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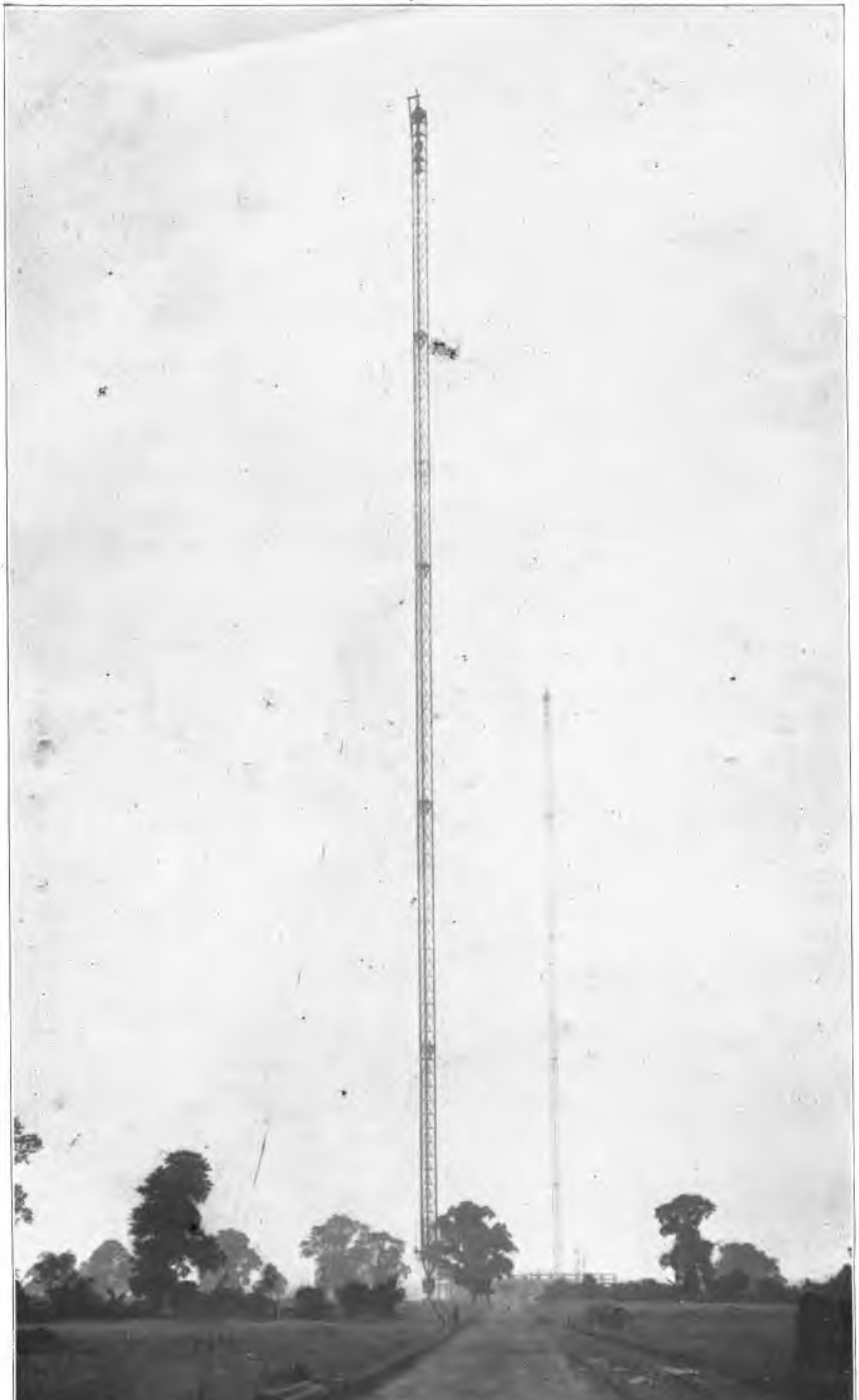


APPROACH TO THE RUGBY RADIO STATION, SHOWING TWO OF THE TWELVE 820 FEET MASTS.

THE
Post Office Electrical Engineers' Journal

THE THEORY OF THE SHUNTED CONDENSER.

By A. B. MORICE, B.Sc. (Eng.), A.M.I.E.E.

THE well-known circuit shown in Fig. 1 is usually employed for the reception of telegraph signals above a certain speed, the shunted condenser being used to increase the rate of rise of the signal current in the relay or receiver coils.

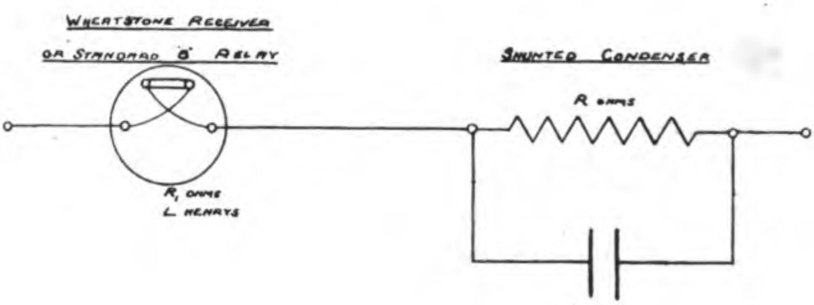


FIG. 1

The writer recently carried out an investigation of the effect of a shunted condenser on the rate of rise of the current in the coils of a Standard "B" Relay. It is proposed in this article to give a brief outline of the results obtained which, it is thought, will prove interesting and instructive. These results lead to conclusions which should apply equally to a Wheatstone Receiver or a Standard "B" Relay as the coils and magnetic circuit of the two instruments are of the same design.

I.—Mathematical Treatment.

The following symbols will be used :—

V = voltage of fixed value suddenly applied to the circuit.

i = instantaneous current in the circuit at time t secs. after the application of V.

I = maximum steady current in the circuit.

E = maximum value of a sinusoidal E.M.F. applied to the circuit.

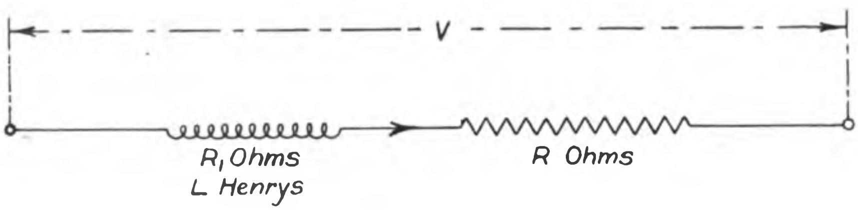
f = frequency in cycles per second.

ω = angular velocity in radians per second = $2\pi f$.

R_1 & L = resistance and inductance respectively of the receiver or relay.

R & C = resistance and capacity respectively of the shunted condenser.

FIG. II



If we consider, in the first place, the circuit shown in Fig. II the value of the current at any time t is given by :—

$$i = \frac{V}{R+R_1}\left\{1-e^{-\left(\frac{R+R_1}{L}\right)t}\right\} = I\left\{1-e^{-\left(\frac{R+R_1}{L}\right)t}\right\} \quad \ldots(1)$$

Formula (1) is proved in a number of text-books, for example, "Magnetism and Electricity," by H. E. Hadley, p. 431, 1905 edition.

The ratio $\frac{i}{I}\left[\text{which equals } 1-e^{-\left(\frac{R+R_1}{L}\right)t}\right]$ has been calculated for various values of $(R+R_1)$ ohms, using an inductance L of 3.5 henrys, and the results are given in Table I, and are plotted on Fig. III. The value of L used in these curves is a reasonable average figure for the ballistic inductance of a Standard "B" Relay with coils in series.

TABLE I.

Time t secs.	Ratio $\frac{i}{I}$ when $(R+R_1)$ ohms is equal to						
	100	300	500	700	1000	2000	5000
0.001	0.028	0.082	0.133	0.181	0.249	0.436	0.761
0.002	0.056	0.158	0.249	0.330	0.436	0.681	0.943
0.003	0.082	0.227	0.349	0.451	0.576	0.820	0.986
0.004	0.108	0.290	0.436	0.551	0.681	0.898	0.997
0.005	0.134	0.349	0.511	0.632	0.760	0.943	
0.008	0.204	0.496	0.681	0.798	0.898	0.990	
0.010	0.249	0.576	0.760	0.865	0.943	0.997	
0.015	0.349	0.724	0.883	0.950	0.986		
0.020	0.436	0.820	0.943	0.982	0.997		
0.025	0.510	0.883	0.972	0.993			
0.030	0.576	0.923	0.986	0.998			

From these tabulated figures and the corresponding graphs it will be seen that the rate of rise of the current in a circuit of constant inductance steadily increases with an increase of the

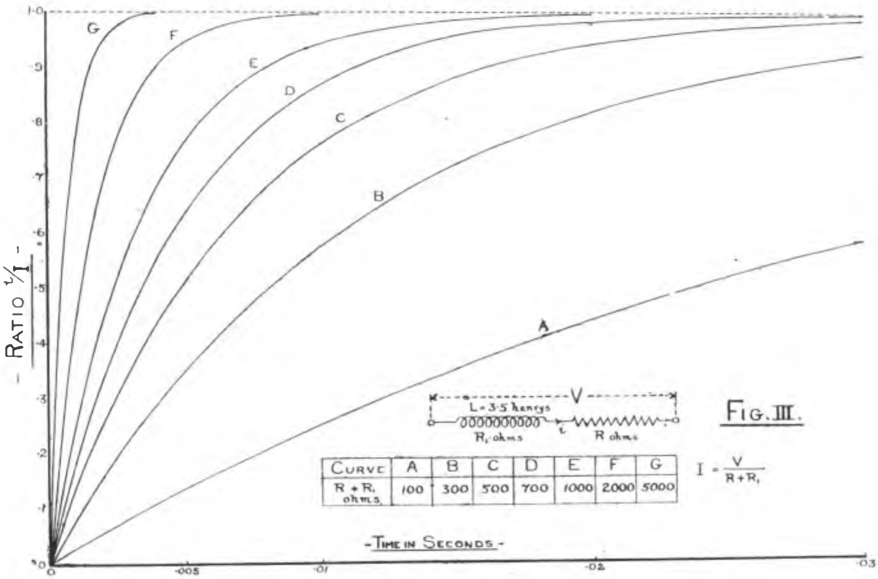


FIG. III.

resistance of that circuit. The voltage necessary to establish the required maximum steady current is directly proportional to the total resistance of the circuit. If there were no limit to the value of the voltage V then the current in the circuit shown in Fig. II could be made to rise as quickly as required to a definite maximum value by simply increasing the value of R.

In practice, however, V has a definite limit so that there is a maximum value beyond which R cannot be increased; if with this value of R the rate of rise of the current is not sufficiently rapid then it can be improved by shunting R with a capacity, and this improvement will be effected without altering the value of the maximum steady current.

Consider next the circuit shown in Fig. IV. The value of the current i at any time t is not, as far as the writer is aware, published in any technical literature and is therefore developed here.

The periodic solution is:—

$$i = \frac{Ee^{j\omega t}}{R_1 + j\omega L + \dfrac{1}{G + j\omega C}} \quad \text{where } G = \frac{1}{R}$$

Let $y = j\omega$

and $\phi(y) = R_1 + yL + \dfrac{1}{G + yC}$

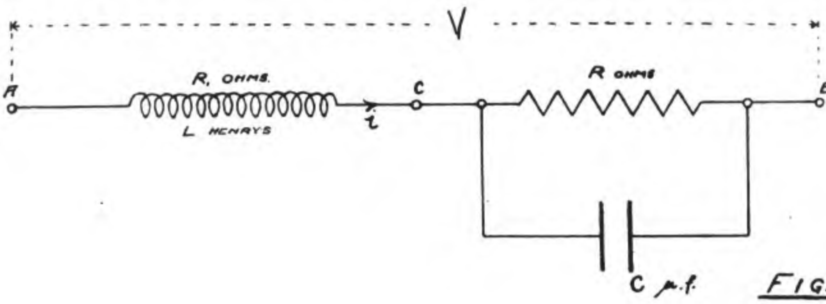


FIG. IV

Then the transient solution is:—

$$i = \frac{V}{\phi(0)} + \frac{Ve^{yt}}{y\phi'(y)}$$

where y is obtained from the equation $\phi(y) = 0$

and $\phi'(y) = \dfrac{d}{dy}[\phi(y)]$

Now $\phi(0) = R_1 + \dfrac{1}{G} = R_1 + R$

and $\phi'(y) = L - \dfrac{C}{(G + yC)^2}$

To find the value of $y\ \phi'(y)$ it is necessary to find y from $\phi(y) = 0$.

If $R_1 + Ly + \dfrac{1}{G + yC} = 0$

$$\text{then } y = -\left(\frac{R_1}{2L} + \frac{G}{2C}\right) \pm \sqrt{\left(\frac{R_1}{2L} - \frac{G}{2C}\right)^2 - \frac{1}{LC}}$$

$$= -\alpha \pm \beta \text{ (say).}$$

Two values of $y\,\phi'(y)$ will consequently be obtained according as y is equal to $(-\alpha+\beta)$ or $(-\alpha-\beta)$ and these two values are $\dfrac{2L\beta(R+R_1)}{(R+R_1)-L(\alpha+\beta)}$ and $\dfrac{2L\beta(R+R_1)}{L(\alpha-\beta)-(R+R_1)}$ respectively.

The complete transient solution is therefore :—

$$i=\frac{V}{R+R_1}+V\left\{\frac{e^{(-\alpha+\beta)t}}{\dfrac{2L\beta(R+R_1)}{(R+R_1)-L(\alpha+\beta)}}-\frac{e^{(-\alpha-\beta)t}}{\dfrac{2L\beta(R+R_1)}{(R+R_1)-L(\alpha-\beta)}}\right\}$$

or $$i=\frac{V}{R+R_1}\left\{1+e^{-\alpha t}\left[\frac{(R+R_1)-L(\alpha+\beta)}{2L\beta}e^{+\beta t}-\frac{(R+R_1)-L(\alpha-\beta)}{2L\beta}e^{-\beta t}\right]\right\}\quad\ldots\ldots\ldots(2)$$

where $\alpha=\left(\dfrac{R_1}{2L}+\dfrac{G}{2C}\right)$

and $\beta=\sqrt{\left(\dfrac{R_1}{2L}-\dfrac{G}{2C}\right)^2-\dfrac{1}{LC}}$; also $I=\dfrac{V}{R+R_1}$.

By using equation (2) the value of $\dfrac{i}{I}$ can be calculated for any value of t if R_1 L G and C have definite values. A series of such calculations has been made and is given in Table II, taking $L=3.5$ henrys, $R_1=300$ ohms, $R=700$ ohms, and $C=$various values.

TABLE II.

$R=700$ ohms. $R_1=300$ ohms. $L=3.5$ henrys.

Time t secs.	Ratio $\frac{i}{I}$ when C $\mu.f.$ is equal to							
	0	0.5	1.0	1.483	2.0	3.0	5.0	10.0
0.001	0.249	0.260	0.264	0.408	0.421	0.271	0.271	0.273
0.002	0.436	0.457	0.473	0.650	0.690	0.499	0.508	0.515
0.003	0.576	0.605	0.626	0.793	0.854	0.681	0.704	0.727
0.004	0.681	0.709	0.736	0.877	0.947	0.818	0.860	0.905
0.005	0.760	0.786	0.814	0.927	0.997	0.915	0.977	1.050
0.008	0.898	0.915	0.935	0.985	1.027	1.037	1.140	1.306
0.010	0.943	0.954	0.968	0.995	1.018	1.045	1.148	1.357
0.015	0.986	0.990	0.994		1.002	1.013	1.058	1.255
0.020	0.997	0.998			1.000	1.000	0.998	1.080
0.025					1.000	0.999	0.990	0.979
0.030					1.000	1.000	0.997	0.959

The figures given in Table II have been plotted in Fig. V. From these curves it will be seen that the rate of rise of the current in the circuit increases as C is increased until when $\beta=0$

a critical value of C is reached, which in this particular case is 1.483 $\mu.f.$ If C be still further increased the instantaneous current will rise above its maximum steady value and then oscillate about this value until the oscillation is damped out. The larger C is now made, the greater the maximum transient current value becomes. These curves assume fixed values of R_1 and L for the resistance and the inductance; as these values vary considerably with frequency and testing current in the case of a Wheatstone Receiver

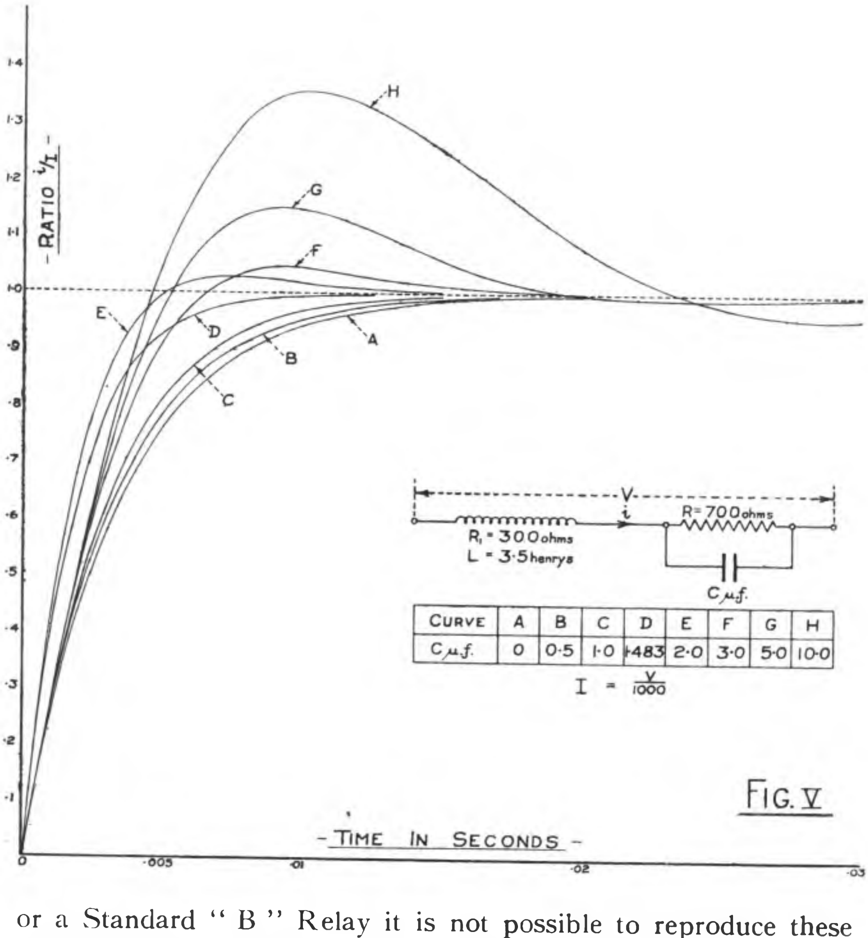


FIG. V

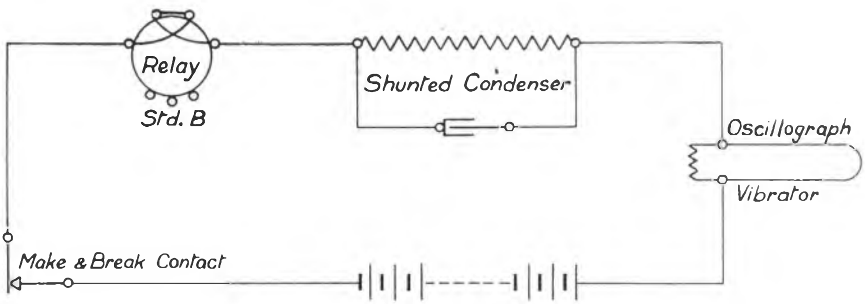
or a Standard "B" Relay it is not possible to reproduce these curves exactly in practice. But it will be seen from several oscillograph records which will now be shown that a similar set of curves is actually obtained under practical conditions.

