit. When there are three stations on a circuit the total current required will be 40 ma., and therefore the joint resistance of the circuit should not exceed $\frac{80}{0{\cdot}04} = 2000^{\omega}$. With a five-station circuit the maximum joint resistance will be $\frac{80}{0{\cdot}08} = 1000^{\omega}$. It will be apparent that where a number of offices radiate at the end of a long wire of high resistance it may not be possible to work the circuit as D.C. omnibus, and in this case other arrangements will be necessary.

On **15** is shown diagrammatically a typical case of a C.B.S. omnibus circuit. The head office set is connected at (h) and the out office sets at (e) and (g) respectively. The diagram shows the circuit when the value of r_0 is equal to $50{,}000^{\omega}$ and with no keys depressed. It has already been shown that a direct C.B.S. circuit will work satisfactorily provided the ratio R_1 Rc does not fall below 1·8. The value R_1 is obtained from the diagram as follows:

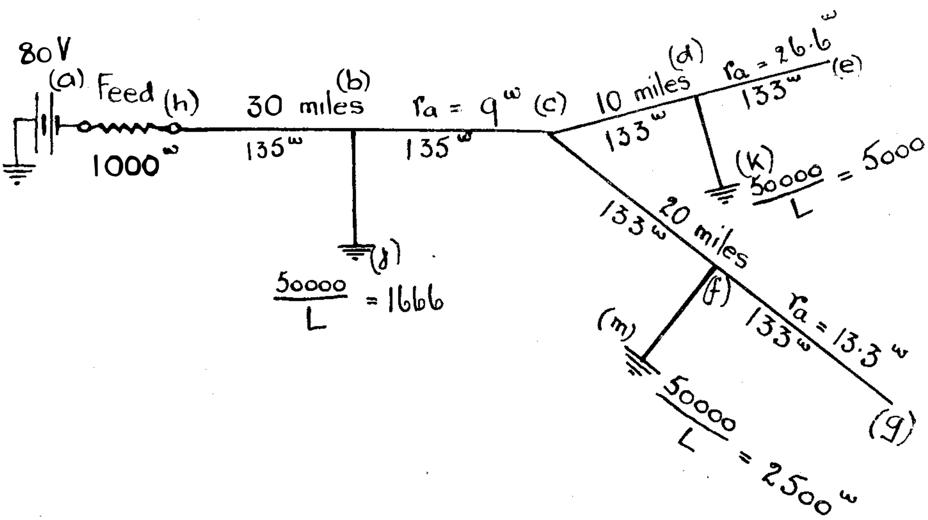
$$\text{Resistance path } (c) \text{ to } (k) = 133 + 5000 = 5133^{\omega}.$$

$$\text{,, \quad ,, } (c) \text{ to } (m) = 133 + 2500 = 2633^{\omega}.$$

$$\text{Joint resistance } \frac{(1740 + 135) \times 1666}{1740 + 135 + 1666} = 882^{\omega}.$$

$$\text{Therefore } R_1 = 882 + 135 = 1017^{\omega}.$$

There will be two values of Rc, viz.: (1) when station (e) earths the line by depressing the key, and (2) when (g) similarly puts the line to earth.



15.—C.B.S. Omnibus Circuit. A Typical Case.

(1) The first value of Rc when station (e) depresses key:

$$\text{Joint resistance } dk \text{ and } de = \frac{133 \times 5000}{5133} = 129^{\omega}.$$

$$\text{,, \quad ,, \quad } cm \text{ and } ce = \frac{262 \times 2633}{2895} = 238^{\omega}.$$

$$\text{,, \quad ,, \quad } bj \text{ and } bge = \frac{373 \times 1666}{2039} = 304^{\omega}.$$

$$\text{Therefore } Rc = 304^{\omega} + 135^{\omega} = 439^{\omega}.$$

Similarly the value of Rc when (g) earths the line is found to be 445^{ω}, and as this is the higher value the ratio for the circuit will be

$$\frac{R_1}{Rc} = \frac{1017}{445} = 2{\cdot}28.$$

This value is well above the minimum required.

When R_1 and Rc have been obtained the actual value of $(V_1 - V_2)$

the voltage drop at the head office condenser can readily be determined, since

$$V_1 = \frac{R_1}{f + R_1} \times V = \frac{1017}{1000 + 1017} \times 80 = 40{\cdot}3 \text{ volts,}$$

$$\text{and } V_2 = \frac{Rc}{f + Rc} \times V = \frac{445}{1445} \times 80 = 24{\cdot}6 \text{ volts.}$$

$$(V_1 - V_2) = (40{\cdot}3 - 24{\cdot}6) = 15{\cdot}7 \text{ volts.}$$

These calculations have been given with the object of indicating methods. It is evident that any form of C.B.S. circuit can be dealt with in a similar manner. A close approximation can, however, be obtained by the application of the formula $L = 223 \sqrt{r_a}$, thus:

The sum of the lengths of the overhead sections is $(30 + 20 + 10) = 60$ miles. The sum of the calculated conductor resistances of the different sections is $(270 + 266 + 266) = 802^{\omega}$. The mean value of (r_a) the conductor resistance per mile $= \frac{802}{60} = 13{\cdot}36^{\omega}$. The limiting distance for this value of r_a is given by the formula $L = 223 \sqrt{r_a}$ from which $L = 69$ miles. The circuit will therefore be workable when $r_o = 50{,}000^{\omega}$.

Another point to be taken into consideration in connection with C.B.S. omnibus circuits is the reception at the out offices when communicating with each other. From an inspection of the diagram it is evident that the line conditions might be such as to place one of the out offices in a worse position than the head office from the point of view of reception.

When (e) earths the line:

Joint resistance dk and de $\frac{133 \times 5000}{5133} = 129^{\omega}$.

" " Cm and Ce $\frac{(129 + 133) \times 2633}{2895} = 238^{\omega}$.

" " bj and bge $\frac{(238 + 135) \times 1666}{2039} = 304^{\omega}$.

Total joint resistance $Rc = 304 + 135 = 439^{\omega}$.

$$\text{Now, } V_1 = \frac{R_1}{f \times R_1} \times 80 = \frac{1017}{1000 + 1017} \times 80 = 40{\cdot}3 \text{ volts.}$$

Hence the voltages at the different points of the circuit will be as follows before (e) has depressed the key:

$$\text{Potential at } b = \frac{882}{135 + 882} \times 40{\cdot}3 = 34{\cdot}9 \text{ volts.}$$

$$\text{Potential at } c = \frac{1740}{135 + 1740} \times 34{\cdot}9 = 32{\cdot}3 \text{ volts.}$$

$$\text{Potential at } (f) = \frac{2500}{133 \times 2500} \times 32{\cdot}3 = 30{\cdot}6 \text{ volts.}$$

The apparatus at (g) is therefore normally charged to a potential of $30{\cdot}6$ volts.

When the key at (e) is down, the value of $Rc = 439^{\omega}$ and

$$V_2 = \frac{439}{1000 + 439} \times 80 = 24{\cdot}4 \text{ volts.}$$

The corresponding potentials at the different points of the circuit will be:

$$\text{Potential at } b = \frac{304}{135 + 304} \times 24{\cdot}4 = 16{\cdot}8 \text{ volts.}$$

$$\text{Potential at } c = \frac{238}{135 + 238} \times 16{\cdot}8 = 10{\cdot}7 \text{ volts.}$$

$$\text{Potential at } (f) = \frac{2500}{133 + 2500} \times 10{\cdot}7 = 10{\cdot}1 \text{ volts.}$$

The voltage drop at the apparatus at (g) when the key at (e) is depressed will therefore be $(30{\cdot}6 - 10{\cdot}1) = 20{\cdot}5$ volts.

J. L. T.

[*In our next issue, the writer will deal with the application of the theory to countries where the insulation resistance and consequent leakage vary from the values obtained at home.—Eds. 'Post Office Electrical Engineers' Journal.'*]

CABLE-LAYING IN IRELAND.

THE effects of coast erosion are very apparent in different parts of Ireland, and the efficient maintenance of the miles of railway track laid alongside the sea is a constant source of anxiety to the officers of the various companies and of expense to the shareholders. Retaining walls several feet in length and of very substantial dimensions have been erected in the hope of checking the ravages of the waves, but it has been necessary on different occasions to have recourse to the more drastic expedient of more or less extensive diversions. In many places, when traversing existing stretches of line, the locations of portions of previous routes are readily traceable, but there are large gaps at points where some more considerable inroads of the sea have taken place. A diversion which involved the building of 3¼ miles of double track was completed in October, 1915; and before this new length was opened for traffic, considerable progress had been made on another similar undertaking some distance further south. This latter work, which involved the laying of 1¾ miles of single track and the boring of 1100 yds. of tunnel was commenced in 1913, the new line being opened to traffic on December 17th of last year. The boring of the tunnel was a work of considerable magnitude owing to the rocky formation of the eminence through which the track was to be laid. The height of the tunnel is 17 ft., its width 16 ft., the distance bored through rock is 2100 ft.