II.—Oscillograph Curves.

A series of curves was taken by means of the oscillograph in order to show the actual effect of a shunted condenser on the rise of current in a Standard " B " Relay when a voltage is suddenly applied to the circuit. The connections employed are shown in Fig. VI, and the curves are shown in Figs. VII*a* and VII*b*.

In all these records, with the exception of No. IX, the value of R was fixed at 700 ohms; the condenser values were increased from 0 to 10 $\mu.f.$ as shown in Table III which follows. Curve No. IX shows the rise of current given in Fig. VI, when C and R

FIG. VI



Voltage adjusted to give a steady Current of 30 m.A.

are both zero. By comparing this last curve with No. I of the series it will be seen clearly that by adding non-inductive resistance alone in series with the relay the rate of rise of the current in its coils has been appreciably increased.

TABLE III.

Oscillograph Curve No.	Shunted Condenser Values. R ohms.	C $\mu.f.$	Maximum steady current in m.a.
I.	700	0	30
II.	,,	1	,,
III.	,,	2	,,
IV.	,,	3	,,
V.	,,	4	,,
VI.	,,	5	,,
VII.	,,	8	,,
VIII.	,,	10	,,
IX.	0	0	,,

The values of $\frac{i}{I}$ for different values of t have been obtained from these curves by measurement and are given in Table IV. By comparing these figures with those given in Table II a fair agreement is observed, but it would not appear to be possible for any figures calculated with fixed values of R_1 and L to agree

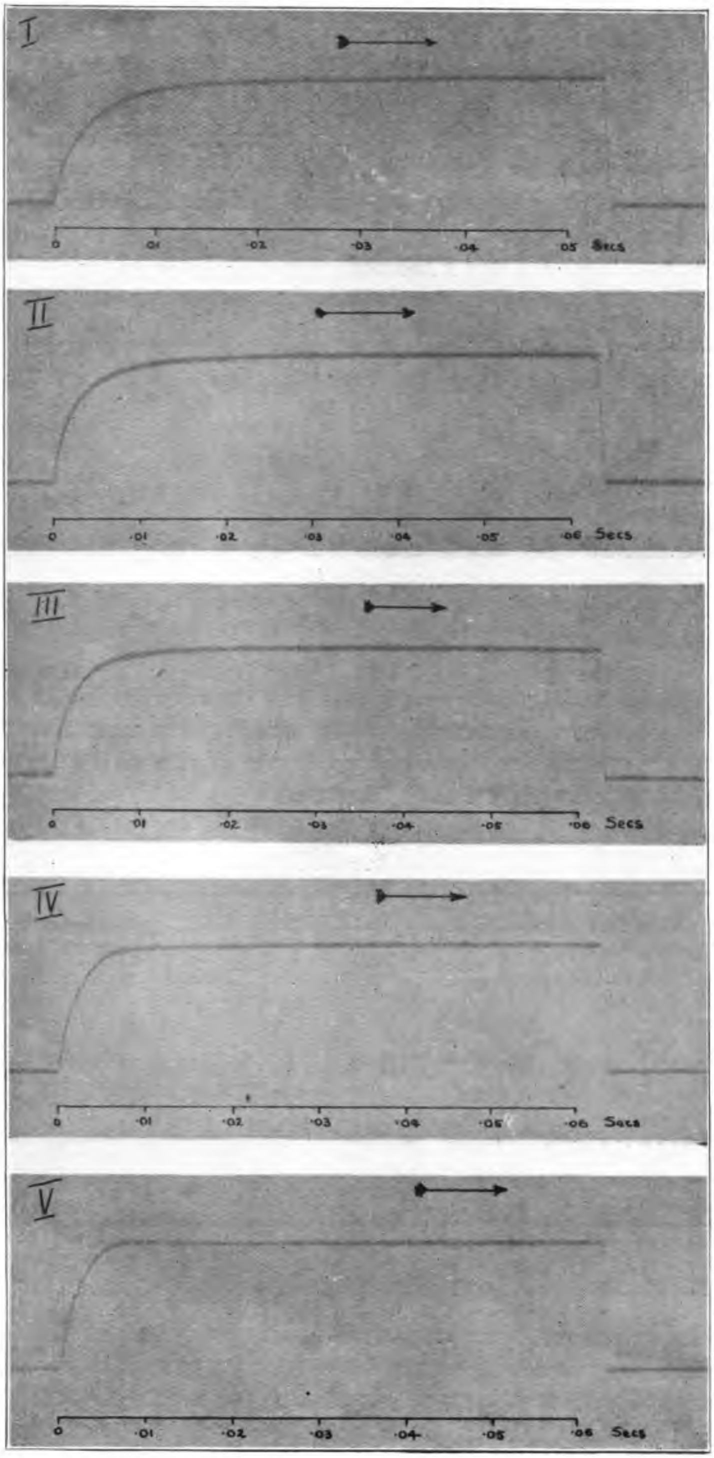

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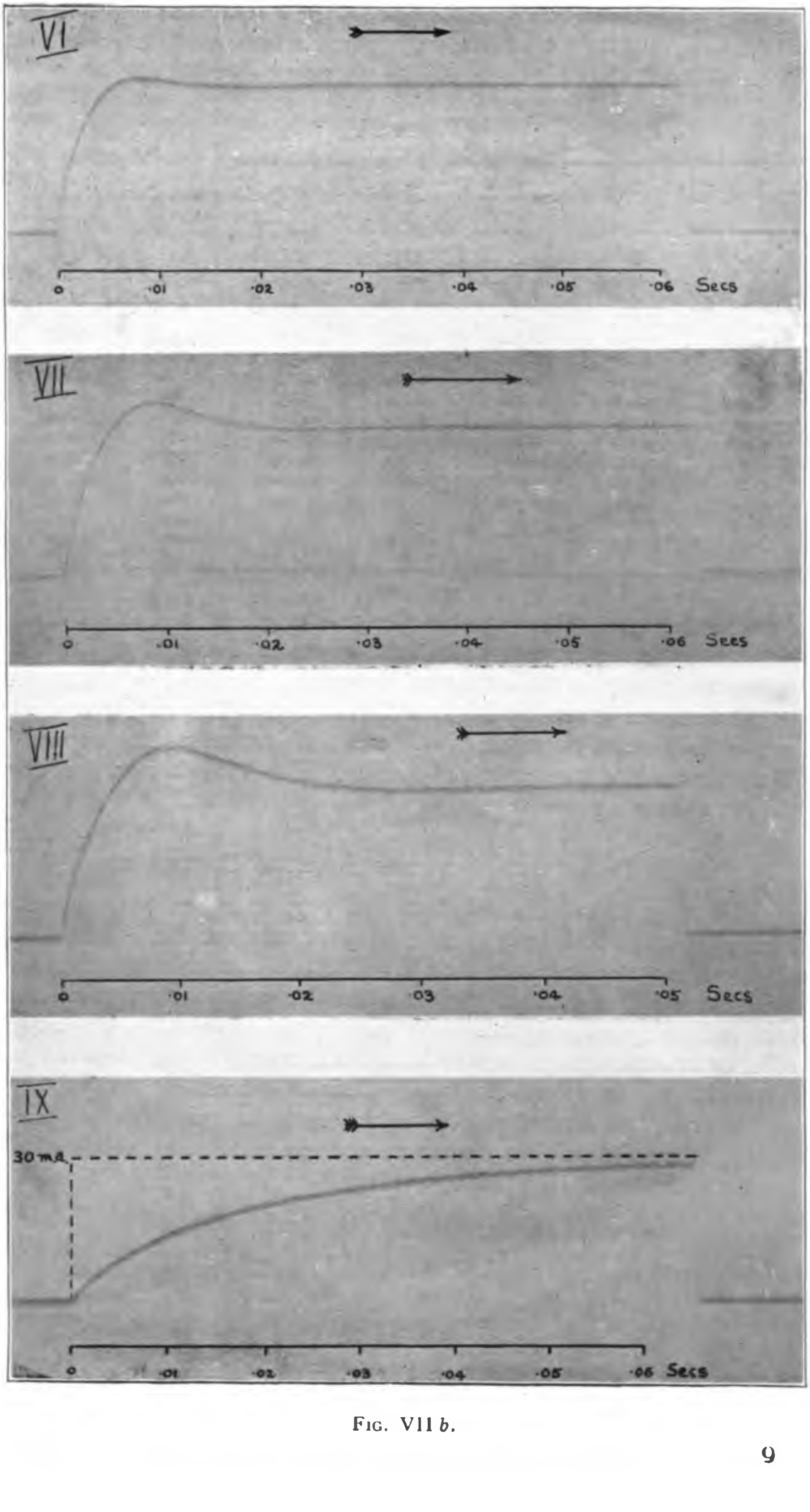
FIG. VII *a*.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IX
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Secs

Fig. VII *b*.

exactly with those actually obtained with a relay having a resistance and inductance which vary considerably with current and frequency.

TABLE IV.

Time t secs.	Values of $\frac{i}{I}$ by measurement of Oscillograph Curve No.					
	I. C=0 $\mu.f.$	II. C=1 $\mu.f.$	III. C=2 $\mu.f.$	IV. C=3 $\mu.f.$	VI. C=5 $\mu.f.$	VIII. C=10 $\mu.f.$
0.001	0.320	0.404	0.428	0.356	0.392	0.396
0.002	0.488	0.592	0.592	0.592	0.620	0.604
0.003	0.592	0.688	0.712	0.732	0.784	0.828
0.004	0.660	0.760	0.792	0.836	0.898	0.972
0.005	0.732	0.808	0.832	0.890	0.976	1.104
0.008	0.872	0.896	0.920	0.960	1.076	1.290
0.010	0.912	0.928	0.952	0.976	1.051	1.290
0.015	0.960	0.968	0.980	0.992	1.000	1.164
0.020	0.980	0.988	0.999	0.999	1.000	1.060
0.025	0.992	0.999			1.000	1.016
0.030	0.999				1.000	1.000

It is thought, however, that the results given in Table IV are sufficiently in agreement with those given in Table II to confirm the accuracy of the mathematical theory outlined.

The curves given in Figs. V, VII*a* and VII*b* enable a clear mental picture to be made of the effect of increasing the capacity of the shunted condenser in the circuit of Fig. VI, other parts of the circuit remaining unaltered.

III.—THE "LAW" OF THE SHUNTED CONDENSER.

Referring to the circuit shown in Fig. I, it has been stated* that when the inductance of the relay or receiver (L) is balanced by the shunted condenser then $L=CR^2$. From this statement it has generally been assumed that when this relationship exists the received telegraph signals will be "square-topped." A large number of oscillograph curves have been taken in an endeavour to prove this assumption without any definite success.

In order to investigate whether such an assumption was justified the following mathematical and experimental investigation has been made:—

(*a*) *Mathematical Investigation of the Problem.*

If an alternating voltage, frequency $= \frac{\omega}{2\pi}$, be applied at the terminals AB of the circuit shown in Fig. IV, then the current in

* See "Telegraphy," by T. E. Herbert, p. 315, 1906 edition.

the circuit will be in phase with this voltage if a certain condition is satisfied. This condition may be obtained as follows:—

Impedance $AC = R_1 + j\omega L$

$$\text{,,} \quad CB = \frac{jR}{j - \omega RC}$$

$$\therefore \text{Impedance } AB = R_1 + j\omega L + \frac{jR}{j - \omega RC}$$

$$= R_1 + j\omega L - \frac{jR\,(j + \omega RC)}{1 + \omega^2 R^2 C^2}$$

$$= \frac{(R_1 + j\omega L)\,(1 + \omega^2 R^2 C^2) - jR\,(j + \omega RC)}{1 + \omega^2 R^2 C^2}$$

$$= \frac{R_1 + R + \omega^2 R_1 R^2 C^2 + j\,(\omega L + \omega^3 LR^2C^2 - \omega R^2 C)}{1 + \omega^2 R^2 C^2}$$

If the current is in phase with the voltage in this impedance then it follows that:—

$$\omega L + \omega^3 LR^2C^2 - \omega R^2 C = 0$$

Hence $\omega = 0$ or $L + \omega^2 LR^2C^2 - R^2C = 0$

$$\textit{i.e.,} \quad CR^2\,(1 - \omega^2 LC) = L$$

$$\therefore CR^2 = \frac{L}{1 - \omega^2 LC} \qquad \text{..............................(3)}$$

Condition (3) must be satisfied if the impedance AB is to be non-reactive when the applied voltage has a frequency of $\frac{\omega}{2\pi}$.

Now if telegraph reversals applied to the circuit AB are to be exactly "square-topped" it follows that this circuit must be non-reactive to currents of all frequencies which are present in these signals. It is necessary, therefore, to consider what frequencies are present in telegraph reversals. The current curve of such signals, neglecting the short period of break between marking and spacing currents, is shown in Fig. VIII, and the equation to this curve is:—

$$y = \sin \omega t + \tfrac{1}{3} \sin 3\omega t + \tfrac{1}{5} \sin 5\omega t + \tfrac{1}{7} \sin 7\omega t + \tfrac{1}{9} \sin 9\omega t + \ \text{..........(4)}$$

where y represents the current at any time t, and $y = 0$ when $t = 0$.

It will be seen from equation (4) that (*a*) there are an infinite number of frequencies included in the current shown in Fig. VIII, and (*b*) if the magnitude of the current of the fundamental frequency be represented by unity, the magnitudes of the currents of the third, fifth, seventh, etc., harmonics are represented respectively by $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{7}$, etc.

It is next necessary, using the information given by formulæ (3) and (4), to ascertain under what conditions the circuit shown in Fig. IV will be non-reactive when the telegraph signals shown in Fig. VIII are sent through it. In order to make this investigation

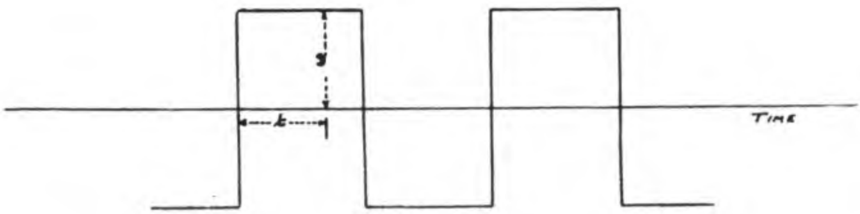

FIG. VIII

assume a telegraphic speed of 60 words per min., corresponding to a fundamental frequency of 24 cycles per sec. The inductance of a certain Standard "B" Relay, between the limits—

24 cycles per sec. with 20 m.a.
and 984 ,, ,, ,, 0.49 m.a.

was measured and the results are given in Fig. IX (Curve E). The testing currents in m.a.'s at the intermediate frequencies were equal to $\frac{20 \times 24}{f}$ *i.e.* $\frac{480}{f}$ in order to satisfy the current law given in equation (4). Now using formula (3) the values of L can be calculated for various values of ω and C, assuming CR^2 is a constant. This constant, when $\omega = 0$, is equal to L, which is the inductance of the relay obtained by d.c. or ballistic test. In the case of the relay under consideration the ballistic L, with a current of 20 m.a., was found to be 3.9 henrys. The results of the calculations for L are given in Table V which follows:—

TABLE V.

f	ω	Value of $L = \frac{3.9}{1+3.9\omega^2 C}$, when C in $\mu.f.$ =							
		0.10	0.25	1.0	2.0	3.0	4.0	5.0	6.0
0	0	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90
24	151	3.87	3.82	3.50	3.32	3.10	2.90	2.72	2.57
72	453	3.61	3.25	2.17	1.50	1.15	0.928	0.780	0.672
120	755	3.19	2.51	1.21	0.717	0.509	0.395	0.322	0.272
168	1057	2.72	1.87	0.728	0.402	0.277	0.212	0.171	0.144
216	1359	2.27	1.39	0.476	0.253	0.173	0.131	0.105	0.088
264	1661	1.88	1.06	0.332	0.173	0.117	0.089	0.071	0.060
360	2265	1.30	0.650	0.186					
504	3171	0.793	0.360	0.097					
744	4681	0.409	0.175						
984	6191	0.244	0.102						

The variation of L with frequency given in Table V, for four of the values of C assumed, has been plotted on Fig. IX, Curves A, B, C and D. These four curves give, for any value of C, the variation of the inductance of the relay with frequency in order that the circuit, Fig. IV, may be non-reactive to telegraph reversals when CR^2 is constant and equal to 3.9.

Although the figures given in Table V have been calculated using a fundamental frequency of 24 cycles per second (corresponding to 60 words per minute) yet the same values will be obtained for any assumed speed of the telegraph reversals, if CR^2 is equal to 3.9.

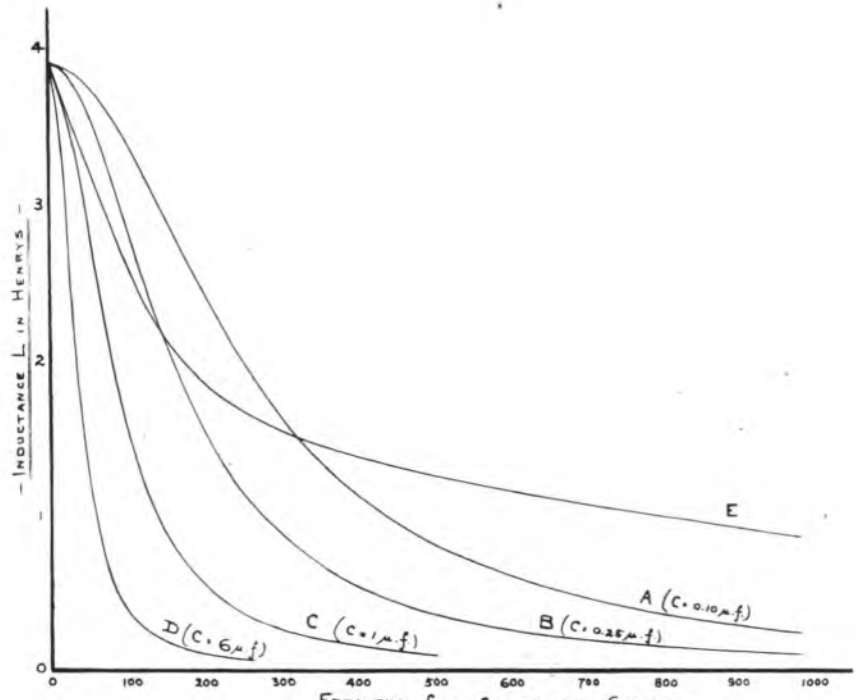

Fig. IX.—Variations of Inductance with Frequency.

The curve E, however, is an experimental one and is only correct for the particular relay tested and with the testing currents in accordance with the law stated.

From the curves given on Fig. IX, the following deductions can be made:—

(1) Using the Standard "B" Relay before-mentioned and a fixed value of CR^2, no value of C can be found which will make the circuit shown in Fig. IV exactly non-reactive when telegraph reversals at 60 words per minute (maximum current = 20 m.a.) are

being received. It will also be seen that with small values of capacity C and consequently large values of R the circuit Fig. IV is more nearly non-reactive to the telegraph reversals than when large values of C and small values of R are used.

(2) With any given relay or receiver there is, at most, only one value of C (assuming CR^2=constant) which will make the circuit shown in Fig. IV truly non-reactive to telegraph reversals. This condition occurs when curve E is coincident with a curve such as A, B, C or D, Fig. IX. This means that exact "square-topped" reversals can only be obtained with, at most, one value of C if CR^2 is constant.

(3) If a value of CR^2 other than 3.9 be used for a series of curves such as A, B, C and D, they will not coincide with E when the frequency is zero.

By using the values of L given by the curve E, Fig. IX, and assuming CR^2 equal to 3.9 say, it is possible to calculate the values of C which will satisfy the equation (3) for different frequencies. In Table VI are given the calculated values of C for the different frequencies, up to the 41st harmonic, contained in telegraph reversals corresponding to a speed of 60 words per minute.

TABLE VI.

$$C = \frac{3.9 - L}{3.9\omega^2 L}$$

f	ω	L hys. (See curve E, Fig. IX.).	C $\mu.f.$
24	151	3.55	0.111
72	453	2.90	0.450
120	755	2.37	0.290
168	1057	2.00	0.218
216	1359	1.74	0.173
264	1661	1.58	0.137
312	1961	1.48	0.109
360	2265	1.41	0.088
504	3171	1.24	0.055
744	4681	1.04	0.032
984	6191	0.85	0.025

From the foregoing it appears evident that if, by a coincidence, exact "square-topped" telegraph reversals are obtained in a Standard "B" Relay or Wheatstone Receiver by placing a shunted condenser in series with it, then only one value of C with the corresponding value of R will effect this. No such law as CR^2=L or some constant appears to apply.

In actual telegraph working, however, the shunted condenser will function satisfactorily provided that it causes the current in the relay coils to rise to its maximum value within a certain time. This time, t, which will depend on the speed of working, should not exceed the time occupied by a dot signal. With a telegraph speed of 400 words per minute a dot signal occupies $\frac{1}{320}$ or 0.0031 second.

Oscillograph curves show that if the time t be reduced to a very small value by means of a shunted condenser, using the circuit shown in Fig. IV, the shape of the telegraph signal will generally be similar to that shown in Fig. X. This type of signal

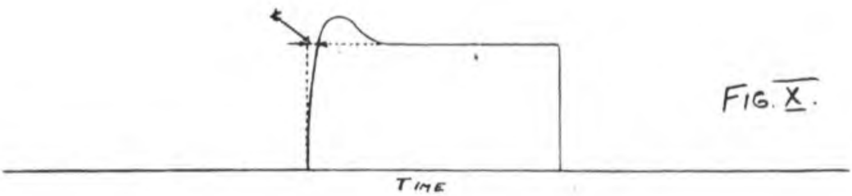

FIG. X.

is usually considered to be ideal, as the initial excess of current will result in a quick movement of the relay contact arm from one stop to the other and the steady value will then hold the arm firmly on the working contact.

Some investigations have recently been made to determine the inductance of a Standard " B " Relay with different currents and frequencies. It is thought that these may prove a useful addition to this section of this article and they are, therefore, included here.

(*b*) *The variation of inductance of a Standard " B " Relay with variation of current and frequency.*

The following experiments, selected from a number which have been made, will suffice to show how variable is this inductance with different conditions of test :—

(1) Six Standard " B " Relays were obtained and the resistance and inductance of each of them measured, using an alternating current of 4.5 m.a. (R.M.S.) of a frequency of 50 cycles per second. The figures obtained, with coils in series, were as given in Table VII.

TABLE VII.

Relay Sample No.	1	2	3	4	5	6
Effective Resistance in ohms ...	475	522	495	540	511	485
Inductance in henrys	3.50	2.90	2.60	3.65	3.00	3.35

These results show that, under the same conditions of test, there was as much as 1.05 henrys difference in inductance between two of the relays; the maximum difference in effective resistance of these relays, under the same conditions of test, was 65 ohms.

(2) The inductance of a selected relay, coils in series, was measured with frequencies from 0 to 160 cycles per second, and currents from 1 to 25 m.a. Table VIII gives the experimental results.

TABLE VIII.

INDUCTANCE OF STANDARD "B" RELAY, COILS IN SERIES.

Frequency f	Testing current in m.a.						
	1.0	3.0	4.5	10	15	20	25
0 (Ballistic Test)	2.64	3.21	3.47	3.69	3.85	3.88	3.90
12	2.35	2.66	2.76	3.09	3.23	3.39	3.51
25.5	1.96	2.34	2.48	2.97	3.20	3.27	3.32
52.5	1.64	1.92	2.11	2.72	2.90	2.97	3.01
71.5	1.47	1.75	1.97	2.56	2.74	2.79	2.81
100	1.27	1.55	1.74	2.36	2.43	2.50	2.53
134	1.17	1.37	1.62	2.22	2.36	2.38	2.36
160	1.08	1.29	1.50	2.08	2.23	2.25	2.22

The inductance in Table VIII varies from 3.90 henrys (ballistic test with 25 m.a.) to 1.08 henrys (frequency of 160 cycles per second with 1 m.a.). This latter frequency is the fundamental one for telegraph reversals corresponding to 400 words per minute.

As an interesting comparison the inductance of the same relay, coils in parallel, with a current of 4.5 m.a. is given in Table IX.

TABLE IX.

INDUCTANCE OF STANDARD "B" RELAY, COILS IN PARALLEL AND A TESTING CURRENT OF 4.5 M.A.

Frequency (f)	0 (Ballistic test).	11.0	26.4	50.0	75.7	81.6	102	134	167
Inductance in Henrys	0.775	0.653	0.501	0.453	0.384	0.360	0.324	0.297	0.262

The figures given in Table VIII (current 4.5 m.a.) and also those given in Table IX are plotted on Fig. XI.

IV.—CONCLUSIONS.

(*a*) The effect of the shunted condenser, shown in Fig. I, is to reduce the time taken by the current to reach the maximum value due to a suddenly applied constant voltage. The exact effect with different values of R and C may be studied by means of formula

(2) if R_1 and L are fixed values; using a Standard "B" Relay the rise of current curves will only approximate more or less to those given by (2) on account of the variation of R_1 and L with current and frequency.

(*b*) In order that telegraph reversals applied to the circuit shown in Fig. I may be exactly "square-topped," this circuit

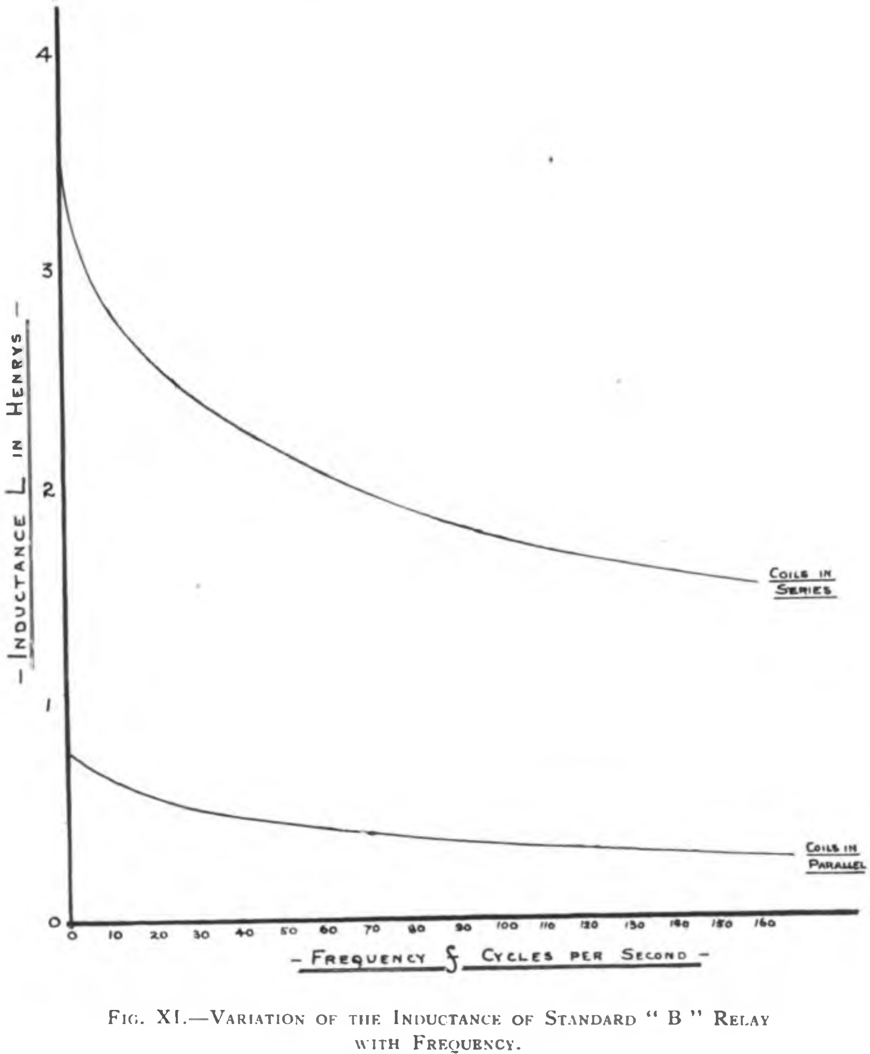

FIG. XI.—VARIATION OF THE INDUCTANCE OF STANDARD "B" RELAY WITH FREQUENCY.

must be non-reactive to such signals. It can be proved mathematically that (1) this condition cannot be satisfied, if CR^2 is a constant, for more than one value of C with the corresponding value of R and (2) if this condition be satisfied it is a coincidence. In order that the current may rise to its maximum sufficiently quickly for high speed working, oscillograph curves show that the shape of the signal in this circuit will usually be of the type shown in Fig. X.

(*c*) The inductance of a Standard "B" Relay varies considerably with the testing current and frequency, See Tables VIII and IX.

(*d*) The conclusions already enumerated are considered to apply equally to a Wheatstone Receiver or a Standard "B" Relay, as the coils and magnetic circuit of both instruments are of the same design.

ALARMS, REPEATER, No. 3.

At telegraph repeater stations the sounders which form part of the repeater sets are, as a rule, normally kept out of circuit. In such cases a means whereby the other stations on the circuit can gain the attention of the repeater station is provided. The arrangement at the latter point has been changed from time to time, but the procedure at the other points has never varied; a marking current is sent to line through an interval of 20 seconds. This results in an audible signal at the repeater station; either the appropriate sounders are automatically brought into circuit or the signal takes the form of a ring on a trembler bell; in the latter case the sounders are switched in by hand. Formerly the calling apparatus at the repeater station was comprehended under the term "Sounder Silencer." The subject was dealt with in an article by Mr. J. J. Hardie in the July, 1919, issue of this Journal. Since then the term "Sounder Silencer" has been displaced by that of the "Alarm Repeater," principally for the reason that attention is attracted by the ringing of a bell.

The basis of the action of the "Sounder Silencer No. 3," the "Alarm Repeater No. 1," and also of the "Alarm Repeater No. 3," which is now being introduced, is the slow charging of a condenser through the 20 seconds period, followed by the direct discharge of the condenser through the alarm indicator or relay. That is to say, the charge accumulated in 20 seconds is sufficient to actuate the indicator or relay, with a reasonable margin over. A 15 seconds charge, for instance, or anything less, should fail. The alarm is therefore unaffected by the ordinary working currents of the circuit.

The theory underlying the charging and discharging may be briefly stated thus: the equation of electro-motive forces for a battery of voltage v joined in series with a condenser of capacity c, a resistance r and an inductance l is:—

$$l\frac{d^2q}{dt} + r\frac{dq}{qt} + \frac{q}{c} = v \qquad \text{...(1)}$$

q being the instantaneous value of the accumulated charge. If l and r are small, as in the ordinary case of connecting a condenser direct to a battery, the first and second terms in (1) may be rejected, reducing that statement to the well-known and explicit form :—

$$\frac{q}{c} = v \qquad \text{...(2)}$$

FIG. 1.—ALARM, REPEATER, NO. 3.

The condenser becomes fully charged instantaneously.

When a resistance r is interposed between the battery and condenser in the above case the rate of charging is decreased. The equation is now :—

$$r\frac{dq}{dt} + \frac{q}{c} = v \qquad \text{...(3)}$$

At the moment of completing the circuit the value of $\frac{q}{c}$ is zero and that of $r\frac{dq}{dt}$ is v. With the passage of current a charge accumulates, so that $\frac{q}{c}$ increases and $r\frac{dq}{dt}$ decreases until, when the condenser is fully charged, $\frac{q}{c}$ equals v, as before, and $r\frac{dq}{dt}$, that is, $\frac{dq}{dt}$, is zero. In short, the charging current $\frac{dq}{dt}$ starts with the maximum value $\frac{v}{r}$ and decreases towards zero; time enters into the charging process.

The solution to (3) is :—

$$q_t = cv\left(1 - \epsilon^{-\frac{t}{cr}}\right) \quad \text{.......................................(4)}$$

where q_t is the accumulated charge after t seconds and cv is the final steady charge. The product cr is, of course, the time constant of the circuit and as such constitutes a basis or standard for the few necessary calculations in the present case. For if t is made numerically equal to the product cr in (4) that statement simplifies to :—

$$q_t = \cdot 634\, cv \quad \text{.......................................(5)}$$

That is, in time t equal to cr the accumulated charge amounts to roughly two-thirds of the final steady charge.

On the assumption that the charging circuit is made up of the battery, condenser and a pure resistance without inductance, the procedure now is simple. Employing equation (2) the quantity q is ascertained by experiment that will just actuate with certainty the relay or indicator it is proposed to use. Replace q_t in (5) by the value of q just found and so obtain the value of the slowly charged condenser c, v having the same value as in the experimental application of (2). It only remains to ascertain the value of r from the relation $t = cr$, which was made the basis of (5).

The assumption as to the absence of inductance, however, is in practice inadmissible for the following reasons. The lead from the battery to the resistance at repeater stations, as at any large telegraph station, is very probably one of a number of wires in a lead-covered cable, the length of which may be anything from ten to thirty yards; the high resistance unit itself cannot be said to be non-inductive. It might be urged that the values of the inductances in the circumstances are small and negligible, but not when it is considered that the initial and maximum value of the charging current is no greater than of the order of ten microamperes. Now, any individual case might be met by applying the solution to equation (1) but for the fact that if the presence of inductance is admitted by reason of the contiguous conductors in the battery cable, it must also be admitted that that inductance varies with the number of contiguous conductors in use at any given moment.

The effect of any such inductance must be, by equation (1), to make the initial value of the charging current zero and to reduce its maximum value; the accumulation of charge q is delayed. Fortunately, it is only necessary to recognise the effect; the 20 seconds charging interval allows of a fair safety margin.