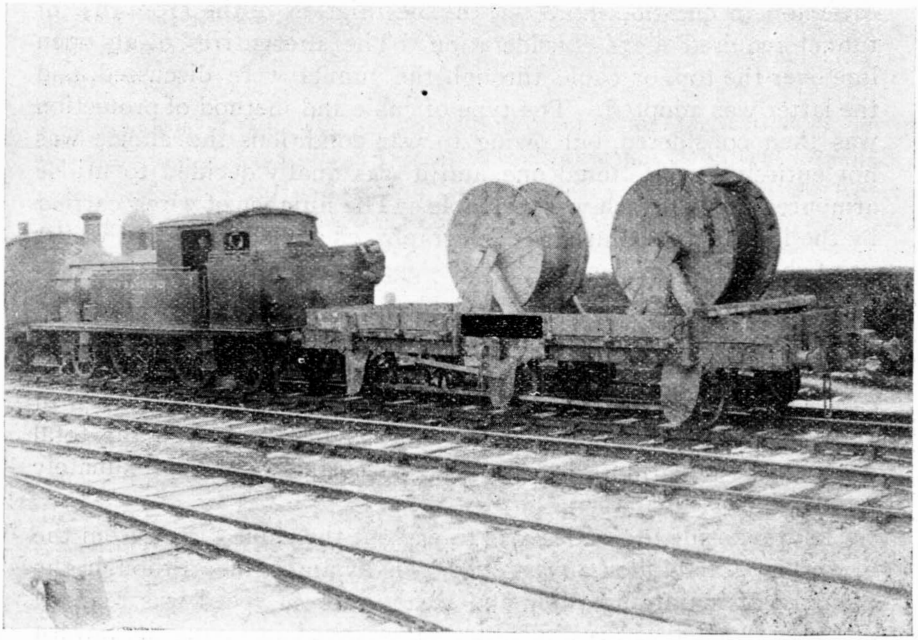
The diversion of a railway track in England has not any particular significance for an engineer of the Post Office, but in Ireland the conditions are otherwise. As my readers are aware, the Engineering Department is responsible in Ireland for the maintenance of the railway signalling apparatus, and in addition the main telegraph lines are erected alongside the systems of the various railway companies. This being so, a railway diversion and a telegraph diversion are coincident. The carrying out of a telegraph diversion does not usually present particular difficulty, as the building of an open line alongside a railway track is a more simple matter than a similar operation on roads in town and country. In the case of the diversion in question, however, the negotiation of the 1100 yds. of tunnel required more consideration. The alternatives of an open line over the top, or cable through the tunnel were discussed, and the latter was adopted. The type of cable and method of protection was then considered, but owing to war conditions the choice was not entirely an unfettered one, and it was finally decided to utilise armoured cable, which was available. The number of wires carried by the line at this point are: Telegraphs, 25; telephones, 6; whilst 12 of the former are long-distance telegraph circuits.

The type of cable provided is Cable P.C. 8/100 + 10/40, armoured with thirty steel wires. The use of two lengths of cables meets the working requirements and five conductors remain as spares. The cables were received on nine drums each containing an average of 270 yds., and as the weight of the cable is 12 lb. per yard the total weight of each drum when carrying the cable was approximately 2 tons.

It was decided to endeavour to pay out the cable direct from the drums mounted upon a waggon drawn by an engine, although the difficulty of maintaing a low and steady rate of speed was realised and a knowledge of the difficulties experienced in laying the Severn Bridge cable, as described in THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL for April, 1912, was not encouraging. The original intention was to utilise the standard type of cable-jack secured to ballast waggons, but it was finally considered, having regard to the weight of the drums and the special conditions which would attend the laying, that a more stable structure would be obtained by the use of strutted trestles bolted to a waggon (1). Only one ballast waggon (32 ft. long) was fitted with pairs of trestles, two in number, as it was not considered reasonable to request the railway company to specially equip a greater number, having regard to the small quantity of drums to be handled. The train employed consisted of (A) covered truck, (B) brake van, (C) engine, and (D) cable waggon, in the order named.

The availability of only one waggon, the rigid type of mounting, and the single pair of railway metals, made it impossible to arrange to pay out the whole of the cables in any one period when the track was free from traffic, either day or night. It was decided, therefore, to make five separate journeys at suitable times between trains during the day.

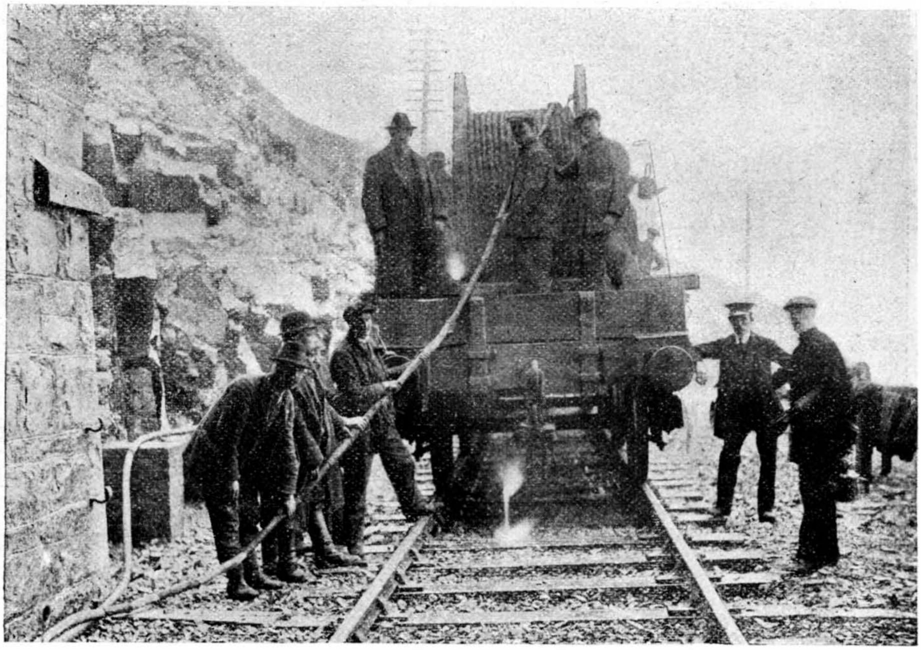
The first trip was arranged for Tuesday, January 13th, and the nearest station was left at 2.10 p.m. The mouth of the tunnel was reached at 2.20 p.m. A number of paraffin flare lamps were taken on board. The men were put to their positions upon the waggon as follows: Four at the rear of the drum: two to steadily turn it, one to



I.—Ballast Waggon with Mounted Drums.

maintain a bight in the cable, and one to brake the drum if required. Two at the front of the drum ; one to pay off the cable, and the other to apply a brake if necessary. A foreman was also upon the waggon provided with a whistle to watch the operations and control the actions of the driver by means of standard tramway-signals—one to stop and two to start. Five men remained on the ground ; two of these to pull the cable from the drum and clear of the waggon, whilst the other threelifted it to the base of the wall of the tunnel (2).

The paying out of the cable from the drum nearest the rear of the waggon was commenced at 2.24 p.m. The brakes in the van were put hard on and the engine pushed the van slowly forward. It was not necessary to call a halt until the whole of the length had been uncoiled without confusion or mishap, when it was found that exactly fourteen minutes had been occupied in the operation. It will thus be seen that, as the length laid was 270 yds. in fourteen minutes, the combined efforts of our efficient driver and guard obtained for us the almost incredible speed of under 1200 yds. per hour. The second cable was immediately prepared for laying and the loose end was passed over the top of the empty rear drum and so to the ground. The paying-out commenced five minutes after the laying out of the first had been completed, and the time occupied was again fourteen minutes. All concerned got aboard without

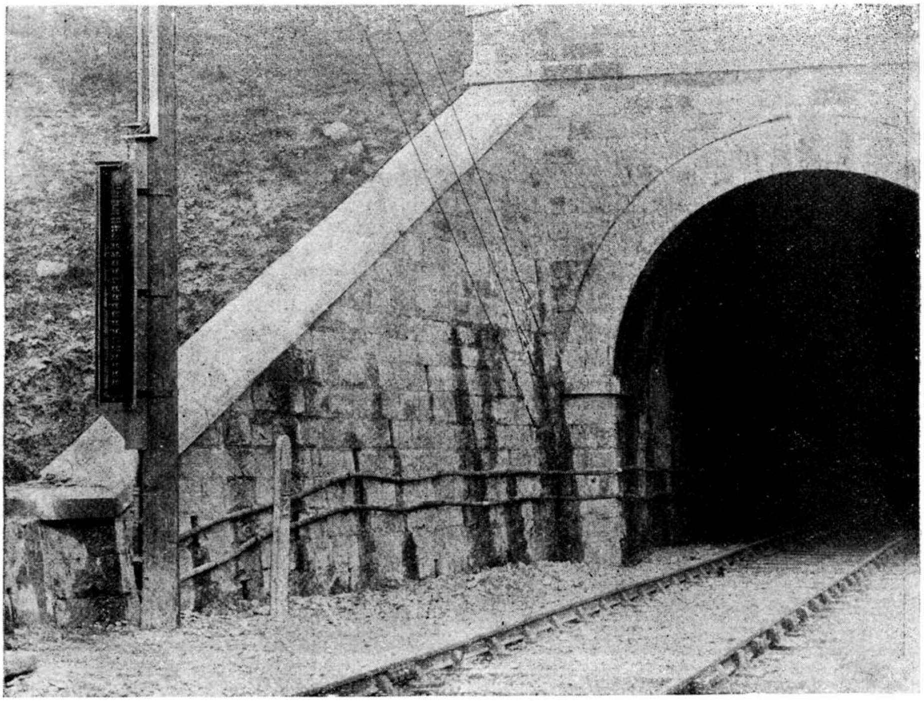


2.—Laying Cable.

delay, and the station was reached sixty-eight minutes after the time of departure. The remaining cables were laid between trains on the two following days. The shortest time occupied in the actual laying of any cable was eight minutes. On one occasion forty-seven minutes only were expended in leaving the station, laying two cables, and returning to the starting-point.

The conditions attending the laying operations were decidedly weird and require the pen of a descriptive writer to do them justice. The cable waggon was fitted with such a number of paraffin lamps as would have afforded ample light in the open air, but owing to the steam and smoke from the engine the area of illumination was very limited. It was with great difficulty that forms and figures were distinguished at a distance of over 1 yard, and the whole *cortège* had an air of ghostly unreality. The surroundings were such that the men performing one set of operations were totally unable to see the nearest group, and any hitch in the proceedings would have been likely to engender confusion. Everyone, however, carried out their respective tasks with care and facility, and all drums were disposed of without any untoward incident.