The Indicator No. 100A has been adopted for the Alarm Repeater No. 3, its coils being joined in parallel. This instrument can be actuated unfailingly by a 1 μf condenser charged direct from 80 volts (Equation 2). The appropriate condenser of C μf charged from the same voltage through a resistance of R ohms, the value of which is such that t equals $C_f R$, is 1.6 μf (Equations 4 and 5). C_f being stated in farads, R is at once seen to be 12.5 megohms.

This, however, leaves no safety margin whatever, even if the retarding inductance effect were not present. Actually, the stock 2 μf condenser is being used; taking this value for C and reducing t from 20 seconds to 15 gives the value of R as 7.5 megohms. From what has been learned from the limited trials it is expected the conditions generally will be met by the use of 6-megohm resistances.

A reference to Mr. Hardie's article will show that the idea of employing this method of calling repeater stations is by no means new. The idea itself is neat and appealing in its theory, but in those days practice failed, unfortunately, to support the theory in so far as it was difficult to obtain resistances having values suited to the stock instruments that the conditions demanded. Not only so, such resistances as were available were very inconstant. The position to-day is very much improved though not perfect. With a little trouble fixed resistances can be obtained which closely approximate to almost any stated value up to ten megohms. What is more important, selected types show very little variation with current, especially with the small maximum of ten micro-amperes or so used in the present case.

The new instrument is shown in Fig. 1 and a diagram of its wiring in Fig. 2. It will be seen that the audible alarm is supplemented by a visual signal in the shape of a lamp. The terminals RS, RT and RM on each side of the diagram are connected to the S, T and M terminals of the leak relay and receiver respectively of the repeater.

In investigating the subject recently a trial was made of a relay having a retaining connection. It was thought a relay would be preferable to use in place of a drop indicator for the

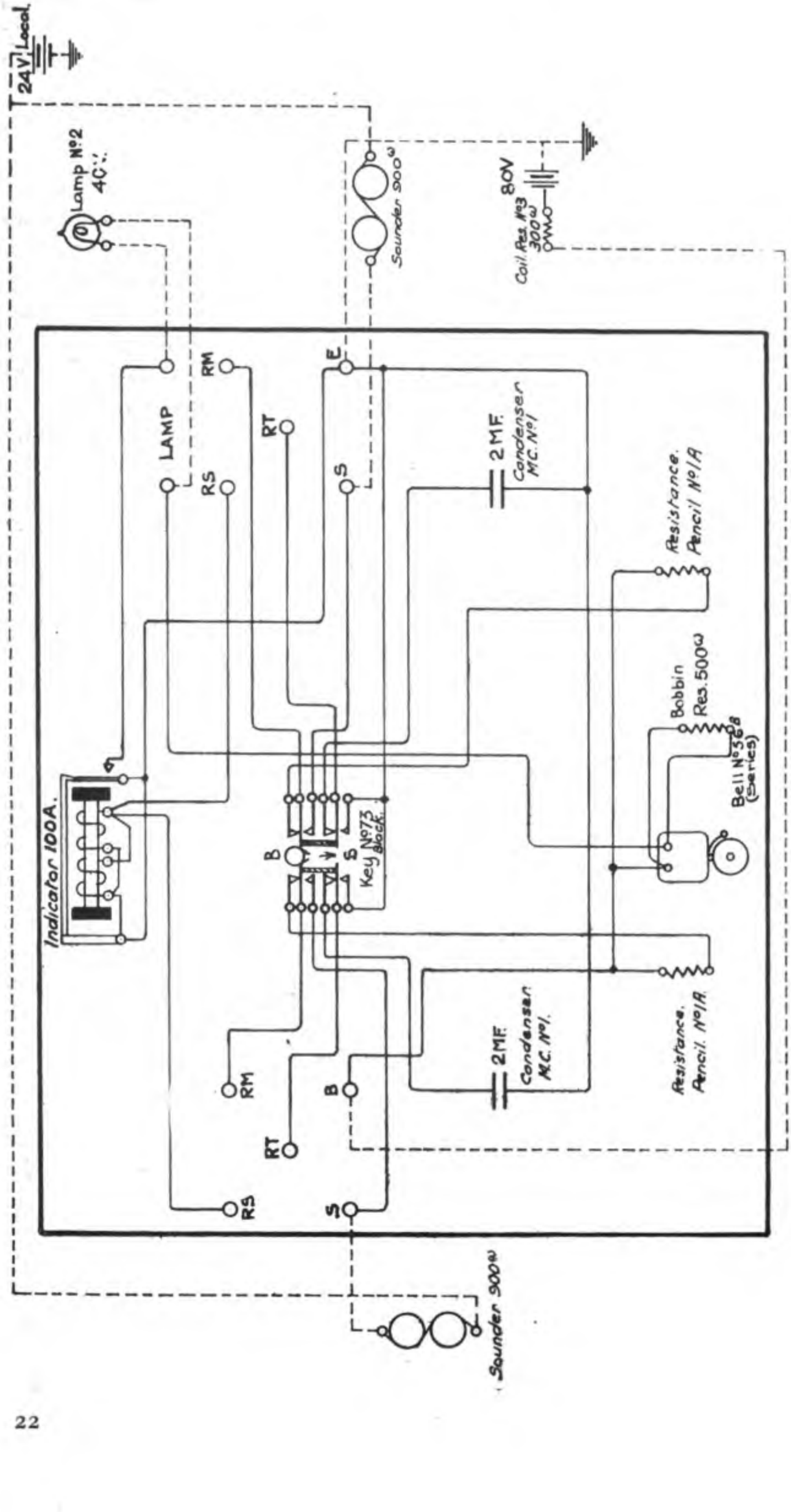

Fig. 2.—Wiring of Alarm, Repeater, No. 3.

reason that with the latter a cumulative action resulting in a false call might be exhibited. That is to say, if the signalling currents were such that charging periods of, say, five seconds or so were met with, any one of these charges, while insufficient by itself to actuate the drop definitely, might move the armature to a new position relatively to its shutter, *i.e.*, the trigger overlap would be reduced. Consequently, if this were repeated sufficiently often the indicator would ultimately be actuated. So far as experience has shown, the fears are unfounded. Nevertheless, the point may be mentioned as likely to interest the maintenance staff.

J.B.L.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST DECEMBER, 1924.

Telephone Stations.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
433,002	618	4,153	57,752	502	London	22,097	46,219	1,497,619	48,972
51,008	1,904	19,160	51,464	1,680	S. East	3,723	18,169	81,702	12,437
53,965	4,340	24,252	41,513	1,740	S. West	13,473	3,153	82,320	6,169
42,058	8,719	29,658	37,777	5,706	Eastern	13,688	20,285	42,526	26,005
73,794	8,592	40,957	49,137	3,383	N. Mid.	16,258	28,546	122,631	80,044
51,097	4,907	25,247	52,182	4,514	S. Mid.	10,452	12,948	99,551	83,768
48,552	5,100	27,600	42,771	1,970	S. Wales	5,304	13,410	71,682	24,326
76,328	8,551	23,223	40,503	4,838	N. Wales	11,818	28,155	134,927	44,414
121,089	3,006	16,692	46,554	3,384	S. Lancs.	12,259	55,139	300,380	42,368
72,643	6,282	28,763	42,840	2,833	N. East	7,901	22,354	145,865	24,926
47,868	3,890	23,614	38,132	2,026	N. West	7,587	26,792	91,759	20,971
38,069	2,539	15,111	23,217	2,103	North	2,740	8,256	59,910	7,383
17,308	4,784	5,821	11,122	246	Ireland N.	139	58	28,243	100
50,124	5,601	20,749	32,375	1,261	Scot. East	1,575	5,745	79,902	11,566
72,852	7,514	22,419	39,088	953	Scot. West	12,366	18,962	180,703	27,999
1,249,738	76,347	327,419	606,427	37,139	Totals.	141,380	308,191	3,019,720	461,448
1,219,323	76,960	321,916	598,072	35,468	Figures on 30th Sept., 1924.	139,184	288,446	2,954,003	452,936

MECHANICAL AIDS.

SOME ASPECTS OF "AUTOMATIC" TELEPHONE WORK.

By W. Wheeler.

In a brief and convincing article appearing in the July, 1920, issue of this Journal, Mr. B. O. Anson dealt with the dominating factors which have been responsible for the commencement of the era of "The Automatic Telephone." The article bases the case on the claims of "Service," and concludes with the statement: "*If the telephone man's ideal of Universal Service is to be attained, it is clear that he must employ a machine for switching.*"

Satisfactory Automatic Exchange Maintenance involves a fair number of routine operations on the considerable number of automatic units which go to make up a telephone exchange. To entrust the care of these operations to "the machine" would, in the opinion of the writer, not only relieve the manual staffs of unwanted duties (thereby promoting "Manual" efficiency) but lead to their performance with increased speed and efficiency.

The considerable number of circuit diagrams and switching arrangements developed during recent years makes it very difficult for one to get matters in their true perspective to-day. Views are held in some quarters that automatic testing arrangements which dealt fully with Automatic Switching equipment must be fearful and wonderful as well as "expensive." Men who supported unstintingly the introduction of automatic switching long before such views were popular consider that automatic testing must mean also a manual "Tester to test the Tester," and rule the matter as being outside the realm of practical politics. It is therefore necessary to deal with this conception before furnishing any actual circuit details relating to suggested Automatic Routine testing schemes.

However natural such views may appear on the surface, careful examination of the problem reveals that, instead of employing for this important work uncanny automatic schemes necessitating frequent overhaul by highly skilled manual staffs, the functions which automatic testers have to fulfil may be simpler and more clean-cut in character than those required of automatic switching equipment. In order to gain this end each complete test may be split up into a cycle of single simple operations, each tester operation being associated with a definite function of the automatic switching plant under test. A pointer moving over a circular scale as each function is tested can serve to denote any particular function which, through failure, causes automatic stoppage of the testing cycle. A glance at the case of the Final Selectors (or Connectors) of the ordinary P.B.X. type will be helpful in this connexion. Under the influence of the last 2 digits dialled the wipers of these switches move in the Vertical and Rotary planes, and, when necessary, continue to hunt automatically beyond the last number dialled in search of the first disengaged line of a group. Seizing of a wanted line leads to that line being " engaged " against intrusion by other callers, and also to the transmission of ringing, speaking and metering currents, etc. The satisfactory operation of the relays, magnets, wipers and mechanical switch contacts, etc., which function (on each single switch) to reach and search over groups of lines, can be confirmed by employing the Generator currents (transmitted to the only disengaged line of a " test " group) to advance an automatic testing cycle a single step.

The practicability of establishing interdependence between the complete and satisfactory functioning of the tester and the plant tested can also be demonstrated by reference to the alternative case of a simple jack-ended junction circuit. In this instance commencement of the cycle of tests would occur only with the forward movement of a tester relay, which draws its operating current through the answering lamp of the junction under test. The next step in continuance of the cycle of tests occurs only when releasing of this relay follows earthing of the answering lamp circuit by the junction line relay. (The first forward movement of the tester relay is employed to close a circuit which originates a call on the junction equipment.) To summarise the foregoing. *Each tester will proceed automatically from the first junction (or automatic switch) to the second, when, and only when, the first junction has been tested and proved satisfactory. Therefore, whenever the machine stops before all tests have been completed, the stoppage is due to the existence of a fault. An investigation must be made into* *the cause of the fault and the machine restarted. It is true that the fault in question may be located in the testing machine, but there is no need to apply a " parasitic " routine test of the Automatic Routine tester in order to determine this.*

The folowing affords an idea of the relative numbers of moving contacts involved :—

P.B.X. type	Final Selector	... ...	40
Manual type Tester for	do.	... ...	25
Semi-Auto. do.	do.	... ...	22

The object of the present article is to deal in broad outline only with principles thought to be capable of useful development and application. For this purpose it is proposed to describe :—

(*a*) A set for making full automatic tests of junction circuits.

(*b*) A semi-automatic set for final selectors.

(*c*) i. An automatic circuit-selecting scheme suitable for hunting over large groups and connecting junctions or switches to sets similar to those referred to under (*a*) and (*b*).

ii. A means of adapting the circuit-selecting scheme for enabling automatic traffic-recording facilities to be applied.

The Traffic-Recording scheme to be dealt with under (*c*) ii. is based upon principles first evolved some years ago by Mr. G. F. O'dell. The employment for routine testing purposes of a switching scheme covering large groups of switches would lend itself to the employment of a Traffic-Recording scheme of this particular character.

Tests of Auto to Manual Junction Circuits.
(i.e., *of simple line and associated direct signalling equipment*).

The routine operations performed daily in completely testing trunk and junction circuits connecting manual exchanges are familiar to all. At large automatic exchanges a considerable number of junctions connect the Automatic Switches to the manual portions of the exchange, and it is the practice for each of these circuits to be tested daily.

In planning to test each function which the junction equipment performs, the scheme followed has been to endeavour to set up electrically each changing condition as is it established by the connecting of the calling subscriber's loop across the junction and by the insertion of an answering plug, etc. The arrangement to be described is shown in Fig. 1. The junctions are led to the bank contacts of a preselector which has the testing equipment associated with its wipers. The junction shown in Fig. 1 is a typical circuit. The functions which will be tested are :—

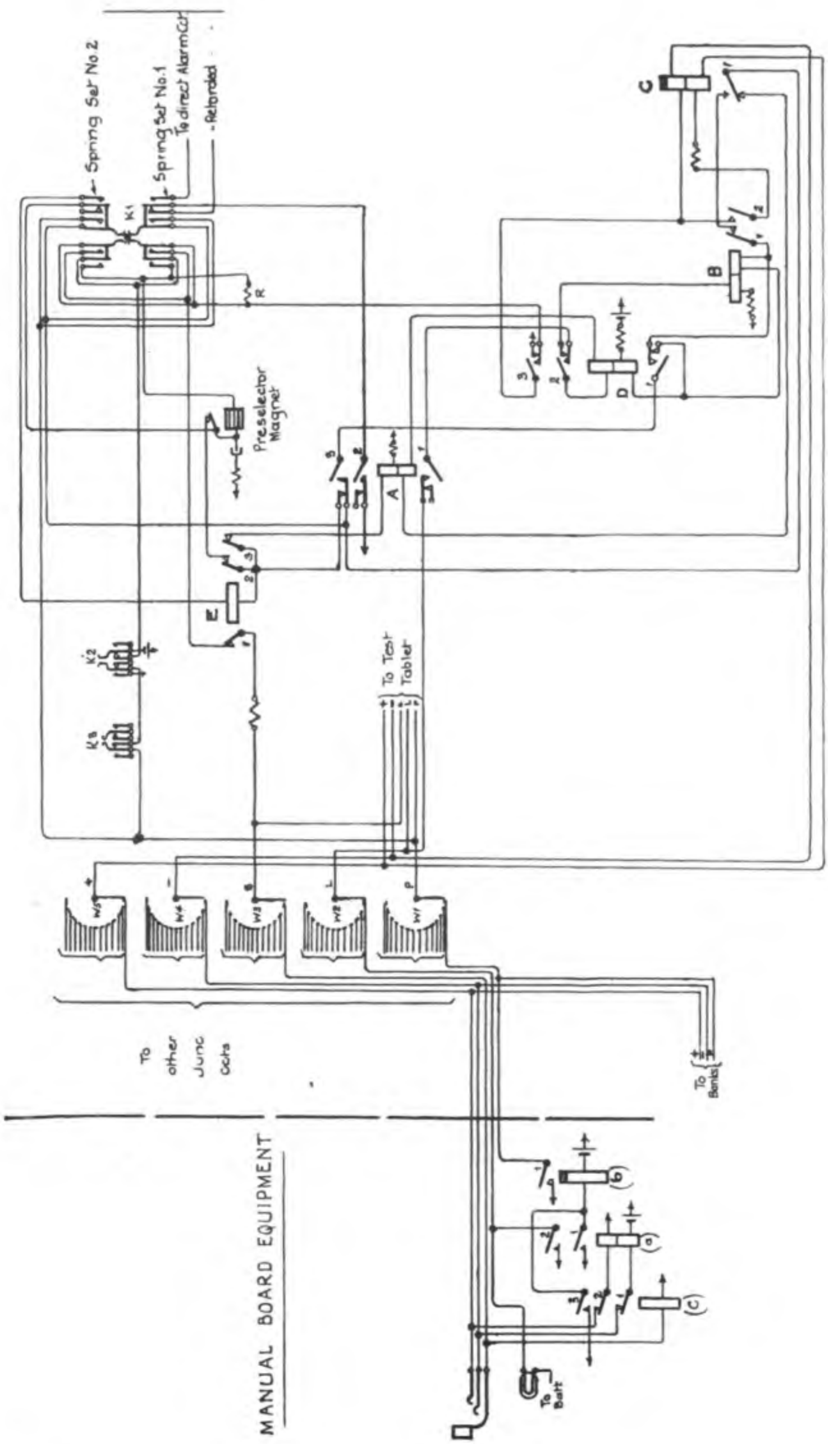

FIG. 1.—AUTO TO MANUAL JUNCTION CIRCUITS.
Relay equipment, etc., for routine testing when Circuits are wholly internal.

1. Continuity of line lamp circuit.
2. Operation of the line relay on Sub.'s loops of maximum resistance.
3. "Holding" of the calling subscriber's line, *i.e.*, earth connecting of the "engaged test" or "P" wire.
4. Control of the cut-off relay on the junction equipment.
5. Insulation of the junction circuit.

The lever of key K1 is operated to control spring set No. 1, when battery is connected through the Preselector Magnet and its interrupter to the wiper which connects up the "P" or "test" wires of the different junctions. The preselector rotates until an idle junction is reached, when a cycle of operations as under takes place. Before proceeding to deal with the actual junction testing circuits it will be well to trace the path of the preselector magnet when "engaged" junctions are tested. Under these circumstances current flows from battery K2, K1, magnet coil and interrupter contacts, E2, A3, K1, Wiper No. 1 and the junction circuit, to earth at the operated contact of relay (*b*) of the auxiliary equipment.