There are four joints in each cable. They are each 3 ft. 6 in. in length, the centre of the 12 in. lead sleeve being 1 ft. 9 in. from each end. The length of lead-sheath on each side of the sleeve is wrapped

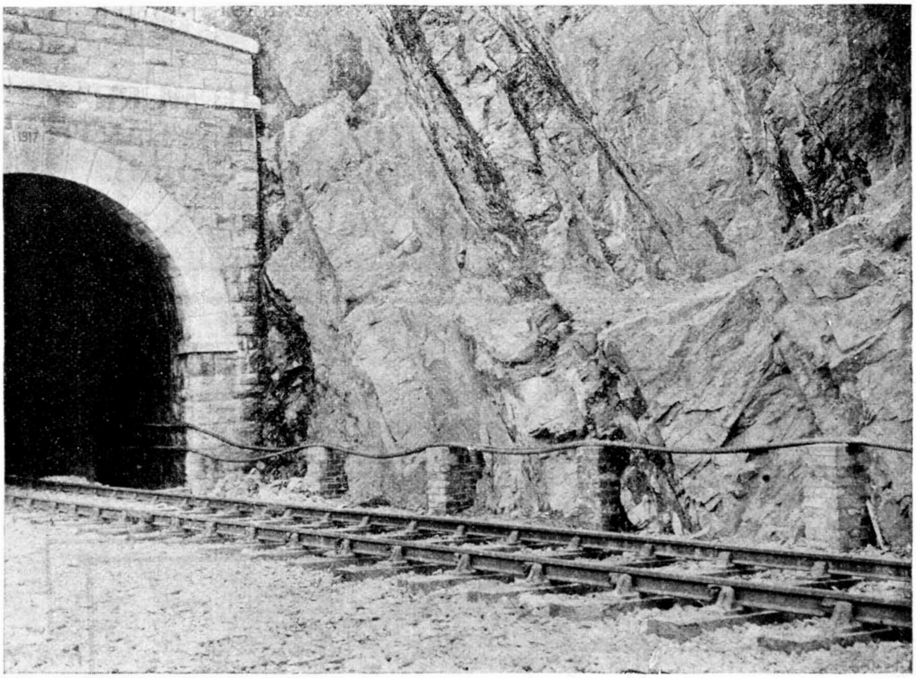


3.—South End of Tunnel: Cable on Hooks.

with tarred yarn up to the shoulder of the sleeve, and the whole 3 ft. 6 in. is then served with another wrapping of the same material. The armouring is double over the whole joint, half the steel wires from each side being laid alternately to form one layer, the remaining halves being similarly used to complete the second layer. The whole joint is then covered with two servings of prepared tape. The cable as a whole has been treated with a mixture of tar and whitening.

The conditions attending the jointing operations were even more trying than those experienced when the laying was in progress. The jointers spent the whole day, exclusive of meal times, surrounded by black darkness. The noise of the blow-lamps, etc., made it necessary for the men to be especially alert in listening for the warnings which were given of the approach of the trains. As each signal was received the work was temporarily abandoned, and refuge was taken in the nearest man-hole. The departing train left behind it a thick volume of smoke which made the atmospheric conditions exceedingly unpleasant, and did not dispel for several minutes. The man-holes are provided at intervals of 50 yds. throughout the tunnel.

Each of the two cables are supported through the tunnel on iron hooks held in position in the stone wall by means of concrete. The hooks forming each cable-run are 6 ft. apart, the lower run being



4.—North End of Tunnel: Cable on Piers.

2 ft. 6 in. from the ground line, and the higher 3 ft. 6 in. The wings of the tunnel at the south end permit of the hooks being fixed for the whole distance up to the terminal pole, but the absence of wings at the north end made it necessary to provide independent supports (3, 4).

Each cable is terminated in a plug at each end, which is connected to the pole test-box. Cable conductors of 100 lb. are allocated to the long-distance circuits and to the one-trunk circuit. The local telegraphs and telephones are served by the means of the 40 lb. conductors.

The open-line diversion involved the erection of 34 poles and the recovery of 51 poles. Eight new conductors, four copper and four iron, were first erected on the new line and a similar number of circuits transferred. Eight wires were then recovered from the old route and re-erected on the new, the process being repeated until the diversion was complete. The long distance circuits are 150 lb. copper conductors, whilst the remaining telegraphs are 400 lbs. G.I.

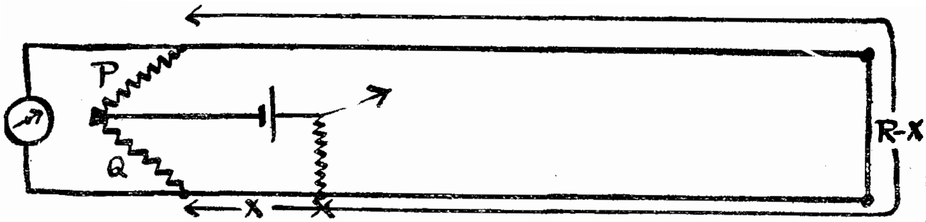
The satisfactory completion of the work was due to the enthusiasm shown by all concerned. The driver and guard of the "special" vied with the Department's workmen in their efforts to achieve success.

I have great pleasure in placing on record my high appreciation of the valuable services rendered.

ERNEST J. WILBY.

CONSIDERATIONS RELATING TO THE MURRAY TEST FOR THE LOCATION OF AN EARTH FAULT IN AN UNDERGROUND CABLE.

By A. MORRIS, A.R.C.Sc., and R. M. CHAMNEY, A.M.I.C.E.



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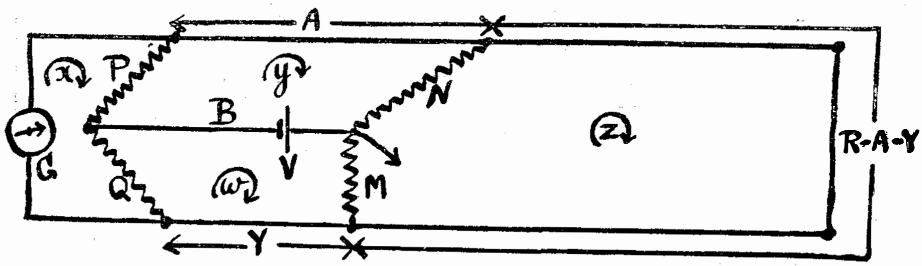


2

CONDITION FOR BALANCE OF BRIDGE SHOWN IN I. $PX = Q(R - X)$, OR $X(P + Q) = QR$, OR $X = \dfrac{Q/P}{(Q/P + 1)} R$.

IN using the ordinary Murray test for the location of a fault to earth (1) the resistance to the fault is given by

$$X = \frac{Q/P}{(Q/P + 1)} R. \quad \ldots \quad (1).$$

If now the resistance of the fault (M) and the insulation resistance of the auxiliary wire (N)—which is assumed concentrated at a point

A ohms from the testing end—be taken into consideration (**2**) the resistance to the fault is given by

$$Y = \frac{Q/P}{(Q/P + 1)} R - \frac{M}{N} \left\{ \frac{R}{(Q/P + 1)} - A \right\} \quad (2) \text{ See Appendix.}$$

The error introduced into the location by using the Murray formula is therefore $(X - Y) = \frac{M}{N} \left\{ \frac{R}{(Q/P + 1)} - A \right\}$; which is always a positive quantity. Expressing this as a percentage of the resistance of a single wire:

$$\frac{X - Y}{\frac{R}{2}} \times 100 = \text{percentage error of Murray formula}$$

$$= 2 \frac{M}{N} \left\{ \frac{R}{(Q/P + 1)} - A \right\} \frac{100}{R} = E \quad . \quad . \quad (3)$$

I. e. E is directly proportional to $\frac{M}{N}$ and is greater the nearer the fault is to the testing end. The question as to the conditions under which E becomes relatively important naturally arises.

Table I gives calculated values of E for different values of $\frac{M}{N}$ and $\frac{Q}{P}$ when A has the value $\frac{R}{4}$. It will be seen that for faults near the testing end a value of $\frac{M}{N}$, equal to 0·01, will give rise to an error of about 1 per cent., whereas for faults near the distant end $\frac{M}{N}$ may have twice this value before the same error arises.

Limits of Accuracy owing to Insensitivity of Test.

When the resistance of the fault is very high the test is insensitive, and an accurate value for Q/P is difficult to obtain. If in such a case an error of "f" per cent. is made in the reading of Q/P, then the error in the location (X), expressed as a percentage of the resistance of a single wire, is given by

$$F = 2f \left\{ \frac{Q/P}{(Q/P + 1)^2} \right\} \quad (4) \text{ See Appendix.}$$

which is directly proportional to f, and is greater the nearer the fault is to the distant end of the circuit. Table II gives calculated values of f for values of Q/P between zero and unity, when f is successively 1, 5, and 10 per cent.

From a comparison of Tables I and II it would appear that in the location of an earth fault, if the conditions of the test are such as to ensure that the error in the measurement of Q/P is not greater than about 5 per cent., the correction E might be applied with advantage to the ordinary Murray formula, if the ratio of the resistance of the fault to the insulation resistance of the auxiliary wire to earth exceeds the value 0·01. The following illustrates the value of the correction in a particular case:

The 200-lb. circuits of a cable 90 miles in length were faulty to earth. The 100-lb. circuits of the same cable were in good condition and available for testing purposes. It was required to locate the fault on the 200-lb. circuits: Two 200-lb. circuits in parallel had a resistance of 4 meghoms to earth. One 100-lb circuit had a resistance of 120 meghoms to earth. In applying the Murray loop test the bridge balanced with a ratio of $Q/P = \frac{51}{800}$.

If $\quad r =$ resistance of one 200-lb. wire,

then $\frac{r}{2} =$,, two 200-lb. wires in parallel,

and $2r =$,, one 100-lb. wire.

Hence $R = 2{\cdot}5r$ and $X = \frac{51/800}{1 + 51/800} \times 2{\cdot}5r = \frac{3}{20}r$, but $\frac{r}{2}$ ohms along the 200-lb. wires in parallel corresponds to 90 miles.

Hence distance to fault (using Murray formula) $= \frac{3}{20} \times \frac{180}{1}$ miles $= 27$ miles.

$$Y = \frac{3}{20}r - \frac{4}{120}\left\{\frac{2{\cdot}5r}{1 + 51/800} - r\right\} = \frac{2676}{851 \times 30}r.$$

Hence distance to fault (using corrected Murray formula) $= \frac{2676}{851 \times 30} \times 180$ miles $= 19$ miles.

APPENDIX.

MAXWELL'S EQUATIONS for the network shown in 2 are:

$$\left.\begin{array}{ll}
(P + Q + G)x - Py - Qw \quad . \quad . \quad . \quad . & = O \\
- Ny - Mw + (M + N + R - A - Y)z \quad . & = O \\
Px + (P + A + N + B)y - Bw - Nz\ . \quad . & = V \\
- Qx - By + (Q + Y + M + B)w - Mz \quad . & = - V
\end{array}\right\}$$

Rewriting:

$$\begin{array}{ccccc}
x & y & w & z & \\
P+Q+G & -P & -Q & O & = O \\
O & -N & -M & M+N+R-A-Y & = O \\
-P & P+A+N+B & -B & -N & = V \\
-Q & -B & Q+Y+M+B & -M & = -V
\end{array}$$

Hence:

$$x = \frac{1}{\Delta}\begin{vmatrix}
O & -P & -Q & O \\
O & -N & -M & M+N+R-A-Y \\
V & P+A+N+B & -B & -N \\
-V & -B & Q+Y+B+M & -M
\end{vmatrix}$$

Solving this determinant for $x = O$, we get the conditions for balance of the network represented in 2. The solution is:

$$\frac{P}{Q} = \frac{Y + \dfrac{M(R - A - Y)}{(N + M + R - A - Y)}}{A + \dfrac{N(R - A - Y)}{(N + M + R - A - Y)}}$$

$$= \frac{Y + \dfrac{M}{N + M}(R - A - Y)}{A + \dfrac{N}{N + M}(R - A - Y)} \text{ (approximately)}$$

$$\text{or } Y = \frac{Q/P}{(Q/P + 1)} R - \frac{M}{N}\left\{\frac{R}{(Q/P + 1)} - A\right\} \quad . \quad (2)$$

Limits of Accuracy of the Murray Formula owing to Insensitivity of the Test.

$$X = \frac{Q/P}{(Q/P + 1)} R \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\therefore \delta X = R\left\{\frac{(Q/P + 1) - Q/P}{(Q/P + 1)^2}\right\}\delta Q/P.$$

$$\therefore \frac{2\delta X}{R} \times 100 = \frac{2Q/P}{(Q/P + 1)^2} \times \frac{\delta Q/P}{Q/P} \times 100.$$

I.e. error of the Murray expressed as a percentage of the resistance of a single wire $= \dfrac{2Q/P}{(Q/P + 1)^2} \times$ percentage error in reading of Q/P. *I.e.* $F = 2f\left\{\dfrac{Q/P}{(Q/P + 1)^2}\right\}$ . . . . . (4)

Table I.

Table giving Calculated Values of E *for Various Values of* M/N *and* Q/P.

M/N.	Values of Q/P.										
	0.	·1	·2.	·3.	·4.	·5.	6.	·7.	·8.	·9.	1·0.
·001	·15	·13	·12	·10	·09	·08	·075	0·7	·06	·055	·05
·005	·75	·66	·58	·52	·46	·41	·37	·35	·30	·27	·25
·01	1·5	1·3	1·2	1·0	·9	·8	·75	·7	·6	·55	·5
·05	7·5	6·6	5·8	5·2	4·6	4·1	3·7	3·5	3·0	2·7	2·5
·10	15·0	13·2	11·7	10·4	9·3	8·3	7·5	7·0	6·1	5·5	5·0

TABLE II.

Table giving Calculated Values of F *for Values of* Q/P *between Zero and Unity when* F *has the Values* 1, 5, *and* 10.

f.	Values of Q/P.										
	0.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.	1·0
1	0	·16	·28	·36	·41	·44	·47	·48	·49	·5	·5
5	0	·82	1·39	1·78	2·04	2·22	2·35	2·42	2·47	2·49	2·5
10	0	1·65	2·78	3·56	4·08	4·44	4.70	4·84	4·94	4·98	5·0

HEADQUARTERS NOTES.

TELEPHONE DEVELOPMENTS.

INSTALLATION work on the following contract has been commenced:

Avenue Exchange.—Removal of monitors' and supervisors' desks.

The following equipment contract has been completed ;

Admiralty P.B. Exchange.—Additional equipment for 300 lines. Rearrangement of existing boards.

JANUARY SNOWSTORM.

The interruptions to trunk communications between London and the large provincial towns were not so serious as in March, 1916, as we were able, by means of telephone repeaters, to use the extensive underground cable system. For instance, Leeds and Cardiff were kept in communication with London by this means, although all the aerial circuits were stopped.

Further details of the use of telephone repeaters will appear in our June issue.

WAR SEAL MANSIONS FUND.

In addition to the sums subscribed at Headquarters and in the various Engineering Districts for the above fund, details of which we published in our last issue, Mr. H. A. Miles advises us that he has received £22 11*s.* 0*d.* from the Submarine Superintendent and his staff, and that a cheque for that amount has been passed forward to the Secretary of the fund. The object of the fund is to provide for the erection of self-contained flats for the accommodation of totally disabled soldiers and sailors with their families at a very low rental.

LONDON DISTRICT NOTES.

INTERNAL CONSTRUCTION.

Telephone Lines and Stations.—During the thirteen weeks ended January 24th, 1918, 1037 exchange lines, 3842 internal extensions, and 159 external extensions were provided. In the same period 1040 exchange lines, 1266 internal extensions, and 94 external extensions were recovered, making a net decrease of 3 exchange lines and net increases of 2576 internal extensions and 65 external extensions.

Private Branch Exchange Installations.—In connection with war activities the following items have been provided in the district since the outbreak of war to the end of 1917:

Switchboard sections	412
Exchange lines connected thereto . .	1962
Tie lines	1504
Extensions	18,170

Central Telegraph Office Section.—An improved method of localising pneumatic tube faults has been devised by an inspector in the C.T.O. Section. A winder in conjunction with a temporary plate replaces the permanent plate on the inspection trough usually fitted on a "Street" tube. The temporary plate is bored to allow of a cord being passed through, to which a carrier is attached.

It has been found that when power is turned on gradually, a carrier may be propelled several hundred yards along the tube and withdrawn again by means of the cord after the power has been cut off. This method has enabled both "indentation" and "leakage" faults to be located in much less time and with less expense than hitherto.

An auxiliary telegraph office has been established on a somewhat larger scale than that described by Mr. Tanner on pages 224–227 in the last issue of this JOURNAL but on somewhat similar lines, except that it has been found possible to utilise 4 generators to provide 40 and 80 volts positive and negative. Additional voltage is obtained by placing Van Raden cells in series with the generators for the few long-distance circuits that require 120 volts. The office is complete with Wheatstone apparatus and sets available for intermediate and direct working.

Machine Telegraphs.—An additional quadruple duplex Baudot set has been installed, and at the time of writing is undergoing test between London and Edinburgh.

EXTERNAL CONSTRUCTION.

For the three months ended January 31st, 1918, the net increase in telephone exchange wire mileage in the London Engineering District was 1181 miles, the increase under the head of Underground being 1989 miles, whilst open (bare wire) and open (aerial cable) decreased by 523 and 285 miles respectively.

Telephone trunk wire mileage decreased by 476 miles, and telegraphs by 184 miles. Of these decreases 238 miles were due to an alteration in the district boundary. Pole-line mileage decreased by 1 mile and pipe line by 5 miles from the same cause.

The aggregate mileages in the district at the end of January, 1918, were as follows:

Line Mileage.

Pole line	2559 miles.
Pipe line	3519 ,,

Single Wire Mileage.

Telegraphs	17,736	Excluding wires on railways maintained by railway companies.
Telephone Exchange	995,560	
,, Trunks	17,279	
Spare wires (not allocated)	18,452	

The total length of underground cable is 7104 miles.

I.P.O.E.E. NOTES.

Council Meeting.

A meeting of the Council of the Institution was held in London on the 19th and 20th ult., under the chairmanship of Mr. A. J. Stubbs.

The Financial Report showed the Institution to be in a favourable position, and authority was given for the printing of the following papers:

"The Western Electric Company's Automatic Telephone System," by Mr. Anson.

"The Provision of a C. B. Exchange," by Mr. Greenham.

"The Keyboard Perforator," by Mr. Harrison.

Several others are in the hands of the Editing Committee.

It was decided to continue the issue of the Journal, and to give it such support as the Committee deems necessary.

The question of holding local centre meetings for next session will remain in the hands of the Local Committees.

The existing Council will retain office, as the cost of holding elections was not considered justifiable in the circumstances.

A SERIES OF LETTERS FROM LIEUT. P. W. TURNER, R.E. SIGNAL SERVICE.

(Construction Section, E.-in-C. O.)

(1)

Gallipoli;

December 5th, 1915.

I have had some interesting experiences out here, particularly at Anzac, where the scenery is grand owing to its precipitous hills and deep gullies. I have had to run wires all over the place and not in accordance with Post Office ideas, I am afraid. Weird lines, with the poles hidden from shell-fire, uneven spans, some 400 yds. long! Everything dominated by the one idea that a line if safe from shell-fire need not be constructionally ideal. Much of the work was done at night, especially the wiring, owing to the snipers, and when you want a pleasant change try running about twelve wires on a bad line in pitch dark with barbed wire and old trenches about. It's great!

I fell into a trench last week and now I have my ribs strapped up. It was fortunate I did not break one or two, as I have got very fat since living in the open air with plenty of good simple food. One cannot speak too highly of the efforts made to feed the forces here. We never see fresh vegetables, butter, and that sort of thing, but of meat (tinned and fresh), bread, biscuits, tea, sugar, jam, and so on, we get ample supplies. We are promised pea-soup, curry, oatmeal, and cocoa, commencing this month owing to the severe weather now setting in, so we shall be O.K. here.

(2)

BOUND FOR ALEXANDRIA;
January 19th, 1916.

Thanks very much for bundle of "Red Tapes." I don't know quite when you posted them, but I got them on the 13th of this month, after the evacuation of Helles. Our mail service was very bad for a week before Christmas and then was suspended altogether, so I went over three weeks without getting a letter and could not post one either. Part of the policy of secrecy, of course. The last stage of the drama was played, as far as G.O.C. is concerned, on the Admiral's yacht about a mile from the shore. I had the job of going on board and fitting up telephones to the shore. We cut into one of the submarine cables lying about there and got through on that, and then laid a special cable from ship to shore as a standby. It was all very interesting and exciting, and probably in a few years' time when I am trying to solve the problem of putting up a shapely and ornamented "Rupingised" in some suburban road, I shall think of my life on the Peninsula where the only wayleave difficulty was to get a line through to Constantinople, and yet and yet, it couldn't be done.

You can well understand some of our people are very cut up over the failure, as it seems rough after spending men's lives by the thousands to have to throw up the sponge.

We are probably going to strengthen the Suez defences for a month or two, and then, who knows? India, East Africa, Salonica, or Persia, I suppose. I sometimes wonder when I shall have the pleasure of crawling up the stairs of 43, Newgate St., and inhaling the glories of its radiators. Good Lord! how we should have welcomed those radiators in one or two of the blizzards we had on the Peninsula.