The following circuits are set up as each junction is seized:—

i. Relay A operates due to the current connected to the preselector magnet and its interrupter, flowing *via* E2 and E3 to earth through the upper coil of A.

ii. Current from the answering lamp circuit then flows *via* Wiper No. 2 and relay contacts A1, D2, to the left hand coil of relay B, which operates. Satisfactory continuity of the answering lamp circuit (see function No. 1 above) is thereby proved.

iii. Closing of the No. 2 contacts of B connects the coils of relay C across the junction loop *via* Wipers 4 and 5, when the flow of current through the coils of the junction relay (*a*) cause that relay and also relay C to operate. The operation of (*a*)2, earth-connects the answering lamp circuit direct, thereby short-circuiting the operating coil of relay B which releases in consequence. Release of B confirms satisfactory closing of the (*a*)2 relay contacts—see function No. 2. The operation of relay contact (*a*)1 completes the path of relay (*b*), which in turn earth connects the "engaged test" or "P" circuit.

iv. Relay C is slow-releasing and completes a path immediately B falls back for the operation of D. The path for the operation of D is completed *via* its lower winding and the contacts normally closed on its own No. 1 spring set, *via* B1, C1, K1 and Wiper No. 1 to earth at the operated No. 1 contact of relay (*b*). Satisfactory "holding" of the calling "line" (see function 3) is thereby confirmed.

v. The operation of contacts D_1 causes its retaining current to circulate through the right hand winding of B. This latter relay operates a second time to loop the two coils of C which bridge the junction circuit. The retaining current of D and B flows *via* D_1 and A_3, etc.

vi. The operation of D_3 removes an earth connection, short circuiting the cut-off relay circuit, when there is a flow of current *via* K_2, K_1, R, the second springs of K_1 and E_1 to the No. 3 wiper and thence *via* the junction circuit to the cut-off relay (*c*)—see function 4. The operation of the cut-off relay opens the circuit of relay C on the testing equipment.

vii. A path is also provided for the current connected to R to pass *via* D_3 to both wires of the junction loop (contacts B_2 are closed). Should any earth or battery fault exist on the junction a current will flow through the winding of the slow releasing relay C and so hold up that relay—see function 5.

viii. When the junction circuit is clear relay C releases shortly after the cut-off relay (*c*) operates, when a path is completed for the answering lamp circuit *via* Wiper 2, A_1, D_2, upper coil of D, lower coil of A, C_1, etc., to earth at the contacts of relay (*b*). The flow of this current through the separate coils of relays D and A neutralises the earlier magnetisation of these two relays. Both relays release in consequence.

ix. The release of D causes (*c*) to release, relay (*b*) then releasing with a retarded action due to its copper slug. The restoration to normal of contacts A_3 extended the preselector magnet circuit to the earth connection existing on $(b)_1$ when the preselector steps forward to select another trunk.

The cycle of operations just described takes about half a second to complete. Should the presence of a fault on a junction prevent release of relay A, the circuit through the contacts A_2 completes the circuit of an audible alarm.

In order to afford ready access to a circuit whenever premature stoppage of the testing cycle indicates the existence of a fault the five wipers of the stepping preselector are connected to the Test Panel, and a locking type Key (K_2) is provided to enable Auto testing to be suspended whilst the faulty junction is taken in hand. The third non-locking type Key (K_3) enables the guarding earth to be removed from the faulty junction during the fault localisation tests.

It will be seen that the number of junctions which can be tested is limited by the number of positions on the preselector arc. Details will be furnished later of arrangements whereby completion of the tests of a group of circuits can be made to lead automatically to the switching over of another set of circuits to the bank contacts of the test-set preselector.

As already indicated the equipment described will test junctions at the rate of 120 per minute, so that even for the largest exchanges the time taken in an early morning test of all disengaged junctions would be almost negligible.

The operation of key set springs No. 2 so alters the connections of the equipment as to test each junction in turn, instead of skipping over each circuit found to be engaged. Upon the wipers reaching an engaged junction, relay E operates and so delays the commencement of the normal testing cycle. The normal release of the junction causes E to release when the testing cycle is recommenced. The scheme provides therefore for a quick early morning test of all disengaged junctions, to be followed by a test of each junction taken in turn.

The arrangements described would, of course, require amplifying for cases where the automatic switch banks and the Manual Board equipment are accommodated in separate buildings.

This scheme does not provide for the employment of a pointer for indicating each switch function under test.

Semi-Automatic Tester.

Fig. **2** furnishes the circuit arrangements, etc., of a Semi-Automatic Tester suitable for use on Final Selectors. These switches have subscribers' lines connected to the bank contacts, and, in addition to selecting the wanted line under the control of the caller's dial, feed Ringing, Busy back, and Transmission currents, etc., as occasion requires.

Flexible cords are employed to connect up the tester to each switch, and to the test line (usually 99) appearing in the subscribers' multiple.

Tests of a purely manual character, have called hitherto for the manipulation of each appropriate test key in turn in order to "switch" the conditions required for each test. In the semi-automatic set the switchings are performed by the employment of moving preselector wipers and four relays. The moving wipers are made to "step" only in response to the satisfactory functioning of the automatic switch. The ideal arrangement would, of course, be one in which the auto switch functions were allocated individual positions in the stepping cycle, thus leading to any failure of the switch to "step" being definitely associated with a single switch function. The chart which accompanies the

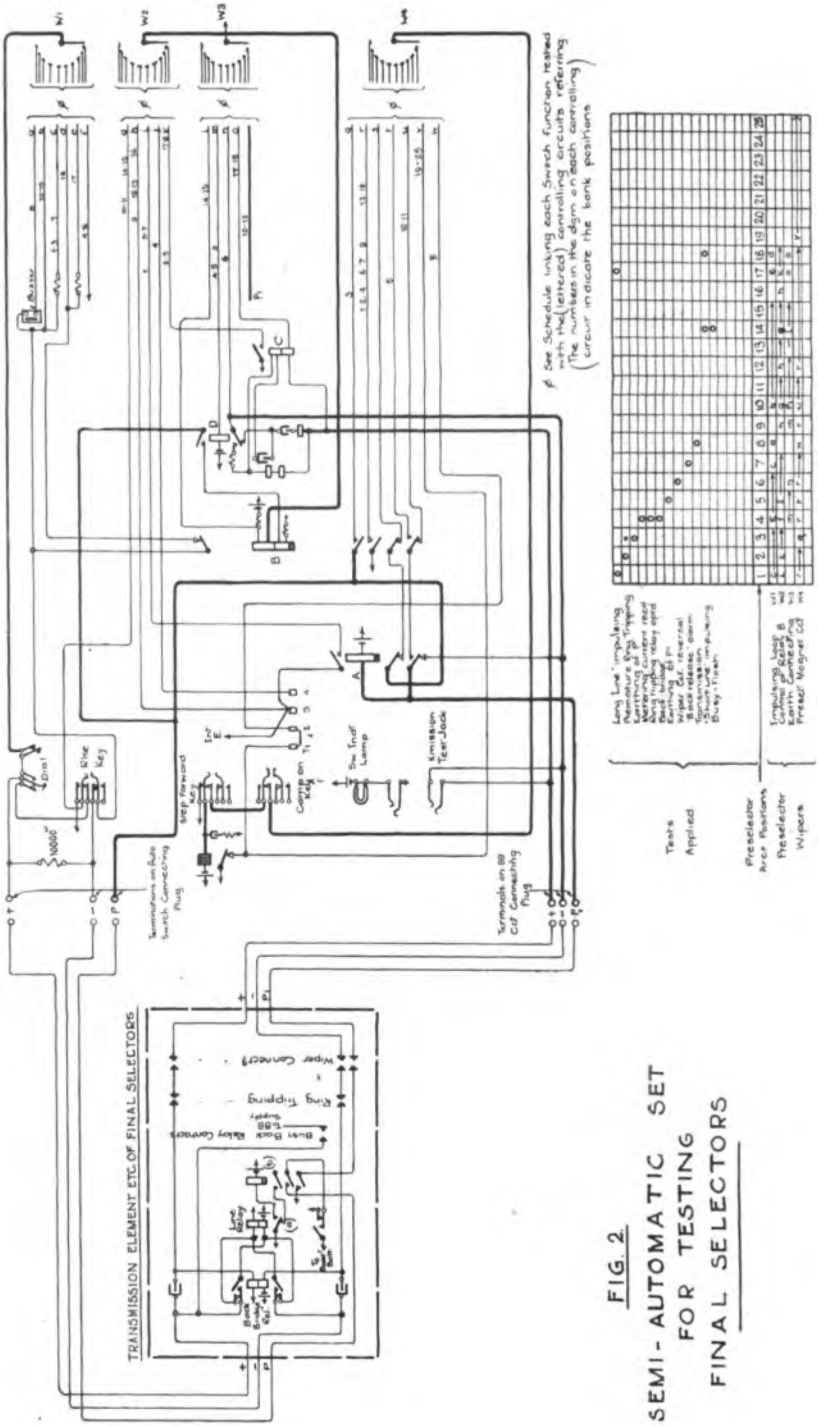

FIG. 2
SEMI-AUTOMATIC SET FOR TESTING FINAL SELECTORS

diagram links the switch functions with the relevant positions of the stepping preselector. The moving wipers switch four different circuits as desired, and it will be necessary to trace each of the four control circuits relating to any particular position of the stepping switch in order to understand the tests relating to the switch function concerned. The lower part of the schedule links the circuit controls with each switch position.

In reviewing the arrangements shown it is preferable to consider the whole as being built up of a number of self-contained units or functions. Each position of the arc and the control circuits which operate should be considered apart from the remaining arc positions.

Commencement of the testing cycle follows the dialling of 99 by the switchman, the dialling circuit being *via* Wiper No. 1, and circuit (*c*). The wipers of the Final Selector are raised to the 9th level and come to rest upon completion of the 9th rotary step. The following notes deal with the control of the preselector magnet, and consequently direct attention to the testing conditions linked with the different switch functions upon which stepping of the test set depends.

1. *Stepping from Position No.* 1. (Proving satisfactory impulsing on " long line " circuits).

The magnet circuit (with battery behind it) which is connected to Wiper No. 4 and circuit (*r*) depends upon the movements of relay B. This relay is *via* (*i*) and operates from the intermittent earth circuit, only after relay A has operated. Relay A (which is comparable with a subscriber's cut-off relay) is connected to the bank contacts of the line which corresponds with the number dialled, hence the operation of A confirms satisfactory impulsing.

2. *Stepping from Position No.* 2. (Confirming " No premature ring-tripping ").

The magnet circuit is again connected to circuit (*r*). Relay B now receives its circuit *via* (*k*), which is earth-connected with the forward movement of relay C. This latter relay forms part of a " ring-receiving circuit " bridged across the 99 line and responds to generator currents. (The further movement of the preselector magnet from position 3 to 4 is also dependent upon the continuance of the machine-ringing signal through C). The ring-receiving circuit through C, etc., applies a severe test of the liability of the auto switch relay to trip prematurely.

3. *Stepping from Position No.* 3. (Confirming that a full earth connection has been applied to P).

As indicated in (2) relay B still operates *via* the contacts of C to control the magnet circuit, an alternative contact of B is employed however, circuit (*q*) serving to connect the magnet to the P circuit.

4. *Stepping from Position No.* 4.

(*a*) Receipt of "Booster" metering current.

(*b*) Operation of "Ring-tripping" and "Back-bridge" relays.

(*a*) The magnet circuit *via* (*r*) is connected to full earth at the operated contacts of relay B. The normal winding of B is left disconnected. The second earth-connected winding of B has a path provided from it to the release trunk circuit P *via* the operated contacts of relay D. A momentary positive battery (known as a "Booster Metering current") is applied to the release trunk after the called subscriber has answered, and to this current B responds.

Relay D, referred to above, is operated *via* (*m*) and serves the double purpose of completing a path for the metering current and also connects up a ring-tripping circuit across the 99 line.

(*b*) Application of a ring-tripping loop not only operates the ring-tripping relay, but also the back-bridge relay which reverses the battery and earth connections to the incoming trunk. Immediately ring-tripping conditions are applied therefore, the holding loop on the incoming trunk (*via* Wiper No. 1) is replaced by a single earth connection applied to the positive line. A current reversal is therefore necessary for the switch to "hold" by virtue of the flow of current through the line relay. Under normal circumstances the ring-tripping and back-bridge relays operate in quick succession to establish the reversal conditions referred to above. Any slugginess in the operation of either these two relays delays the time when a "holding" current flows and causes premature release of the switch. Release of the switch intercepts the automatic stepping of the tester.

At exchanges where "booster battery" metering is not provided a strap is placed between the terminals T3 and T4 in order to provide for the operation of relay B from the intermittent-earth circuit.

5. *Stepping from Position No.* 5. (Confirmation of "holding" earth on P_1).

The magnet circuit receives its earth from the P_1 conductor *via* circuit (*t*), which is closed finally with the movement of relay B. This relay operates on the intermittent earth *via* circuit (*i*) and the operated contacts of relay A.

6. *Stepping from Position No.* 6. (Test for reversal of wipers).

The magnet circuit is controlled *via* (*r*) from the contact of B which connects up earth direct. Relay B depends upon the retention of A for its intermittent-earth connection. Holding of the auto switch (for the retention of A) is by means of an earth connection on the positive trunk only, the "current reversal" condition being arranged for by an earth connection (*via* circuit (*n*)) on the wiper circuit, which should connect up the negative coil of the back-bridge relay.

7. *Stepping from Position No. 7.* ("Back release" alarm signal).

This is the first position in which auto stepping is independent of the existence of a fault. The magnet control is *via* the "direct earth" circuit of B. Relay B operates *via* the intermittent earth circuit. During the time the wipers stand on Position No. 7 (1.5 second) a supervisory signal on the switch glows, indicating that although the switch is still "held" on the calling side the called subscriber has cleared and his line is being "held" after completion of a call.

8. *Stepping from Position No. 8.* (Transmission tests).

Normally the preselector magnet circuit is closed *via* its own interrupter and circuit (*w*) in order to skip quickly over this position, since the normal routines do not test the continuity of the condensers employed in the transmission circuit. Removal of the strap between terminals T_1 and T_2 leaves the preselector magnet disconnected in position 8 in order that transmission tests may be made. The incoming trunk is connected across a buzzer *via* circuit (*a*) in this position, and satisfactory transmission conditions can be confirmed by connecting a switchman's hand telephone to the "transmission test" jack (bridged across the 99 line) when a characteristic "buzz" is heard. The switch has to be stepped forward manually by means of the "step forward" key in completion of the tests.

Occasional tests for transmission would be made by means of the "step forward" and "camp on" key controls.

9. *Stepping from Position No. 9.*

Automatic releasing of the switch occurs in position 9 preparatory to commencement of a test call to an "engaged" number in position 10. Normally a disconnection of the incoming trunk circuit on Wiper No. 1 causes release. Arrangements are made on Wiper No. 3, however, to operate relay D and the back-bridge relay, in order to bring to light during ordinary routines any failure of the back-bridge relay to operate quite definitely. It will be seen that the trunk-circuit reversal is effected by the employment of make-before-break springs on the back-bridge relay. Any failure of an inner spring to "break" short-circuits the caller's line and would prevent automatic release of the switch in this position.

The preselector magnet is connected to the earth-connecting spring of relay B, which operates in turn under intermittent-earth control.

10. *Call to an " engaged " number.*

As in the earlier test relating to a completely effective call automatic stepping of the test set preselector occurs only with the manipulation by hand of the test set dial. The earth-connected Wiper No. 3 is employed to "engage" the 99 Test line, and it has been found desirable to economise in the number of relays required by employing a scheme which results in a single automatic step of the preselector each time a digit is dialled. Upon completion of dialling, therefore, the preselector stands in position No. 12. Stepping of the switch to positions 13 and 14 is under the direct control of relay B, which operates *via* the intermittent-earth circuit, the test for " busy back " being applied in positions 14 and 15. The single wire Exchange busy-back circuit which supplies battery and earth alternately is applied to the positive wire of the ingoing trunk on "engaged" calls, and relay B is connected to this wire *via* circuit (*g*) in positions 14 and 15 of the arc. Relay B, which closes the magnet circuit direct, has the opposite side of its winding (which normally has battery connected through a resistance) earth connected *via* circuit (*l*) by Wiper III. This relay therefore " flashes " in the same manner as does an ordinary cord circuit supervisory relay on connection to a busy-back circuit, and the switch wipers step to position No. 16 when automatic releasing occurs due to the incoming trunk loop being disconnected at the bank circuit of Wiper No. 1. The preselector steps forward to position No. 17 under the control of relay B (this relay is connected to the intermittent-earth circuit). It will be noticed that impulsing for this test is *via* a " short line " circuit (on Wiper No. 1), and the completion of a satisfactory test may be taken as an indication that the switch will impulse satisfactorily when connected to lines of zero resistance.

11. *Simple tests for impulsing.*

Rapid tests for satisfactory impulsing can be made without the necessity for going through the whole cycle of operations involved in complete calls. Position No. 17 so connects the circuits that in response to satisfactory switch functioning when 99 is dialled automatic releasing occurs, the impulsing loop being re-connected ready for another test without the necessity for stepping. The circuits shown provide normally, however, for a step-forward movement to position 18 to accompany the automatic release of the switch. A similar cycle of operations takes place in response to 99 impulses from the dial when the switch is standing in position

18. The difference between tests made in positions 17 and 18 lies in the fact that in the latter "short line" impulsing conditions are applied, whilst in the former "long line" conditions obtain. The operation of the "camp on" key enables a series of "long" or "short" line impulsing tests to be applied when necessary. Releasing of the auto switch occurs when the 99 line is reached due to the impulsing loop through (*d*) and (*e*) being completed *via* the resting contacts of relay B which operates. As will be seen from the diagram, the operating circuit of B is *via* the contact of relay C, the latter being connected *via* circuit (*o*) to operate on the "ringing return" current which is applied through the Selector wiper to the + conductor of the 99 line after that line has been seized by the automatic switch.