I am now on a transport bound for Alexandria and not quite so fed up with the war as I was a fortnight ago. Life on a decent transport is not at all bad—it is the first holiday I have had for five months. We work a 24-hour day and a 7-day week out here; I did not like it at first, but it prevents one from thinking of England, home, and beauty, so has a certain merit. *Au revoir.*

(3)

ALEXANDRIA;
February 19th, 1916.

Your letter of January 2nd rolled in a few days ago. As you will readily understand, our mail service has been out of gear for two months. While the evacuations were going on, the mail service was suspended altogether for obvious reasons and now there is no need for such secrecy, what with the necessity for getting rid of the accumulations and the difficulty of keeping pace with constant movements of troops, things have not settled down again. It is no uncommon thing for mails to go to Mudros and pass several transports on the way to Egypt. Then the mails for these are sorted out and returned to Egypt, and a game of hide-and-seek goes on. Our little company of about 200 has been split up over four places, and the mails chase round from place to place, spending about a week at each. However, things ought to settle down a bit before long. It is curious when one gets a long way from home how important the mail service suddenly becomes and how eagerly one looks forward to news from home.

I have a new address now—15th Army Corps. This means more trouble, of course, until people at home begin to use the new address, but we must put up with it, I suppose.

It is jolly fine in Egypt in the winter, as the weather is ideal. Not too hot, but just like an English summer. Roses, sunflowers, violas, and so on, bloom in the open here, even in January. Bathing is not yet in full swing, but it has started and is quite pleasant.

Most of the troops taken away from the Peninsula are being brought into Egypt and fitted out with fresh clothing and so on. Of course, the opportunity is being taken to overhaul and replenish our stores as well, so we were fairly busy for a fortnight after our arrival at Alexandria. We have now commenced work again along the canal in the neighbourhood of Port Said. I nearly had a rather interesting job to build a line through the desert with camel transport, but after being told to go I was stopped at the last minute and shoved back on office work again—it's a way they have in the Army.

Personally, I think we should be better employed in killing Germans rather than Turks or other heretics, as that seems to be the quickest way of ending the war. But those who say the Dardanelles stunt was an easy thing are talking through their hats, as what was accomplished was really wonderful and complete success was within reach several times. We were unlucky, that's all.

(4)

CAIRO;

March 8th, 1916.

I have been rather lucky in getting a few days' leave to visit Cairo, so I have been enabled to see the celebrated pyramids and sphinxes both at Ghizeh and Sakkara. Of course, as you may guess, these are examples of distance lending enchantment to the view, as, on close acquaintance, these huge affairs are somewhat rough and ready. The roughest part is climbing up the Great Pyramid. The Arabs profess to be able to go up and down in eight minutes, but I confess I would rather take an hour over the job. You can get some idea of the difficulties when I tell you it's about twenty times worse than the staircase at 43, N. St.

The scenery, also, is typical round here. The rolling desert, with palms, natives, camels, donkeys, and the Nile make a pleasant picture, slightly improved, when the wind blows, by clouds of fine sand. Altogether a fine place to open a "pub." would be here, as thirsts are cheap and drinks are dear. Beer is 1*s*. 3*d*. per bottle—BEER, not champagne!

I should think, however, that Egypt would be a splendid place to spend a winter holiday if you had plenty of money, as there is no doubt as to the many interesting things to be seen, and the climate just now is ideal. I started swimming early in February and found it just like English bathing in July; in fact, warmer than some English bathing I have known.

They have a very interesting native bazaar at Cairo, where various forms of brass-ware are made before your eyes. Hammered and engraved brass bowls, etc., are plentiful and genuine. Some of the silks and embroideries are genuine also, but there is a lot of dud stuff about and one can never be sure of getting genuine hand-made native things.

There is, however, a very good native factory where real antiques are made. "Scarabs," 5000 years old, and various little porcelain odds and ends, such as hyænas and models of Isis, also quite 5000 years old, are made here by the thousand.

A man sold me two antiques the other day, and after bargaining he reduced the price from 20s. to 1s. His chief argument was that he had a wife and seven children, so I bought them out of charity and don't suppose I was swindled for more than tenpence.

I went to the races the other day and backed a horse owned by a Mr. Sinnott, but it ran second, so I have a grievance once again!

(5)

MESOPOTAMIA;
April 18th, 1916.

Many thanks for your letter of the 5th ult., received 15th. I was delighted to hear all the news and am sorry that circs. prevent a longer reply. I daresay you are anxious about Kut, so are we. My address is Name and Rank, R.E., Corps Signal Coy., Mesopotamia; and three cheers for the Garden of Eden!

Sorry about the 8-hour day, but I've got so used to an 18-hour day and a 7-day week that I would rather have the burdens of 43, N. St., for a change. However, when the war is over I expect I shall grumble about it as much as the others. I was sorry to hear I had not been promoted! What a war to be sure! Tell K. I am writing him soon.

(6)

MESOPOTAMIA;
June 15th, 1916.

We have at last travelled up the Tigris and have reached the limit for the moment, being about 4000 yards from the trenches. Fortunately, the Turks seem very short of ammunition and do not shell the camps much, though we had an uncomfortable experience a few days ago and it was decided to shift our camps a bit, but eventually it fell through. It is a bit unusual for a corps camp to be shelled, but everything is unusual in this place. At present three of our divisions are behind the corps and one in front! The country here is nothing to write home about, as it is flat, treeless, and dusty. Flies, mosquitoes and other winged relics of the Spanish Inquisition thrive pretty well on us, so someone is getting a bit of benefit from the expedition. We are fed very well, especially when one considers the difficulties of transport. We also get mosquito curtains, but campaigning in a hot country can never be a picnic. For a man living here in a cool house with electric fans and iced drinks, life would be more or less tolerable, but 110° in the shade in a bell tent with no fans and no iced drinks is h-o-t.

We are about 300 miles from our base by water and about 230 by road, but practically all transport is done by water. Quite a lot of the telegraph work is done by wireless, but there is also an iron pole line carrying four wires all the way up. It is, I believe, a line belonging to the Indo-European Company, and was repaired by the Indian Government Telegraphs after the advance up the river. Quite a decent line with sectional iron poles about 20 ft. and quite light. Two men can erect one in about three minutes, as the hole is merely bored out about 3 ft. deep. The Indian Government work the telegraphs from the base to the corps with a mixed staff of white and Hindoo operators, about one-third army men and two-thirds civilians. From the corps onwards it is purely an army occupation.

The date palms are numbered by the million from Fao to Kurna, but above Kurna there are no trees, merely a desolate, sparsely populated waste, with a narrow strip of pasture land near the river. Kurna is the site of the Garden of Eden, and the Tree of Life had been carefully preserved on the edge of the river ever since. But one of our *blasé* navy men anchored his beastly steamer to it one night and pulled it down, so my chance of doing the Treasury in the matter of Pension Complete, Mark I, is correspondingly lessened. But cases have been known where white men have lived here several months unharmed, so I have hopes of seeing 43, N. Street, again if the war ends soon enough! My address is I.E.F., "D," c/o India Office. And considering it is over 110° in the shade to-day, Indian Expeditionary Force "D" is a good name for it. *Au revoir.*

(7)

MESOPOTAMIA;
August 15*th*, 1916.

I have not heard from you for many moons, and as it is exactly two months since I wrote to you I am emulating our friend Woodrow and getting a bead on you with my indelible.

We are still lying doggo here: the Turks have no stomach for further fighting and are on the defensive. Why we do not attack is not revealed to the babes and sucklings; probably the very hot weather has a lot to do with it, as fighting here is intimately connected with transport and water problems, and the heat accentuates the difficulties of these. If it had not been for the Kut business, I imagine we should rest content as we hold thousands of miles of the country here; quite enough to keep us amused for many a long day. The original object of the expedition has been attained, and up to that point the whole thing was a big success, but the Kut failure leaves something to be wiped off the slate, and probably in the cooler weather the wiping will commence.

We are still about 300 miles up the Tigris, on the site of the battle of Falayeh—in fact, we were in it. Probably you read the highly-coloured account in the English papers about June 15th; as usual, about 10 per cent. of truth only.

The Turks have very few aeroplanes here, but one was a powerful Fokker which had given us furiously to cough on occasion. Yesterday one of our machines brought it down just in front of the Turkish lines. The Turks rushed out to bring it in, but were driven off by our guns which then destroyed the machine. By way of reprisal the Turks sent an Albatross over this morning bomb-dropping—killed and wounded several. There is not much bombing by aeroplane here, as a rule, the machines being used mostly for reconnaisance.

I am fit still, notwithstanding the heat.

(8)

MESOPOTAMIA;
September 7th, 1916.

Your letter of July 12th rolled along here on the 5th instant—not too rapid; slow and sure is our motto.

I was very interested in all the news you gave me; out here we seem so far away from everything that we get a lonely feeling at times. Of course, the Turks get chummy occasionally and heave over a few spare shells, but they are rather short of ammunition, fortunately, so we view their efforts rather with pained surprise than with any passionate resentment. Moreover, they get it all back with interest.

Lately we have been able to put up some cheering placards in the trenches, touching the successes of Russia and the adhesion of Rumania. An aeroplane is also going to drop some cheering literature over their trenches in a day or two, so that the wily Turk ought to recognise soon that his reckoning is shortly to be paid. During the hot weather there has been no fighting here, but with the advent of cooler weather we may get a move on. No one knows at present what the programme is. Really we hold more land now than was contemplated when the original expedition landed, but possibly our people may capture Kut just to make a diversion. I should be rather surprised though if another attempt on Baghdad were made. Still, one never knows.

We had an exchange of prisoners yesterday. At 4 a.m. an armistice was declared, and about 5 we sent up a steamer flying the white flag and bearing a load of Turks. We could not see them, as awnings had been arranged to prevent them making notes of our arrangements here. About noon, the boat returned from Kut with some of the prisoners captured there last April. Happy men, they were glad to see the Union Jack once more.

I hope, if the P.O. can spare you, you will take on a job in the R.E.'s, as I feel sure you would enjoy it. Only go to France, if possible, as it is more interesting, and leave, magic word, means something more there than an unattainable dream.

Your talk of gardens made me quite envious. I would give a lot to sit under my own vine and fig tree again.

(9)

MESOPOTAMIA;
November 11th, 1916.

Yours of September 28th to hand, 8th instant, and many thanks for all the news. The weather here is now ideal, bright days but not too hot, and fairly cool, vigorous nights. Food, too, is good, and altogether we have nothing now to mar the beauty of the scene except its distance from home. I keep pretty well, and hope to remain so until next hot season at any rate. What will happen then I cannot tell; perhaps the war will be over, or we shall have marched to the shores of the Black and Mediterranean Seas, though I would bet on neither contingency. We positively had some rain the other day, only a gentle shower, but by good luck it followed on the heels of a sand-storm, so was very welcome. A sand-storm in these parts is a fearful and wonderful thing; the air is full of sand, whirling in clouds—air so thick that it is most unpleasant to breathe, and most work has to be suspended (not telegraphs, of course!) because of the impossibility of seeing more than a yard or two; goggles do not keep the dust out of the eyes. So we just take shelter in tents sealed up as far as possible, and hope for the best.

The main lines here are built by parties supplied by the Indian Government Telegraphs. They have an arrangement somewhat akin to our "K" and "L" R.E. Companies at home. Certain of the engineers are regarded as officers in the Indian Army Reserve, and the construction parties and operators are on a semi-military footing. They undertake all communications from the base to the army headquarters, thence to the corps, divisions, and brigades the work is done by purely military signal units. The main lines are iron poles, quite light, in four sections, tapered so that the sections can easily be put together or taken apart. G.I. wire is used up to five wires on bracket insulators; above that light iron arms are used. The lines are some hundreds of miles long, and between the defensive camps run through areas devoid of troops. So you can imagine that the maintenance of the lines is not too easy. Occasionally the Arabs will cut them, and lie in wait to "strafe" the repairing party. In flooded areas, too, when the unfortunate lineman is either in a small boat or up to his waist in water, life has its drawbacks; but the Indian worker when good is really good, so that things move along well, and interruption of communication is very rare.

One construction party had a curious experience on the retreat from Ctesiphon. They were coming down the river on a boat; the troops were marching by road. The river winds a lot, but the road is fairly direct, and unfortunately the boat got stuck on a sand bank. Sand banks are the cause of a lot of the transport troubles on the Tigris. Well, after fruitless attempts to get the boat off, they had to abandon her and strike the road. By this time the troops were ahead of them on the road to Kut, and it was dark before they overtook them. Judge of their dismay when, after dodging the wily Abdul, they found themselves being fired on by their own comrades, who could not identify them in the darkness. With great presence of mind, one of the British N.C.O.'s saved the situation. In the choicest of trench talk he demanded, "Who the blankety blank do you blanky well think you're blanky well firing at?" "Stop shooting," said a voice, "and let them through—they're British all right!"

People have an idea that Mesopotamia is very unhealthy. There are parts that are quite healthy, however, and under good conditions would be better than some portions of India. Proper houses, baths, lighting, clothing, food, drink, ice, motors, boats, and electric fans would make things very decent indeed, and when the war is over I have no doubt the number of British will increase as compared with pre-war figures. Of course, the natives seem to thrive without these artificialities; in fact, at a place called Kuweit, it is the custom for all men reaching the age of 80 years to take to themselves a young wife and found a fresh family, and then die at about the age of 120. It is perhaps fortunate for the Treasury that Civil Servants are not as hardy as the men of Kuweit.

A reorganisation is in progress here, and the Army is being remodelled more on British than Indian lines. Our Signal Company yesterday came about 18 miles down the river to our advanced base at Sheikh Saad, whence we shall go later on to start work afresh. There is a large rest camp at this place with an open-air cinema, so I saw some "movies" last night for the first time since leaving Egypt. I had to leave for dinner in the middle of a Potiphar's wife sort of story. It was quite an event to see something in skirts even on a film, but when the lady is alluring in addition you can imagine my regret at having to leave. Still, duty must be done, and, now the weather is cooler, dining is more pleasurable than during the hot weather, when food became a disagreeable necessity.

They have a few concert parties from India touring here now. I heard one the other evening. The artists are Territorials, and do the thing very well, some of their imitations of ladies being quite good. Each party has one of those alphabetical nursery rhyme stunts with local allusions complete. I think you might be interested in one of them, and, so far as I can remember, the one I heard ran somewhat like this:

A's for the Army that's now going strong,
We hope you'll all like it as much as this song.
B is the Bacon they gave us at Asher,*
It worked out at just seven men per rasher.
C, Cigarettes, it is awfully hard,
You can't get them here when there's lots at Sheikh Saad.
D is for Dixie in which we do cooking,
You'd best eat your share without too much looking.
E stands for Eden, it must have been rough,
To keep off mosquitoes one leaf's not enough.
F, Foreign service, with wives left behind,
Though sometimes abroad there are wives of a kind.
G is the Grouse that was heard yesterday,
When the troops were paraded to draw a month's pay.
H is for Home, where at papers they glance,
And think there's no war anywhere but in France.
I stands for India, whence, so they say,
Several more generals are now on their way.
J is for Jam, and when you draw "some,"
Out of every five tins are four labelled "plum."
K is the K'nut, when in khaki he's dressed,
He finds that the flappers like Kernels the best.
L is for Limejuice, a popular drink,
They sell it round here at a loss—I don't think.†
M are the Mudbanks, you must have some luck,
If you steam up the Tigris without getting stuck.
N, Nasariyeh, where General Gorringe
At his last fight took the bun and the orange.
O is for Onions, it really is true,
We always draw lots for the one in our stew.
P for Potatoes, and some people say
They really saw one around here t'other day.
Q is the Question, to us it sounds queer,
"Did you come out from England to give concerts here?"
R, our reply, which always has been,
"We've practised in India since 1914."
S for Salutes, which we don't give to those
Who, except for the stars, mimic officers' clothes.
T is for Tabs of that gorgeous red hue,
Which indicate jobs that would suit me and you.
U is the Uniform—grouse, no, we won't,
Though sometimes it fits us and sometimes it don't.

* Base camp near Basra.
† It is 3*s*. to 4*s*. a bottle here.

V are the Very nice girls in Bombay,
Who send presents here that get "borrowed" halfway.
W the Whiteness of those "blighty" knees
That show that the owner's just come overseas.
X for the X-rays, which are very use*ful*
To show if the Turk scored an inner or bull.
Y is the Y.M.C.A. just near here,
They sell everything except spirits and beer.
Z is the *Z*epp'lins, I think you'll agree,
That's the one fever from which we are free.

Will you kindly accept best wishes for Christmas and the New Year, and hand on same message to all who remember me.

(*To be continued.*)

EDITORIAL NOTES AND COMMENTS.

WE have much pleasure in publishing in this issue the paper on the "Metric System, and its Application to the British Empire," which Mr. A. J. Stubbs has read before the London and several of the district local centres of the Institution of Post Office Electrical Engineers. Although Mr. Stubbs' paper read before the parent Institution has already been published in the 'Journal of the Proceedings of that Institution, we make no apology for reproducing his departmental paper, if we may so call it, here, since it contains many points that appeal more directly to the telegraph engineer, and all our subscribers are not affiliated to the I.E.E. The main objections to the adoption of the system are to be found—firstly, in the inherent conservatism of the British public and its dislike of the scrapping of aboriginal methods; and, secondly, to the fear that endless confusion may arise during the process of conversion, and that, after all, the expense may not be justified. Mr. Stubbs makes no frontal attack on the first objection, but advances a very strong case indeed in favour of the adoption of metric measures and marshals the facts in very telling fashion. The advantages of the system may be summarised briefly: In the first place, there would be an enormous saving in school-time which could be utilised for other purposes; and, in the second place, the use of the decimal notation would benefit our manufacturers and traders enormously throughout the world. It has been argued that the learning of the tables of weights and measures by the school-boy and their application in hypothetical sales and laborious sums are invaluable for memory training, but surely a better and more elegant means could be adopted for this purpose. The tools the boy has to use in his problems are unwieldy —$5\frac{1}{2}$ yards 1 pole or perch, ounces avoirdupois and ounces troy, the number of pounds in a stone, and so on *ad lib* , making the young mind weary and developing a distaste for the real use and object of the training. Every one of us will remember how annoyed we were at the last part of the sum which told us to express the answer in tons, cwts., qrs., when it came out so easily in pounds. It is the teaching of how to solve a problem, and not the conversion of the answer afterwards, that matters. The metric system requires no memorising in this respect. In the coming economic struggle after the war this country will suffer from one of its greatest handicaps if it persists in the retention of the present antiquated methods of measurement. One other point may be advanced. The public during the last few years has received a good drilling on what it should, and should not, do. The compulsory introduction of the metric system would be received, we are convinced, with the same complacency as other and even more drastic changes have been accepted. Mr. Stubbs has shown how the system can be brought gradually into force in the manufacturing world; the shopkeeper will be pleased to supply 1 lb. 1 oz. of butter, using his old weights till the new ones are available, when the good wife asks for a demi-kilo.

Since the war began we have been publishing lists of honours won by members of the Engineering Department on the stricken fields of Flanders, France, and the Near and Far East, and the numbers have grown and grown until the roll has reached dimensions of which we may well be proud. But this record, glorious and widespread, is not the only noteworthy service rendered to the Army by the home department. Some day we hope to be able to publish details of the manner in which the expert knowledge and material resources of the Post Office have been brought to the assistance of the forces in the field. Warfare has become scientific to a degree undreamed of by the man in the street, who reads in his paper of great offensives, of the movement of large armies, or the burrowing of the said armies into the earth, without realising the technical skill, the months of labour, and the enormous accumulation of supplies that render those actions possible. Now and again a privileged war correspondent lifts a corner of the veil that covers the preparations and we see something of the working results of the brains of the scientist and the engineer; but these glimpses are apt to be forgotten, and, in fact, are entirely "washed out" from the minds of the people by the laconic yet stirring announcements from G.H.Q.