The circuits set up in positions 17 and 18 enable the set to be employed also for impulsing tests on group selectors, but under these circumstances releasing of the auto switch after each test has to be effected by manipulation of the "Release" key shown.

The preselector steps forward to the Number 1 position *via* its own interrupter circuit from position 19.

Group and Switch Selecting, etc.

General Notes.

In furnishing the following outline of a completely automatic scheme, it should be stated that the testing methods advocated are based merely on the experiences afforded by working trials of a semi-auto set. On the other hand, however, the non-automatic features of the set already described are confined to the manipulation of a dial for impulsing purposes and to the connecting-up of each switch by hand.

The employment of automatic routine testing methods would make it necessary to consider the provision of a switching scheme with which to connect the testing set to each switch in turn. There are very many auto switches employed in even the smaller exchanges and, since each switch is controlled over a 3-wire trunk, the arrangements for switching to individual circuits call for the employment of wipers and banks capable of dealing with large groups of wires.

The arrangement shown in Fig. **3** is based on the employment of preselector type switches. It will be assumed for the purpose of this article that there is available a preselector employing a single stepping magnet circuit and having 33 wipers which sweep over as many bank arcs. The wipers afford simultaneous connection to groups of 33-wire circuits, and, allowing for a "home" position, the standard 25-point arcs cater for the connecting up of 24 separate 33-wire groups. 30 wires of each group are employed

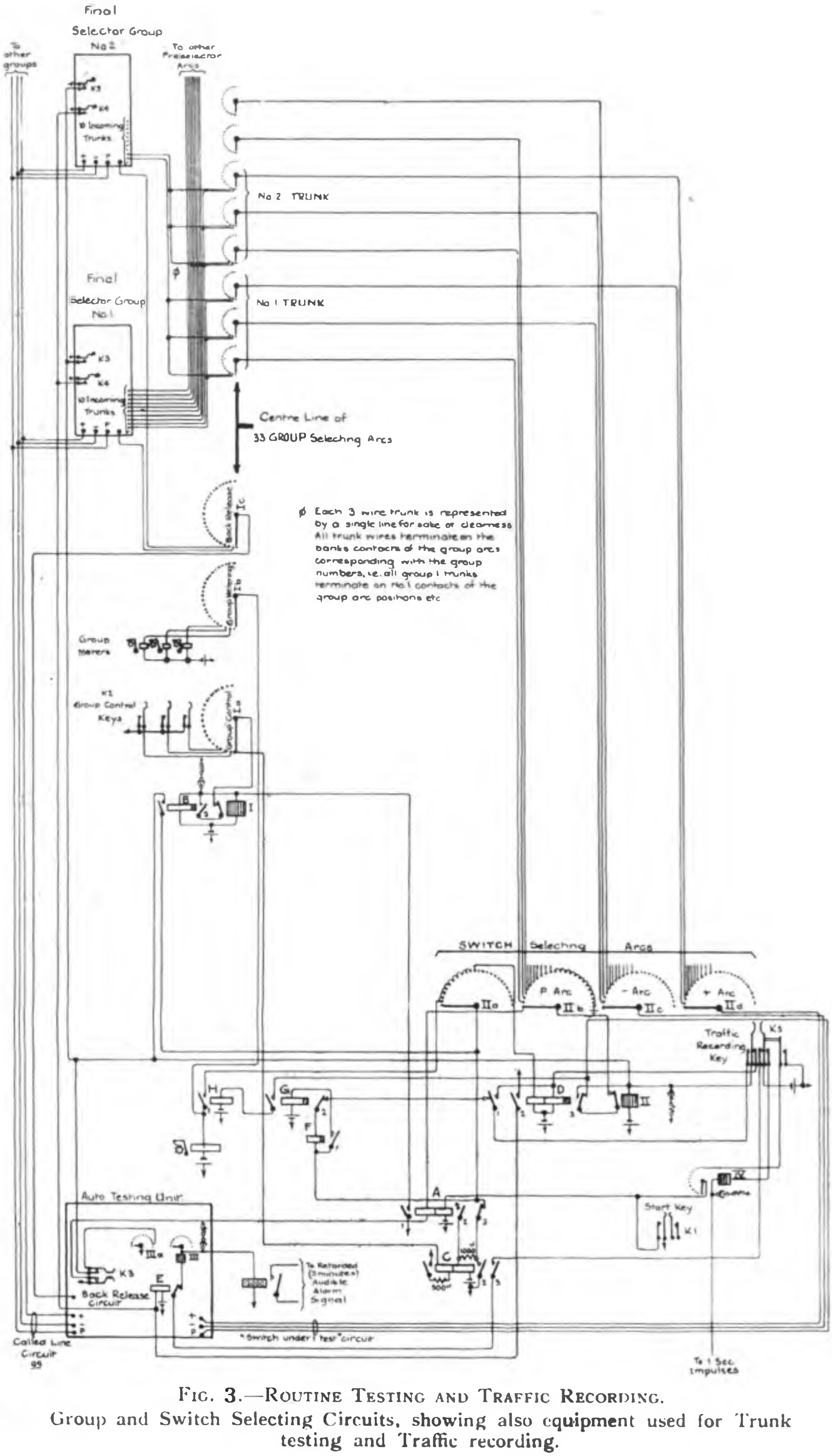

FIG. 3.—ROUTINE TESTING AND TRAFFIC RECORDING.
Group and Switch Selecting Circuits, showing also equipment used for Trunk testing and Traffic recording.

to connect ten 3-wire trunks of a Final Selector group, the remaining three wires serving for "group control," "group metering," and connecting up the "Back-Release" Alarm circuit. It will be seen from the diagram that the 30 wires corresponding to 10 sets of trunks are accommodated on three of the four arcs of a standard 25-point preselector.

Before proceeding further it is necessary to indicate that upon completion of each individual switch testing cycle a short duration earth connection is sent out in order to provide for automatic switching of the test set to the next disengaged switch—See connection of Arc No. III. (*a*).

For Routine Testing Purposes.—For the purpose of ordinary routines each group of switches would be selected in turn, *i.e.*, circumstances would not call normally for any of the groups being omitted. With regard to the matter of individual switch selection it will be most convenient here to deal only with the simple case where the "Switch Selecting" wipers pass over the trunks of switches which happen to be engaged at the time of testing.

The cycle of operations commences with the momentary operation of the start key K1, which, during operation, energises relay A.

The momentary closing of contacts A1 completes the circuit of B and the preselector magnet No. I, when the group wipers move from the "home" position to the first group.

Simultaneous with the above operation the A2 contacts close the circuit of C, which operates and obtains a retaining circuit through its own C2 contacts.

The release of A precedes by a fraction of a second the release of B when a path is provided for D and the preselector magnet No. II. *via* C2, A3 and B1. The release of B opens this last mentioned circuit, when the switch-selecting wipers move forward and select the first disengaged switch in the group now connected to the bank contacts. The "testing" circuit of preselector No. II. is *via* D3 operated and its own interrupter to the "P" wiper on Arc No. II.*b*. The earth-connection which exists on the P circuits of "engaged" switches complete the preselector magnet circuit, the magnet interrupter giving rise to an automatic step forward movement until an "open" P circuit is reached.

The initial movement of contact C3 connected battery *via* the normal springs of the Traffic Recording key to the coil circuit of the preselector employed in the Tester. It will be seen, however, that this battery is again disconnected by the operation of relay E which occurs *via* contacts D2. Forward movements of the Test set preselector during group and switch-selecting is thereby prevented.

As already indicated the short-duration earth which is transmitted from the III.*a* arc upon completion of each switch-testing cycle gives an additional impulse to the Switch-Selecting pre-selector. When the wipers of this latter switch reach contact No. 12 (contact No. 11 connected up the 10th switch) the pre-selector moves quickly forward to its "home" position due to all the bank contacts tested being found "engaged." Immediately the home position is reached current flows momentarily *via* the II.*b* arc to the earth connected coil of A, which operates until contacts D3 of the slow releasing relay restore. Relay D fails to retain through the high resistance circuit of A due to the fact that its coil is shunted by the 75ω winding of the preselector.

The second movement of A1 transmits another impulse to the group-selecting switch which switches in the next group, and provides also another "starting" impulse for the switch selecting arcs by completing a momentary path *via* C2, A3 and B1.

Upon completion of tests over all available routes the testing cycle is brought to a conclusion by the group-selecting wipers reaching the home position. In this position a circuit is competed for the preselector magnet current to flow through the B2 contacts and the wiper of the I.*a* arc to the second coil of relay C. This current reverses the magnetic flux of relay C, which releases in consequence. The release of C leaves its two windings disconnected and cuts the circuit of the battery supply to the routine tester.

Special Case.—In the event of a switchman wishing to examine critically the performances of some particular switch under routine testing controls, arrangements would be made to suspend the automatic step-forward control after this switch has been selected, by operating key K3 on the tester. The operation of any one of the K4 keys fitted on the selector units energises E, disconnecting the circuit of the stepping magnet and so enabling the switchman to "camp on" any desired position of the testing preselector arc. Thus "long line impulsing" conditions could be applied continuously if desired, or alternatively the preselector can be brought to rest in an appropriate position should it be desired to make relay readjustments on the automatic switch.

Before leaving the matter of routine testing of Final Selectors it should be stated that for the sake of clearness the arrangements described assume that the number 99 circuit of each 100 line block may be reserved for routine testing work. Arrangements are being made to obviate the necessity for reserving these lines, but a description of these arrangements would not contribute to the main purpose of this article.

Traffic Recording.—The Traffic Recording facilities cater for the registration of the number of times switches are found to be engaged when they are tested at regular intervals. The testing cycles are timed to occur every 36 seconds, *i.e.*, every .01 hour. With the scheme shown only one switch is tested at a time so that the total number of switches tested within the 36-second period will depend upon the length of time required for each test and successive switching. The arrangements shown will not test more than ten groups of ten switches each within a period of 36 seconds.

All "group control" keys require to be operated excepting those corresponding to the units on which it is desired to take records. When this has been done the Traffic Recording Key K5 is operated. This operation connects up the preselector magnet No. IV., when a complete cycle is made every 36 seconds. Each complete cycle causes a one second impulse to be transmitted to relay A.

The following operations then occur :—

The momentary closing of contacts A1 energises B and the preselector magnet I. when selection of the first group on which Traffic Records are to be taken commences. The group testing circuit is *via* contacts B2 and the group Arc I.*a*.

The closing of contacts B1 during group selection completes a path for preselector magnet II. *via* A3 and C2. Immediately the B1 contacts open, the current through the preselector magnet II. finds an alternative path through K5, D1 (normal), G2, relay F, A3 and C2 to earth. The series relay F operates in consequence, providing a path for the operation of G *via* F1, A3 and C2. The resulting operation of G intercepts the flow of current through the series relay, etc. (at G2) and the preselector steps forward. As will be seen from the diagram, F and G are slow-releasing type relays and the circuit just described provides for a series of single pulses to be transmitted to the switch-selecting wipers.

Each switch trunk is tested for traffic recording purposes by its connection to relay H immediately the switch-selecting wipers move forward to it and before relay G has had time to release. The testing circuit is *via* G1, D3, the magnet interrupter and arc No. II.*b*. The operation of H when an engaged circuit is tested records a call on the common meter (*via* H1,II.*a*, A3 and C2) and also on the group meter concerned (*via* arc I.*b*).

Immediately the switch-selecting wipers reach position number 12, further registrations are prevented by the disconnection of the local circuit of H, whilst an earth connection is applied *via* the II.*a* arc to the second coil of relay D. Immediately the forward movement of D closes its D1 contacts the first coil is once again connected in parallel with the preselector magnet and the two are connected *via* D3 and the interrupter to the earth-connected section of the II.*b* arc. Automatic rotation of the switch-selecting wipers now steps this switch to the home position.

Relay A then receives another short duration impulse (*via* D3 operated, the magnet interrupter and the home position of the II.*b* arc) and thereby sets in motion the Group-Selecting Wipers *via* the A1 contact. The next available group is then selected in the manner already indicated, the release of relay B leading up to the single-step movements of the switch-selecting arcs being recommenced *via* the E series relay circuit, in the manner already described.

As the Group-Selecting wipers move from Group to Group the appropriate group meters are switched in *via* the I.*b* arc.

When the I.*a* wiper reaches the home position upon completion of tests over all available routes, automatic release of C occurs in the manner already indicated in connection with the scheme for routine testing, *i.e.*, *via* the I.*a* wiper and the second or polarity-reversing winding of relay C.

Recommencement of the full traffic-recording cycle occurs with the closing of the circuit of relay A *via* the wiper circuit of preselector No. IV. every 36 seconds.

It should perhaps be stated for the benefit of those readers who have not actually handled preselectors (or rotary line switches) that the foregoing notes have been based on the employment of the type of switch on which the wipers step forward only on the interruption of the flow of current through the magnet coil. In some of the earlier preselectors the wipers were " Magnet driven " as distinct from " spring driven."

The use of a semi-automatic testing set reduces the manhours spent by 40 per cent., and, whilst simpler to manipulate than the purely Manual Tester, applies more searching as well as more uniform testing conditions. Full automatic testing would practically wipe out all labour charges on routine work.

A few further remarks on the assistance which the employment of mechanical aids may afford the exchange staffs, may not be out of place. Under the manual conditions of testing a not inconsiderable proportion of the switchman's time, and some mental effort, is expended in handling and connecting up the portable testers, the manipulation of dials and keys, and in the observation of lamp and bell signals, etc. Transference of the work to a suitable machine would enable the switchman to devote his skilled attention more carefully to relay adjustments and other important work, and also provide him with rapid " fault indicating " sets for the units which perform functions so numerous and varied.

The Automatic Testers lend themselves readily to the inclusion of tests covering the behaviour of a greater number of individual relays on each unit tested than would be practicable with the retention of methods which are wholly manual. They also render practicable the application of both " safe working " and " re-adjustment " standards. The latter standard would, of course, be employed whenever failure of a switch to pass the normal "safe working" conditions rendered readjustments necessary. It is thought that these facilities would be especially advantageous in assisting towards the maintenance of greater uniformity with regard to the adjustments applied by the different exchange staffs. The very considerable increase in the quantity and type of relays employed in Automatic working make the matter of uniform and efficient relay adjustments one of outstanding importance and extensive investigations have been conducted in this connection. This phase is of course inseparably linked up with the matter of fault detection. The length of the present article precludes, however, any more complete reference to this aspect of maintenance work.

LETTERING OF RELAYS IN AUTOMATIC TELEPHONE DIAGRAMS.

About fourteen years ago the first article on Automatic Circuits appeared in this Journal, and since that time the problems incidental to the general introduction of automatic working have been examined with increasing detail.

A minor problem, which was yet sufficiently important to require special treatment, was that of Relay Lettering in Automatic Circuit Diagrams. Until quite recently the lettering of relays was based either upon no particular plan, or upon the positions of the relays on their mounting plate.

In the latter case, modifications in circuit design necessitating an addition to or reduction in the number of relays entailed an alteration in the lettering, with consequent rewriting of all circuit descriptions.

A change of letter also had the serious drawback that a letter which had become familiar to the staff as belonging to a certain function, *e.g.*, F = ringing trip relay, might at any moment be allotted to a relay having an entirely different function to perform. With the increasing use of automatic circuit diagrams, a scheme of standard lettering became essential and the following list was devised. This will be used by all P.O. Contractors in future. It will be noticed that the letters A-M have been reserved for the relays most commonly met with. Double letters are used for the remaining cases. The letters allotted to Switch Mechanisms, etc., are primarily for use on wiring diagrams where every terminal must be clearly indicated.

SCHEDULE OF NOMENCLATURE FOR AUTOMATIC TELEPHONE EQUIPMENT DIAGRAMS.

Single Letters.

RELAYS.

A Impulse Accepting Relay.
B Guard Relay.
C Vertical movement Relay (series or shunt).
D Forward or Called Party's Supervisory Relay.
E Rotary movement Relay (series or shunt).
F Ringing Trip Relay.
G Busy or Test Relay.
H Wiper Cut-in Relay—Selectors.
I Retardation Coil or Relay of High Impedance.
J Booster Relay, Final Selectors Non-Director Areas.
K Wiper Cut-in Relay, Rotary Switches.
L Calling Party's Line or Supervisory Relay (Non-Impulsing).
M Forced Release Relay.

SWITCH MECHANISMS.

N Vertical Off Normal Springs (For Rotary Off Normal Springs see NR).
P Private.
Q
R Rotary Magnet (not breaking its own circuit).
S Cam Springs.
T Test Jack.
U Switch Jack
V Vertical Magnet.
W Wiper.
X, Y } (Reserved for Relay Spring Adustment Conditions).
Z Release Magnet.

DOUBLE LETTERS.

CC Counting (Impulse) Control Relay (Director).
CO Cut Off Relay (Director).
DD Digit Distributor Switch.
DM Driving Magnet (breaking its own circuit) Rotary Switches.
DS Digit Distributor Stepping Relay (Director).
GA First additional Test Relay } 11-20 P.B.X. Final Selectors
GB Second ,, ,, ,, } 11-20 P.B.X. Final Selectors
HS Hunting Start Relay (2-10 P.B.X. Final Selectors).
LC Line (Impulse) Control Relay (Director).
MB Manual Board Relay (Director).
NP Normal Post Springs.
NR Rotary Off Normal Springs.
PA Pulse Alarm (Director).
QA, QB, QC, QD etc. } Condensers.
RT Routine Test Relay (Director).
RA Release Alarm Relay ,,
SA Start Send Relay (Director).
SC Sender Control Switch ,,
SS Sender Switch ,,
SZ Stop Send Relay ,,
TP Time Pulse Relay (Director).
YA, YB, YC, YD etc. } Resistances.

TESTING-OUT AUTOMATIC EXCHANGES.

By W. PRICKETT,
Engineer-in-Chief's Office.

THE testing-out of automatic exchanges will be a subject that the Department's engineers will be concerned in very much in the future, and it was thought that a short article on this subject would not be out of place.