It is gratifying, therefore, to find in the lists of honours issued recently in connection with the Most Excellent Order of the British

Empire not a few worthy representatives of the Engineering Department. First of all, we take the opportunity of offering congratulations to those recipients who although, strictly speaking, are not engineering officials, have been so closely associated with the technical side that we have come to regard them as of ourselves: Col. A. M. J. Ogilvie, C.B., R.E., Knight Commander of the Order; Mr. L. T. Horne, Commander; Mr. W. H. Allen, Officer; Messrs. J. F. Edmonds, J. Stuart Jones, Charles E. Fenton, Members. The services of our own representatives leap to the eyes, and their recognition by His Majesty reflects upon the branch as a whole: Messrs. A. Moir, Superintending Engineer, London District; E. Gomersall, Superintending Engineer, Ireland District; J. Bordeaux, Marine Superintendent; W. H. Winny, Assistant Staff Engineer—Officers of the Order; Mr. E. Lack, Assistant Staff Engineer, Member. We publish elsewhere a list of those who have been awarded Medals of the Order. On reading through the list of names and the reasons, not excuses, for the awards, one cannot fail to realise that there is a home front as well as one overseas, and that the British workman—the butt of cheap music-hall artistes and often held up to ridicule in the columns of the Yellow Press before the war—has displayed the mettle of his pasture and evinced qualities as great as those of Henry's yeomen or Drake's sea-dogs. It would be ungracious to omit a word of admiration for the brave telegraph and telephone young ladies who went to their posts under fire so pluckily and have now had their reward.

CORRESPONDENCE.

The Editor, THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL, *G.P.O., West.*

DEAR SIR,—Mr. Tanner is under a misapprehension in thinking that working the local circuit off the main battery is original or even a recent idea.

A reference to Pendry's 'Elementary Telegraphy' (published in 1910), p. 174, Fig. 148, shows that the idea of working the local circuit from the main battery is very old. The arrangement was devised by Mr. C. J. Mercer at almost the same time that the C.B. telegraph system was introduced. The action of the local circuit is described very fully on p. 173.

There were reasons for discarding the arrangement in large telegraph offices where all voltages are available on practically every table. The question of first cost, maintenance of neutral adjustment, and the undesirability of linking up a local circuit with the main circuit through one fuse being among them.

Yours faithfully,
E. V. SMART.

SECTIONAL ENGINEER'S OFFICE,
EAST EXTERNAL DISTRICT,
17–19, WEST INDIA DOCK ROAD, E. 14;
February 20th, 1918.

UNDERGROUND TESTING.

The Managing Editor, THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL.

DEAR SIR,—I trust you will allow me to encroach *once* more upon your space in order to deal with the points raised by Mr. Turner. The question of wire-to-wire resistance was not overlooked; it simply did not exist in the cases referred to, at least to any appreciable extent. Mr. Turner, however, appears to overlook the fact that such resistance is created by applying a simple loop test, whereas, with zinc permanently to line, not copper, as shown in the diagram, it can very often be removed or at least reduced to a negligible quantity. With regard to Mr. Turner's final conclusions, he will perhaps forgive me if I remind him that the test has been successfully applied in actual practice and that the conditions necessary for its application have been met with frequently.

Mr. Turner's experiment proves nothing new. As he says, anyone can try it. What is equally simple is to produce conditions in which any other particular test would be unreliable, but one does not condemn Murray's loop test, for instance, because an attempt is made to apply it where a good wire is not available.

Yours faithfully,
JAS. A. JACK.

GLASGOW;
February 15th, 1918.

BOOK REVIEWS.

'A Short Course in Elementary Mathematics and their Application to Wireless Telegraphy.' By S. J. Willis. (The Wireless Press, Ltd. Price 3*s*. 6*d*.)

This volume is intended for students who already have some mathematical knowledge, and presents in a condensed form for the wireless student the primary essentials of elementary mathematics.

The difficulty in preparing these condensed specialised mathematical courses is to determine where to begin; the present volume suffers from this inherent difficulty. The chapter on Algebra commences at factorisation, while in the chapters on Geometry the ratios of the circumference and area of a circle to its diameter, and the definitions of a rectangle and a square are given; these would surely be known by a student who had advanced as far as factorisation in Algebra.

Apart from these slight blemishes the book is good; it is well printed, and the diagrams are clear; the chapters on Logarithms, Trigonometry, and the use of Squared Paper are excellent.

Although we should hesitate to recommend the volume to the budding wireless engineer, whose course of elementary mathematics should be thorough, we can recommend it to the serious-minded wireless operator or to lay members of the public interested in Wireless Telegraphy who desire to extend their knowledge of the calculations in the elementary branches of the art.

If it serves only to whet the appetite of such for a more thorough course of mathematics it will fulfil a useful purpose.

F. W. D.

'Telephone Troubles, and How to Find Them.' By W. H. Hyde. (S. Rentell and Co. Price *7d.*)

A compendium of the more obvious faults to which simple instruments and lines are subject, with "rule of thumb" instructions for their location and removal.

The book is apparently written for the tyro, but if there be any such among the readers of this JOURNAL he would be better advised to spend his leisure in acquiring an intelligent understanding of the underlying principles of a few standard types of instrument and simple circuit arrangements. Armed with such knowledge and assisted by a little of that invaluable commodity—common-sense, he will be able to deal with the ordinary run of faults in a much more intelligent fashion than he would by referring to a book of this character, and, what is more important, he will be laying a more solid foundation for his subsequent progress in the higher branches of his calling.

[We regret to announce that owing to lack of space we ar compelled to hold over several reviews on books received, including Mr. John Lee's 'Telegraph Practice,' which will appear in our next issue.—EDITORS, POST OFFICE ELECTRICAL ENGINEERS' JOURNAL.]

MILITARY HONOURS.

THE Board of Editors has great pleasure in publishing the further list of honours awarded to members of the Engineering Department on active service:

Second Lieutenant H. L. Rew, R.G.A. (Clerical Assistant, South-Western District). Awarded the Military Cross.

Lance-Corporal W. Bell, R.E. Signal Service (Lineman, North Wales District). Awarded the Military Medal.

Lance-Corporal S. Meddings, R.E. Signal Service (Lineman, North Wales District). Awarded the Military Medal.

Petty Officer, 1st Class, T. R. Pells, Royal Fleet Reserve (Liftman, Metropolitan Power District). Mentioned in Despatches.

Sapper J. F. Russell, R.E. Signal Service (Clerical Assistant, Scotland West District). Mentioned in Despatches.

Corporal J. S. Coleman, R.E. Signal Service (Youth, London District). Awarded a Bar to the Military Medal.

Sapper (Acting Lance-Corporal) G.H. Daltry, R.E. Signal Service (Unestablished Skilled Workman, London District). Awarded the Distinguished Conduct Medal.

Private F. Downard, Royal Fusiliers (Unestablished Draughtsman, South Lancashire District). Awarded the Military Medal.

Pioneer (Acting Corporal) F. O. Pease, R.E. Signal Service (Unestablished Skilled Workman, London District). Awarded the Distinguished Conduct Medal and the Military Medal.

Pioneer E. Rawlin, R.E. Signal Service (Labourer, North Midland District). Awarded the Military Medal.

Sapper C. Reading, R.E. Signal Service (Skilled Workman, Class II, North Wales District). Awarded the Distinguished Conduct Medal, and the Military Medal with a Bar.

Company Sergeant-Major C. H. S. Rodway, R.E. Signal Service (Clerk, Second Class, London District). Mentioned in Despatches.

Lance-Corporal W. A. Rudge, R.E. Signal Service (Labourer, North Wales District). Awarded the Military Medal.

Private R. S. G. Whiley, Worcester Regiment (Labourer, South Wales District). Awarded the Military Medal.

Sergeant W. J. Bell, R.E. Signal Service (Skilled Workman, Class II, London District). Awarded the Distinguished Conduct Medal.

Gunner R. N. Taylor, R.G.A. (Labourer, South Lancs District). Awarded the Military Medal.

Staff Quartermaster-Sergeant S. F. Bonner, Army Service Corps (Clerical Assistant, South Midland District). Awarded the Meritorious Service Medal.

Quartermaster-Sergeant G. F. Greaves, Oxford and Bucks

Light Infantry (Assistant Clerk, London District). Mentioned in Despatches.

Temporary Second Lieutenant (Acting Lieutenant) C. T. Barton, R.F.A. (Clerical Assistant, North-Western District). Awarded the Military Cross.

Sergeant H. Butler, R.E. Signal Service (Skilled Workman, Class I, South Midland District). Mentioned in Despatches.

Private R. S. Forse, Gloucester Regiment (Labourer, South-Western District). Awarded the Distinguished Conduct Medal.

Corporal J. Gorman, R.E. Signal Service (Skilled Workman, Class II, South Lancs District). Awarded the Distinguished Conduct Medal.

Corporal E. Mason, R.E. Signal Service (Skilled Workman, South Midland District). Awarded the Distinguished Conduct Medal.

Captain R. J. S. Gold, Civil Service Rifles (Second Class Clerk, Engineer-in-Chief's Office). Mentioned in Despatches.

Regimental Quartermaster-Sergeant A. H. King, King's Royal Rifles (Unestablished Skilled Workman, South Lancs District). Mentioned in Despatches.

Sergeant G. Hornsby, R.E. Signal Service (Skilled Workman, Class II, London District). Awarded the Military Medal and a Bar.

Bombardier E. A. Newman, R.H.A. (Labourer, London District). Awarded the Distinguished Conduct Medal.

Sergeant W. H. Nightingale, R.E. Signal Service (Unestablished Skilled Workman, London District). Awarded the Military Medal.

Pioneer E. Sorensen, R.E. Signal Service (Unestablished Skilled Workman, Ireland). Awarded the Military Medal.

Second Lieutenant B. W. Woodhouse, R.E. Signal Service (Inspector, London District). Awarded the Military Cross.

Sapper S. Ballott, R.E. Signal Service (Skilled Workman, Class II, South Wales District). Awarded the Military Medal and Mentioned in Despatches.

Lance-Corporal W. Dagnall, R.E. Signal Service (Skilled Workman, Class II, North Wales District). Awarded the Military Medal.

Sergeant R. S. McDougall, R.E. Signal Service (Skilled Workman, Class II, Scotland West District). Awarded the Distinguished Conduct Medal and Mentioned in Despatches.

First Class Wireman S. F. Heath, R.N. (Unestablished Skilled Workman, North Wales District). Mentioned in Despatches.

Second Corporal J. Elliott, R.E. Signal Service (Skilled Workman, Class II, Scotland East District). Awarded the Military Medal.

Sapper D. Gibb, R.E. Signal Service (Unestablished Skilled Workman, Scotland East District). Awarded the Military Medal.

Able Seaman W. James, R.N.V.R. (Third Class Clerk, South-Eastern District). Mentioned in Despatches.

Corporal G. M. Atkinson, R.E., Signal Service (Skilled Workman, Class II, North-Eastern District). Awarded the Military Medal.

Driver S. B. Granger, R.F.A. (Unestablished Skilled Workman, London District). Awarded the Military Medal.

Sapper L. J. Juden, R.E. Signal Service (Youth, London District). Awarded the Military Medal.

Sapper P. W. Webb, R.E. Signal Service (Labourer, Eastern District). Awarded the Military Medal.

Private J. Simpson, West Riding Regiment (Unestablished Skilled Workman, North-Eastern District). Awarded the Military Medal.

Lance-Corporal W. H. Cattermole, R.E. Signal Service (Unestablished Skilled Workman, South Lancs District). Awarded the Military Medal.

Lance-Corporal E. A. Scammell, Middlesex Regiment (Labourer, London District). Awarded the Military Medal.

Lance-Corporal G. Stretch, R.E. Signal Service (Skilled Workman, Class II, North Wales District). Awarded the Military Medal.

Medals of the Most Excellent Order of the British Empire have been awarded to the following for services in connection with the war in which great courage or self-sacrifice has been displayed:

Charles Armes, Cable Foreman, employed on cable ships and small craft in connection with war work in dangerous waters.

John Thomas Barber, Carpenter, employed on cable ships and small craft in connection with war work in dangerous waters.

George Patrick Campbell, Carpenter, employed on cable ships and small craft in connection with war work in dangerous waters.

James Henry Davies, Skilled Workman, showed habitual courage in carrying out repairs to submarine cables in difficult and dangerous waters.

Henry Etheridge, Skilled Workman, employed on cable ships and small craft in connection with war work in dangerous waters.

William Heather, Cable Foreman, employed on cable ships and small craft in connection with war work in dangerous waters.

Thomas Hickey, Skilled Workman, has displayed great courage while carrying out telegraph work under dangerous conditions.

William Charles Hicks, Skilled Workman, has rendered valuable service since the beginning of the war. Has remained at his post absolutely alone day and night, in spite of danger from submarine or other attacks.

George William Hobbs, Boatswain, employed on cable ships in connection with war work in dangerous waters.

Horace Ivin, Skilled Workman, has done valuable service under dangerous conditions, repairing submarine cables carrying naval and military wires.

Maurice Jones, Inspector, has carried out two very dangerous missions, successfully passing through hostile lines at great personal risk.

Patrick Lambe, Skilled Workman, rendered very valuable service in picking up and repairing wires which had been shot down.

Robert Andrew Lockwood, Skilled Workman, has done exceptional service during rough weather in effecting repairs to submarine cables carrying naval and military wires.

Tom Oliver Lodder, Skilled Workman, showed great courage and devotion while in charge of a telegraph station, carrying out his duties under fire.

John Joseph Christopher Monks, Skilled Workman, on many occasions continued his work under fire, displaying great zeal and courage.

Edward Henry Lewis Owen, Cable Hand, employed on cable ships and small craft in connection with war work in dangerous waters.

Henry William John Porter, Skilled Workman, showed courage and devotion to duty during repeated air raids. On one occasion he returned to work on the restoration of naval circuits while explosions were taking place fifty yards away.

James Gordon Ross, Skilled Workman, displayed great courage and resource in maintaining telephonic communication during an air raid.

Sydney Simpson, Skilled Workman, showed great courage as well as resource on the occasion of a very severe explosion at adjoining munition works. He sent away to a safe place the women operators, and himself maintained uninterrupted telephonic communication.

Sidney Arthur Stammers, Cable Hand, employed on cable ships and small craft in connection with war work in dangerous waters.

George Gilbert Sutcliffe, Inspector, rendered valuable service in the construction and maintenance of telephones during fire.

Daniel Vincent Ward, Inspector, displayed courage and resource while Controlling Officer in a neighbourhood exposed to many bombardments by sea-craft and aeroplanes.

James Winter, Inspector, rendered special service in repairing wires under very daugerous conditions, and was frequently under fire.

Officers withdrawn for Active Service from the Engineering Department up till March 1st, 1918.

Engineering Officers	76
Chief Inspectors, etc.	49
Senior ,, ,,	17
Inspectors	160
Clerical Officers	1174
Skilled Workmen (Established)	2084
,, ,, (Unest. Labourers, Youths, etc.)	7797
Other Grades	511
	11,868

In addition 106 R.E.'s from Ireland.

ROLL OF HONOUR.

THE Board of Editors sincerely regrets the deaths on active service of the undermentioned members of the Engineering Department. Fourteenth List.

Name.	Rank.	District.
E. R. Adcock	Skilled Workman, Cl. II	S.W.
A. R. Begbie	Labourer	London.
T. Beswick	Skilled Workman, Cl. II	N.W.
R. W. Blacklock	Clerical Assistant	N.
H. E. Chaplain	Labourer	London.
R. W. W. Collingwood	,,	S. Lancs.
A. E. Collins	Labourer	London.
T. Cox	Unest. Skilled Workman	,,
J. M. Craig	,, ,, ,,	Scot. E.
A. Currie	Labourer	,,
A. Daniels	,,	,,
W. A. G. Dobson	Youth	London.
H. R. Emslie	Clerical Assistant	Scot. E.
2nd Lieut. J. Goodwin	,, ,,	Scot. W.
H. Hay	Skilled Workman, Cl. II	,,
B. J. Hibbert	Youth	N. Mid.
C. H. N. Hilton	Clerical Assistant	N.E.
E. E. Hunn	Inspector	N. Mid.
G. A. Hymas	Labourer	London.
F. W. Jenkins	Unest. Skilled Workman	S.Wales.
A. K. King	Skilled Workman, Cl. I	E. in C.O.
W. H. Law	Labourer	London.

Name.	Rank.	District.
J. Lawrence	Unest. Skilled Workman	London.
E. H. Luker	Skilled Workman, Cl. II	,,
S. Mackay	Youth	Scot. E.
W. Mason	Skilled Workman, Cl. II	N. Mid.
C. McLeod	Labourer	Scot. W.
G. McMaster	Slater	Scot. W.
S. Matthews	Clerical Assistant	N.W.
W. S. Philp	Skilled Workman, Cl. II	London.
F. V. Read	Boy Clerk	E. in C.O.
H. W. Scowen	Labourer	London.
F. T. Smith	,,	S. Lancs.
W. B. Souster	,,	S. Mid.
T. R. Thomas	Unest. Skilled Workman	S. Wales.
H. J. Wilmot	,, ,, ,,	S.W.
A. J. Wilson	,, ,, ,,	London.
J. T. Wright	Youth	N.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	From.	To.	Date.
Powell, G. T.	Clerk, Class II, South-West Dist.	Clerk, Class I, Northern Dist.	25 : 2 : 18
Ritchie, W.	Clerk, Class II, Scotland East Dist.	Clerk, Class I, Scotland East Dist.	1 : 2 : 18
Matthews, T. E.	Clerk, Class III, North Midland Dist.	Clerk, Class II, South Lancs Dist.	26 : 2 : 18
McKee, W. C.	Clerk, Class III, Ireland Dist.	Clerk, Class II, Ireland Dist.	30 : 1 : 18
Watson, W. G.	Clerk, Class III, South-West Dist.	Clerk, Class II, South-West Dist.	25 : 2 : 18

Retirement.

Name.	Rank.	District.	Date.
Slader, E.	Executive Engr.	Scot. E. Dist.	25 : 1 : 18

TRANSFERS.

Name.	Rank.	Transferred from.	To.	Date.
Fraser, J.	Exec. Engr.	E. in C.O.	Scot. E. Dist.	21 : 1 : 18
Bramwell, J. T. . .	,, ,,	S. Lancs Dist.	N.W. Dist.	11 : 2 : 18
Whillis, C. . . .	,, ,,	N.W. Dist.	North Dist.	12 : 2 : 18
Lonnon, W. U. . .	Asst. Engr.	London Dist.	E. in C.O.	14 : 1 : 18
Miller, W.	Clerk, Cl. II	S. Lancs Dist.	Scot. E. Dist.	25 : 2 : 18

DEATH.

Name.	Rank.	District.	Date.
Newton, E. W.	Executive Engr.	Northern	30 : 12 : 7

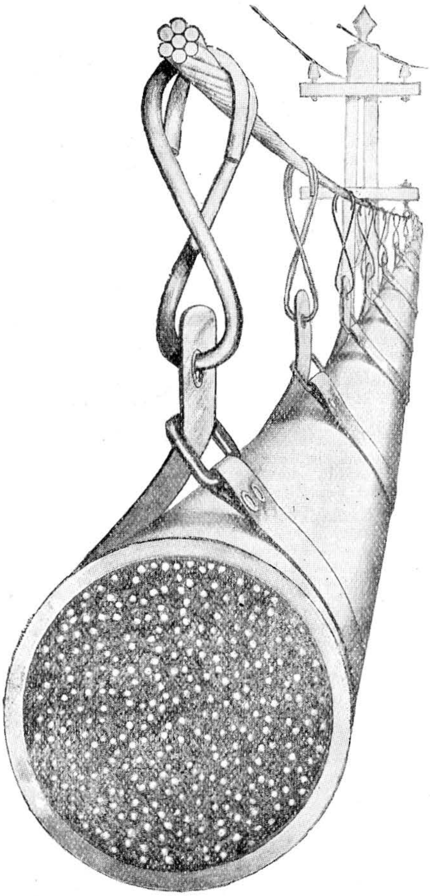
COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.O.E.E. JOURNAL, Engineer-in-Chief's Office, G.P.O. West, London, E.C.1.

Binding covers and copies of the Contents Index for Vol. 10 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol 10 bound, with index included, at a cost of 2*s.* 6*d.*, by sending the JOURNALS to the local agents. Orders should indicate whether the original binding with black lettering, or the later pattern in gold, are required. Covers for earlier volumes and indices may be obtained in the same manner, prices 1*s.* and 2*d.* respectively.

A supply of copies of the Station List of Engineering Officers, down to Assistant Engineers, is in stock, and may be obtained on demand, price 3*d.* each.

INDEX TO ADVERTISERS.



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