At an informal meeting of the I.P.O.E.E. held recently in London, Mr. Judd, of the South Internal Section, gave a very interesting paper on "The Duties of a Clerk of Works." In the course of his remarks he stated that one of the chief duties of the Clerk of Works was to do "testing," "more testing" and "still more testing"; he was referring, of course, to manual exchanges and if this be true, as we know it is, of manual exchanges, how much more so does it apply to automatic exchanges, where apparatus is doing work previously done by operators.

The following tests have been designed principally for automatic exchanges of the A.T.M. Coy's type in the provinces. London, with its Director and Tandem exchanges, will require dealing with specially. The tests given are not necessarily in the order in which they will be done.

Relays, etc.—These are tested for resistance by a Bridge Megger in the usual manner. In exchanges over 1,000 lines at least 5% of the relays and magnets must be tested; in exchanges under 1,000 10% must be tested. The coils are considered satisfactory only if the resistance be within 5% of that specified.

Group Selectors.—These are tested for vertical and rotary motions.

Busy-Back and Continuity of Wipers and Banks.—A tester has been designed to use with the switches, which permit of these operations being verified.

Continuity Test.—The continuity of the cables, etc., is proved by means of buzzing on each wire.

Outgoing Trunks from Preselectors to 1st Group Selectors.—These trunks are being tested automatically. An experimental tester has been designed for the purpose and is being used on different installations. Each trunk on a subscriber's preselector is engaged in turn, so that every trunk is proved from the preselector. This tester will make 5,000 tests in one hour.

Meters.—Every subscriber's meter is tested 10 times with an operating and 10 times with a non-operating current through them. A tester has been designed which gives the necessary conditions and also makes the 10 contacts automatically one after the other. This test is in addition to the tests applied to the meters at the factory.

Insulation Resistance of Cables, etc.—All local wiring and cables are tested for insulation resistance, both before being connected to the banks, etc., and after. The test is made by taking four wires equally spaced in the outer layer of each cable, and testing (*a*) between one wire and the other three wires separately, (*b*) between the four wires connected together and earth.

Each subscriber's line is tested from the Main Frame towards the exchange, (*a*) between the A and B lines, (*b*) between the A and B lines connected together and earth.

After the cables have been connected to the banks and apparatus, each switch is tested from the test jack.

All local wiring is tested between each wire and earth.

Final Selectors.—A modified routine tester, No. 11A, is used for testing the final switches. The tester is used in conjunction with line No. 99 on the unit, this line being extended to a jack for the purpose. The switches are tested for vertical and rotary motion, ringing, premature tripping, No. 99 line engaged, etc., transmission and busy-back.

Test and Trunk-offering Distributors and Final Selectors.—These are tested from the Test Desk and Manual Board respectively. Each distributor is tested to a number reached by each final selector.

Outgoing Lines from " A " Boards to Automatic Equipment.—Each line is tested separately from the manual board. A telephone is connected to a certain number on the MF and this number is dialled on the line at the manual board.

" O " Level Circuits. Enquiry Lines.—All circuits are tested from the first switch on each shelf of 1st Group Selectors.

Phonogram Lines.—These are tested from the test jack of the repeaters associated with the phonogram lines.

Incoming Repeaters.—A tester has been designed to reproduce the manual conditions and the repeaters are all tested locally (*i.e.*, in the automatic exchange) so that all necessary adjustments can be made before being tested with the distant manual exchange.

Supervisory Signals and Alarms.—As the conditions in each exchange will vary, these circuits are tested out to see that they conform to the requirements as laid down in the specification for the particular exchange equipment under test.

Call Through Test.—This test is the final test to be made in the exchange and should not be carried out until the exchange is ready for working. All cross-connections should be run and the charts made out ready for checking. The complete series of tests are as follows:—

(*a*) One outgoing call shall be made and one incoming call shall be received on each subscriber's line at the Main Frame.

(*b*) An outgoing call shall be made from the first subscriber's line in each group as follows :—

(1) To every final switch in the exchange.

(2) To the Manual Board *via* the " 0 " level circuits.

(*c*) A call shall be made from the outgoing end of each junction as follows :—

(1) On all junctions to the other automatic exchanges in the multi-office area.

(2) On all junctions to manual exchanges.

(3) On all junctions from manual exchanges.

The number of tests to be made on the junctions is as follows :—

On each outgoing junction of a group of junctions to the same exchange one call shall be passed to the terminating exchange.

On one of the outgoing junctions of a group of junctions to the main exchange one call shall be passed to each exchange (auto or manual) obtained *via* the main exchange.

As stated at the commencement, this article is not intended to give more than a brief outline of the tests to be carried out. Specifications giving full details of the tests and testers are sent out for each installation.

Some interesting experiments are being made at the moment with testers designed with a view to cutting down the time at present taken for testing-out automatic exchanges, and it is hoped to describe these in a future article.

SUBMARINE CABLE WORK IN TIDAL WATERS.

By J. S. Brown, M.I.E.E.*

The tidal waters in which the cables referred to later were laid or repaired (mainly towards the end of the war period) are those known as Southampton Water, the Solent, and Spithead: they include the mouths of the harbour of Langstone, with a 5-knot flood tide and a 6-knot ebb tide, and of Portsmouth with tides about the same; Southampton Water with its double tides; Keyhaven with its mud flats; the waters round the Forts of Horseand, Nomans and Spithead with their baffling tide races; the Solent between Gurnard and Stone Point with choppy seas and cross tides; and that exasperating place called The Needles, where heavy weather may delay work for weeks.

The first lesson to be thoroughly mastered before attempting any cable work in these waters is to know the "Tides": some work is better and more easily carried out on the spring tides, some on the neap tides, some at high water and some at low water, according to local circumstances.

Under normal conditions the Submarine Department's cable ships or shore parties would have carried out the works, but as the cable ships were following their occupation in mine-infested waters, it was impossible to make up shore parties from an already depleted staff, and the Submarine Department suggested that it might be possible for the Local Engineer to effect some of the repairs and also lay new cables where necessary. Luckily, the Section possessed two good G.P. Jointers and a large number of old seamen who were well used to boat work and who in some

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cases had an intimate knowledge of the tides at Spithead and in and around Portsmouth Harbour.

Naturally all the good craft was in use by the Admiralty and War Department, and for the repairs in the Solent and Spithead it was only possible to obtain boats which were in most cases fairly seaworthy, but absolutely out of date, and not very suitable for the work in hand. An old ship's sailing cutter belonging to Portsmouth Dockyard, about 40 ft. long and 12 ft. beam, was found in one of the Dockyard basins, and this was fitted, as occasion required, with running sheaves fore and aft and the bottom strengthened with planks: it was usually towed on site by a small Dockyard pinnace. When repairing War Department cables an old horse boat was used, and the military daily ration boat for the forts usually towed this craft on site and then went on duty elsewhere, very often not returning until the run had to be made for the harbour before the boom went across at sundown.

In laying and recovering lead-covered cables the method adopted varied according to circumstances, and with special regard to the width of the water and the strength of the tide: in all, four methods were employed.

For laying an armoured lead-covered cable across the River Medina at Cowes—a distance of 220 yards—a primitive but effective method was adopted. A flat-bottomed lighter of sufficient size was obtained from a nearby shipyard, and after jacks had been mounted and secured, so as to give a fair lead over the stern for the cable, the cable drum was lowered into position from a wharf. It was necessary to lay the cable on the top of a spring tide, that is, when there was the greatest depth of water. It was not possible to use the floating bridge for towing purposes and a 2″ rope was therefore taken across the river and kept clear of shipping by means of iron sinkers, one end being made fast to a strong ring in a wharf wall, and the other to an available stanchion. The lighter was then placed in position near the rope, the cable end was taken ashore, and immediately the slack water occurred, *i.e.*, on the top of the tide, the lighter was hand pulled across stream by means of the rope which was passed astern, together with the cable, as the lighter moved forward. By this means the speed of laying the cable could be regulated quite simply, four men being on the drum and 12 men pulling on the rope.

The start was made from the west side of the river and it took approximately seven minutes to lay the cable. On reaching the east side the spare end of cable was lowered overboard and picked up at low water.

In recovering the old cable, which was supposed to have been trenched in to a depth of 6′, it was dug out as far as low water, and then it was drawn across the river by means of double and treble blocks and ropes and luff tackle, the latter being dispensed with as soon as the cable started to move: recovery was effected in two hours.

The *second method* of laying was employed across Langstone Harbour Mouth: the distance in this case between shore and shore is approximately 440 yards and there are no loading facilities available near the terminal points.

It was found possible to hire a tug and a sand lighter, and the latter was drawn up as near as possible to the side of an old wharf. At low water the lighter rested on the mud, and it was necessary to obtain planks and man-handle the drum of cable weighing about 7 tons into position on the stern of the lighter: here it was jacked up ready for running, the jacks were bolted together and secured so that no movement was possible, and arrangements were made for applying brakes to the drum.

The master of the tug decided it would be better to lay the cable on the top of a spring tide, and a start was made from the wharf at Milton (Langstone Harbour) about noon, the landing place on the east side of the Harbour being reached about 20 minutes before slack water. The tide, however, was running so very strongly that the tug was anchored and a rope was got ashore from the lighter which was held fast by the prow, and it was decided, as a very strong wind was blowing, that it would be better, instead of towing alongside, to tow with the lighter astern and stern first.

As the writer was of opinion there might be a quick turn of the tide, the cable was got ashore and made fast, and immediately the slack water occurred the master of the tug raised his anchor and commenced to tow. The actual time taken in crossing was about three minutes and when the western shore was reached the tide had turned and was absolutely racing out. The tug held the lighter up stream until ropes were got ashore for holding the stern of the barge and a good landing was then made. To give some idea of the strength of the tide, I would mention that before the tug master was able to get his lighter into position for towing up stream he was swept seawards for at least half a mile and it was fully half an hour before he passed the point where the cable was laid.

The same method as was employed in connection with the Medina cable, of drawing out the old cable by means of main and luff tackle, was adopted again, but measures were taken to prevent the rope biting into the armouring of the cable and the whole cable was ashore in about three hours.

The *third method* employed was adopted for the laying and recovery of the Itchen Ferry cables, the work, which was necessitated by dredging operations, consisting of the following operations:—

(*a*) Laying a temporary 12-core brass-taped, heavy-sheathed cable, and a temporary 50-pr. 20lb. single armoured lead-covered cable on the north side of the floating bridge; transferring all working wires to these cables; and recovering all existing cables on the south side of the floating bridge and all dead ends.

(*b*) When the dredging was completed, laying a 12-core, brass-taped, heavy-sheathed cable and a 50-pr. 20 lb. double armoured lead-covered cable, on the south side of the floating bridge, and recovering the two temporary cables on the north side.

As all suitable lighters and launches were in use by the Admiralty the difficulty of obtaining craft was mentioned to the Engineer of the Southampton Harbour Board, who said, "Why don't you hire our mooring lifting barge? It is capable of lifting up the heavy mooring chains; come and see it." No sooner said than done; the barge was seen and found to be eminently suitable for the purpose. It is in reality an old gun lighter, 60 ft. long by 20 ft. beam, of very light draught, capable of carrying 30 tons, and fitted by the Harbour Board with a 3″ deck, a good derrick, running sheave forward, 2 strong winches with high and low gear, capable of lifting 6 tons each. There is also a small compartment aft containing a stove, which was found a very great convenience for boiling water for tea and heating meals.

In March, 1918, it was noticed that dredging on the north side of the bridge was nearing completion and a start was made in exposing the cables, usually buried to a depth of 2 ft., between high and low water.

In March (and September) the highest and lowest tides are experienced and mud banks are visible which cannot be seen at other times of the year. On the west side it was necessary to take advantage of this fact to lift the cables from the mud. They were dug out and long wood arms placed underneath them to prevent them sinking again. An ingenious method of labour saving was adopted by Mr. Hill (Inspector), who found that when the bridge was nearing mid stream on the flood tide the bridge cables swung up stream for some distance. Whilst, therefore, the bridge was ashore he fastened a rope to the bridge cable and to one of the Department's cables buried in the mud; as the bridge crossed the river the pull was enormous, dragging the cable out of the mud and saving much digging under very unpleasant conditions. On March 18th, the Harbour Board advised that the dredging was completed on the north side and the temporary cables could be laid. Southampton is well equipped for dealing with heavy goods, and as the heaviest drum to be lifted weighed approximately 8 tons, arrangements were made to use the 12 ton crane on the Town Quay, and on the date named the barge was towed into position under the crane; ropes, chains and all other necessary tackle were got on board; a pair of jacks capable of lifting 12 tons were borrowed from Messrs. Pirelli's and a specially strong steel axle from Portsmouth; the battens were taken from the drums, and the first cable was placed near the crane.

The drum carrying the 12-core cable, weighing 6 tons, was too wide to be accommodated in the hold and it was therefore jacked up on the deck, the jacks being clamped to 8′ brace blocks fastened to the deck and being also secured by 400 lb. G.I. wire to the sides of the barge.

The barge was then towed by the launch as near as possible to the shore, and, after being made fast by means of ropes taken ashore, the end of the cable was run off the drum, over a sheave which had been fixed aft, and taken ashore by hand. A rope had previously been taken forward to a mooring chain in the river and the barge was manhandled to deep water. Two ropes were then taken across to the floating bridge, and on the signal being given to the Bridge Superintendent the floating bridge towed the boat as far across as possible; ropes were then taken ashore by the dinghy and the barge was again manhandled; the actual crossing was in reality about five minutes, but seemed much longer.

Both this and the next cable were laid on the flood tide in order to clear the floating bridge, which swings north on its hawsers when crossing, and the state of the tide did not permit the work commencing until 2.30 p.m., but it was successfully accomplished by 5.30 p.m.

The 8′ drum carrying the 750 yards of 50-pr. 20 lb. cable, weighing 7 tons, was narrower and could be accommodated in the hold of the vessel, which was much safer, as it could not, at all events, go overboard if it broke away.

When a start was made in bringing the cable ashore, one of the centre plates of the drum broke away and the work had to be suspended. An examination showed that the centre was badly affected by dry rot; this was cut away; oak stretchers were placed inside the drum; a new elm centre was fitted, to which the centre plate was bolted, and steel strengthening bands were bolted in position. As the centre plate on the opposite side of the drum also showed signs of shearing through the wood, this was taken off and two stout pieces of elm were bolted in position. The work of repairing the drum and getting it into position again on the jack occupied 15 hours—and the tide was lost for the day.

The cable was successfully laid before 6 p.m. the following day, and the jointers by working all night completed the transfer of the working circuits to both temporary cables by the time the barge was in position ready for lifting the cables made spare on the south side.

The 102-pr. armoured lead-covered cable was first tackled, and was underrun from the shore and heaved on board by using the derrick. The end was coiled on the large drum from which the last cable had been uncoiled, six men manning the drum at this period. The recovery now proceeded by bringing on board over the forward sheave by means of the steel winch ropes and three and sometimes four men were required on the winches, sling chains being used to obtain a grip on the cable and short fleets being made. The actual time occupied was from 10 a.m. to 4 p.m., with a short interval for lunch, and the work was very heavy indeed owing to its completion being necessary before the tide took command. The boat's head was kept fairly well in position by the heavy cable, but when the rear ropes became too long to handle or were in the way of traffic, kedge anchors were used for keeping the stern straight. The cable was raised without damage. It weighed approximately 7 tons, and all spare hands had to be on the drum to coil the last 100 yards.

In recovering the old 4-core cables it was found the sheathing had become too brittle to allow of them being coiled on drums. They were therefore brought inboard and coiled on deck.

The permanent cables were laid in the same way as the temporary cables, but in recovering the latter it was found possible to redrum them as they were brought inboard.

The *fourth method* was employed recently in laying cables across Portsmouth Harbour between Portsmouth and Gosport—a distance of 740 yards.

A lighter propelled by its own power, and specially fitted since the War for cable work by the Admiralty in the immediate neighbourhood of Portsmouth, was hired from the Dockyard Authorities. It was originally one of the boats used for landing troops on the coast of Gallipoli; consequently it is a fine roomy vessel and can accommodate large drums of cable in the hold, but the power unit is not large enough to hold the boat in position with a cable astern and any tide running.

The drums of cable, each weighing 9 tons, were mounted on jacks in the hold and the cable paid out, nearly astern, over a greased boom. The lighter, being of fairly shallow draught, was able to get within 100 yards of the shore on the Portsmouth side and about the same distance on the Gosport side. The getting inboard and the mounting of the jacks and placing the drums in position required much thought and care as regards detail.

The cables were laid at low water on the neap tides, and great precision in the arrangements was necessary, as if delay had occurred the flood tide would have carried the lighter (which can only proceed about 7 knots under its own power) over the Gosport Ferry cable chains, and this would have been disastrous both to the cable and the working of the Ferry.

In laying the second cable extraordinary luck was experienced. The cable end had just been taken ashore on the Portsmouth side when a Swedish man-of-war entered the harbour and proceeded to its mooring, accompanied by a tug. The usual formalities of gun firing, saluting, etc., were carried out and this always means very slow progression. Immediately this vessel had passed up the harbour it was decided to lay the cable and orders were given accordingly; the cable laying was just completed and the Gosport side reached when the seaplane-carrier, "Argus," entered the Harbour. If the "Argus" had been ten minutes earlier the cable laying would have been delayed half an hour, the tide would have been in flood, the cable end would have had to be taken aboard, and the next neap tides awaited.

Laying and recovering G.P. submarine cables.

In laying G.P. submarine cables, which are generally received coiled in railway trucks and not on drums, the method employed is to use a flat-bottomed lighter sufficiently large to accommodate the cable coiled in a figure 8. The coiling of the cable in this form enables it to run off smoothly over the stern of the lighter and does not require men stationed round the coil to keep it in place. It certainly takes some little time to coil in this way, but it has been found to be more economical in time when using the type of vessel available. Having coiled the cable at any convenient wharf in the lighter, a motor launch, steam or otherwise, is hired to tow the lighter to the first landing point, generally an oilship lying in the river.

Having got the end safely on board the vessel to which communication is desired, a large iron sinker is chained to the cable to anchor it near the vessel, this being necessary as the oil ships swing to moorings fore and aft. The lighter is then towed towards the shore, the cable being paid out over the stern.

Usually the towing craft has required 6′ to 9′ of water and naturally could not tow quite inshore. Having gone as far as possible, the lighter is held until a rope is got ashore by means of a boat, the land party then pulling in the lighter by hand and landing the cable end.

This method is typical and the only special point to be watched is that the craft is suitable to take the length and weight of cable to be laid. It is always safe to err on the large side so far as the lighter is concerned.

In one or two cases the G.P. cable has been received on a drum and one of the methods already described for laying lead-covered cables has been adopted.

Repairing armoured lead-covered cable.

Only on two occasions has it been possible to repair lead-covered submarine cables.

In the first instance, a cable which crossed the Medina River at Cowes was slightly damaged, and it was found necessary to cut in a new section of about 80 yards from one side of the river. An old ship's lifeboat was hired, the new piece of cable brought on board, and the good end of the existing cable was underrun and made fast on board. The lead sheaths of both old and new cable were stripped back for about 10 feet and a paper core joint was made in the usual way. A very long sleeve, however, was used. After the wiped joint was completed the lead sheathing was wrapped with adhesive tape for a distance of 6 feet on each side of the joint; this was covered with prepared yarn, the steel tapes were laid in position, and the sheathing was then spliced and bound in. (The method of overlap and splice jointing is described later.)

The second repair to a lead-covered cable was carried out successfully on the Itchen. The damage occurred at a point between high and low water mark and before the tide rose it was possible to protect the exposed end sufficiently by means of cycle tyre tubes to prevent the water entering. At low water the cable was pulled back into position, first by means of main and luff tackle and then with the help of the floating bridge. The damaged end was cut away and the cable is still working satisfactorily.

Repairing G.P. Submarine Cables.

During the winter of 1917 and 1918 many of the G.P. Submarine Cables were damaged, principally by boats having to drop their anchors, and it became necessary to undertake a considerable number of repairs.

The same method was employed in each case, and a general description of the way the work was carried out is as follows:—

In practically all cases both ends of the cable were accessible, and localising tests were made by means of the Wheatstone Bridge, the distance of the fault usually being obtained fairly accurately. As grappling is a difficult process with an open boat and in strong tides, an effort was always made to pick up the end and if this succeeded the cable was underrun until the fault was found.

If the cable was broken the broken end was buoyed and usually the other end of the cable was grappled for or underrun from the other side until the second end was secured. Generally 50 to 100 yards of new cable was carried in the boat in case sufficient slack could not be picked up for jointing.

In making the joint the sheathing wires on both ends of the cable are first opened out for a distance of about 8 yards and the exposed core cut away, with the exception of 4′ required for jointing.

The conductor joint is next made. The insulation on each core is removed for 1½ inches, the copper strand is opened out, each of the seven wires is scraped and cleaned bright with glass paper and then twisted up again to form a strand as before. Each end is soldered and trimmed and is then filed down obliquely on one side. The rough corners left by the solder are filed off and smoothed with glass paper. The ends are now clamped in a jointer's tray and brought close together, fitting truly and presenting a bright silvery appearance, and the joint is bound with fine copper binding wire to within ¼ inch of the clamps on each side, the binding being of open spacing to allow of removal after the solder has been run in. A neat solid joint is thus made and, after removal of the binding wire, a close binding is laid on in the middle part of the joint and soldered; a second wrapping is then laid on to near the clamps on each side and this is soldered at each end only and close to the clamps; and finally the joint is smoothed off and cleaned of the soldering fluid by rubbing with a rag soaked in naphtha, and is then ready to receive its insulation.

To insulate the joint it is first given a complete coating of Chatterton's Compound, which is smoothed with the smoothing iron and worked over with the finger and thumb to ensure that there are no air bubbles in the covering. The gutta percha of each core is then warmed up and drawn until the ends are about ½ inch apart; one end is then drawn down to a point and the other end worked over it, completely covering the copper joint and, after being warmed up and well smoothed down, a serving of compound is given to the gutta percha.

A strip of gutta percha, 3 inches by 1½ inches is next warmed up and, one end being laid under the joint, is worked from one end to the other, in one direction only, with an upward pressure; it is again warmed up and worked round the core until every part is completely covered; the overlap above the joint is nipped together and cropped by scissors close to the core; then it is again warmed up, worked, and smoothed over.

A second strip of gutta percha, about 6 inches by 1½ inches, is next laid on and worked in the same way, so as to taper on to the core on either side. It is given an additional coating of Chatterton's Compound, again smoothed over by rubbing with the hands well moistened.

The completed joint, with the copper conductor well centred and with a complete fusion of the layers, measures from 6 inches to 9 inches long and is very little larger in diameter than the core.

It is important to mention that the cores are cut so that the joints can be "staggered," *i.e.*, spaced, and thus avoid damage by compression when the core is re-covered by the sheathing. In cables up to 8 cores the distance apart is generally about 6 inches, but in the lighter types, or with a greater number of cores, 4 inches is sufficient. Great care is required to cut the wires to the correct length, otherwise, when the set of joints has been completed, there may be a slack or tight wire. A good and convenient method is to cut out the cores with the help of a 6-inch measure.

When the core joint has been completed it is first covered with cotton tape, then with brass tape, and finally with jute yarn. In splicing the sheathing the wires on one side of the joint are laid out in twos and threes, wound in turn round the yarn-covered core and then over the sheathing wires on the other side and as they are carried round into position they are bound with soft iron lapping wire at intervals to prevent any springing out of position. The sheathing is then served with tarred yarn by means of the serving mallet.

The splice just described is known as the "overlap" splice, but the "butt," or "laid in," splice was generally made by the local staff. For this splice the ends are prepared in the same manner as for the "overlap," and the cable end from which the core has been removed is called the "long end" and the other the "short end." When the joints have been covered in, half the wires on the "long end" are laid in as far as the sheathing wires of the "short end" and then unlaid in pairs. One pair is selected and laid on the "short end" after a corresponding pair has been removed. The first pair is carried to the full length, cut off and trimmed so that the butted wires are on the top; they are easily trimmed off with bolt clippers and "butted" so as nearly to touch the ends of the pair cut out on the "short end." A piece of tarred tape is then served over the "butted" ends, three inches on either side of the "butt," followed by a lapping of G.I. wire No. 14. The next pair is then taken and laid in the same way and "butted," say, a yard and a half from the first pair, and so on until the last pair, which is "butted" just clear of the joints. In this way the joints are clear of the "butts," which are all on the "short end." The distance apart of the "butts" depends on the length of the splice and the number of sheathing wires. In the case of short splices made in boats, three or four wires may be "butted" instead of two and the splice will still be extremely strong, provided that the lappings have been tightly served on with a mallet.

Testing (a) New lead-covered cables and (b) Submarine cables before and after repairs.

In testing lead-covered cables the same method is employed as for ordinary underground cable; insulation is tested wire-to-wire and wire-to-sheath by means of a 500 or 250-volt megger and should give results beyond the range of the scale; resistance is tested by the Wheatstone Bridge to one or two places of decimals as the distances are short; for contact and overhearing, tests are made by means of the Detector and Buzzer.

In testing for the distance of faults on G.P. cables where both ends were accessible, a simple ratio test was first tried and this was usually confirmed by the Varley test, the Wheatstone Bridge and 10 to 20 cells being used in both cases. In making these tests peculiar results were sometimes obtained, due to electrolytic action between the exposed copper conductors, the sea water and the brass sheath, which formed, at the exposed end, a small battery sufficiently strong to give misleading figures. After the repairs and 24 hours' immersion, tests for insulation and conductor resistance were made by means of the Wheatstone Bridge; no capacity tests were undertaken at any time.

The experience gained on this class of work has led the writer to the following conclusions:—

(1) Every step in the preparations for cable laying must be carefully considered, and it is well to visualise the whole proceeding from start to finish. No detail must be overlooked; the fraying out of a single rope, or, when dealing with heavy drums, a loose timber, badly placed jacks, wire lashings not firmly secured, etc., may lead to disaster.

Once the officer in charge of the work has decided that all has been done to carry the work to a successful conclusion the remainder can only be left in the hands of the gods.

(2) In both laying and repairing cables it is absolutely necessary to have only one officer in command, and this officer must make quick and bold decisions if things go wrong.

I should like to place on record my thanks to the Brothers Bordeaux (Submarine Superintendents) who were always willing to give advice and help when appealed to.

WIRELESS

RUGBY RADIO STATION.

By T. Walmsley, B.Sc., Assoc.M.Inst.C.E.

To the popular mind, wireless aerials and masts conjure up visions of unsightly wires slung upon protesting branches of trees or anæmic clothes props. Undisturbed by thoughts of stress and strain and regardless of factors of safety, the wireless amateur broadcaster cheerfully attaches his wire to the most convenient fixing and, although the harmony of his happy home may sometimes be rudely broken by the pointed comments of the lady who has promised to love, honour and obey him, the enthusiast pursues the even tenor of his way, wholly contemptuous of Euler and his satellites. Not so the wireless mast engineer. Each icy blast of March sends cold shivers of apprehension down his spine, causing him pangs of regret that he did not double his already high factor of safety. Mentally he vows to add those extra bracings that, when gentle summer breezes blew, he had decided to omit in the sacred cause of economy.

Here at Rugby, where eight of the twelve steel lattice-work masts have been completed, the recent gales have emphasised the wisdom of adopting large factors of safety. Viewed through a telescope, the top of a mast has been seen to oscillate three feet beyond a central position about its pivotal base. The design, however, provides for a deflection of eight feet, and even when this is obtained factors of safety of from 3 to 6 still give ample margin of security. Careless workmanship, however, might cause catastrophe, so careful supervision of the quality of workmanship, both in the shops and on site, must be maintained. Masts 820 feet high, supported on porcelain insulators and granite blocks, are extremely imposing, but behind this spectacular effect lies a vast amount of exact calculation and planning. Before the work of erection could begin, a suitable site had to be found and bore-holes made to determine the suitability of the sub-strata to withstand the great concentrated load of masts whose maximum downward thrust is 400 tons. A careful survey was necessary, transport facilities had to be made and an efficient but flexible testing and supervising organisation had to be undertaken. Months before the masts began to be conspicuous landmarks, a vast amount of ground work was completed. It was essential that the

FIG. 1.—BASE OF MAST, SHOWING STEEL STANCHION, GRANITE BLOCKS, PORCELAIN INSULATORS AND BALL SOCKET.

porcelain insulators upon which the masts stand (see Fig. 1) should be tested electrically, but no testing plant existed with which to make the requisite tests, without interfering with the running of plant in other Radio Stations. The Department, therefore, installed at Rugby a steam-electric plant of 100 Kilowatt capacity. To convert the 500 volt direct current into high frequency current, an electric arc with oscillating circuit, was fixed, old departmental plant being used for this purpose. Up to the present moment, some 2,000 insulators have been tested with a voltage of over 15,000, the frequency being 50,000 cycles per second. The application of this voltage and frequency to

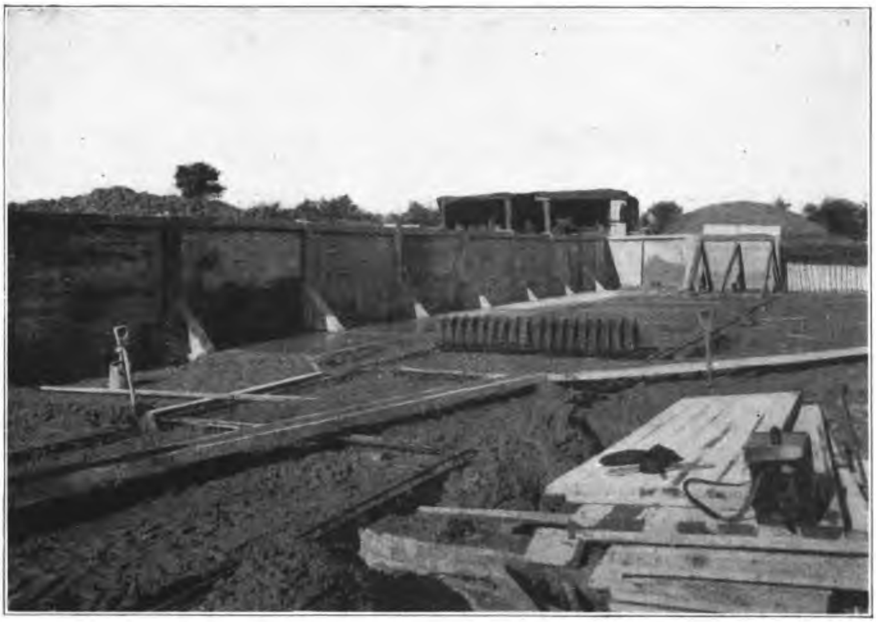

Fig. 2.—500,000 Gallon Ferro-Concrete Reservoir in Course of Construction.

defective insulators has, in some cases, occasionad so high a rise in temperature that the material has become like molten lava. No insulator has been passed if any appreciable rise in temperature has been observed after a period of over one hour.

Some idea of the magnitude of the constructional work involved will be gathered from the fact that about 8,000 tons of concrete have been needed for the mast foundations and the anchor blocks to which the stay ropes are attached. In addition some 700 tons of concrete have been used upon a ferro-concrete reservoir (Fig. 2). This reservoir, designed and built by the Department's staff, is required to hold 500,000 gallons of water required in connection with the cooling system of the transmission valves with which the station will be equipped.

All stay ropes for the masts were made on site, special plant being needed to draw out, two by two, the 150 wires required in the largest stays. These wires were then drawn together by mechanical appliances and bound tightly round with steel wire. The ends of the stays were bent over and fitted into tapered sockets, one of which is shown in Fig. **3**. A low temperature melting metal was then run into the socket to bind securely the ends of the wires.

Concurrently with the work of erection of the masts, the aerial

FIG. **3**.—SOCKETS AT END OF STAY ROPE.

has been prepared and the earth system partially completed. The aerial is in the form of wire "sausages," supported by means of steel spreaders, 12 feet in diameter, clamped on to a central steel cable. When in position on a calm day the tension in the central cable will be 6 tons, but this figure will be exceeded considerably when a strong wind blows. The mast itself is designed for a top horizontal pull of 10 tons and precautions have been taken that this pull shall not be exceeded, by fixing a slipping device to the drum of the aerial winch. Wires have been laid a few inches under the ground by means of a special plough (Fig. **4**) designed and built by the Department's staff. The plough is such that in a single operation a narrow trench less than an inch wide is cut in the earth, a wire is laid down and the trench partially closed. About 80 miles of wire have been so laid

The Station is fittingly termed "the Radio" in preference to "the Wireless." Wire will be everywhere, quietly lying in the earth, gently swaying aloft, and revolving in large motor generators. In the stays alone, 3,000 miles of wire have been used, and if the total lengths of copper, phosphor-bronze and steel wire used in the construction of the Station were totalled together, the sum would be sufficient to build a single line to the Antipodes.

Of the anxieties and humours of erection, much could be said. The former try to forget, the latter we cherish as good friends.

FIG. 4.—WIRE-LAYING PLOUGH.

One can picture the difficulties and dangers of working hundreds of feet above the earth. One such danger is illustrated in the photograph (Fig. 5), showing a man stepping across from a platform to a ladder, which swings from its temporary holdings 20 feet above him. Below is a clear drop of 700 ft.

After a little experience, the workmen adapt themselves wonderfully well to the dangerous conditions. Each mast has its leading hand and each leading hand has his own methods of dealing with his assistants. One such leader is a man of simple speech and many adjectives. Upon occasion his remarks are more lurid than polite and his verbal broadcasts are only appreciated by those not concerned. One day, two of his victims stood silently watching him emulating the monkey tribe. As his leader reached the top of a mast, Bill feelingly remarked to his companion, " Arry, that's as far as 'e will ever get to 'eaven."

FIG. 5.—ONE OF THE MASTS: LOOKING UPWARD FROM THE GROUND.

Men foregather at the Radio Station from all parts of the British Isles. The broad sing-song dialect of the North blends with the monotone of the South ; the staccato of Wales harmonises with the adagio of the Midland Counties. Excavators are mostly local men, steeped in local tradition and practice.

In spite of the many delays experienced owing to strikes and bad weather conditions, the work of erection of the Radio Station is proceeding smoothly. The spirit of good fellowship that exists between workers of all ranks augers well for the success of the project. When, in the near future, the thrilling moment arrives for messages of goodwill to wing their flight to the furthermost corners of the earth, each toiler, in his own sphere, will truly feel that something has been attempted, something done.

THE TESTING OF INSULATING MATERIALS FOR USE AT HIGH FREQUENCIES.

Since certain of the porcelain insulators inserted in the stays supporting the masts at the Leafield Radio Station began to melt for no very apparent reason, a very great interest has been taken by the Engineering Department in the behaviour of various insulating materials when subjected to the influence of strong electrostatic fields alternating at high frequencies. It was at once realised that laboratory measurements of power factor, insulation resistance, etc., would not give a complete indication of the value of a particular material for high frequency work. This will perhaps be more readily realised if the effect be considered of a small amount of impurity, having heavy dielectric losses, embedded near the centre of a mass of insulating material which is also a very poor conductor of heat. If such a body were tested for power factor and insulation resistance it is quite probable nothing untoward would be observed. If, however, it is subjected continuously to a very strong high frequency electrostatic field, heat will be generated. This heat, imprisoned in the heart of the material, will have no easy means of escape and the internal temperature of the body may rise continuously until the material itself fractures, melts or burns in accordance with its particular physical characteristics.

A definite practical test is therefore essential, sufficient power being used so that applied voltages are not considerably reduced by any losses in the test pieces. The Poulsen Arc high frequency generator lends itself admirably to this purpose. It is very robust and is unaffected by the sudden breakdowns, flashings-over, etc., from which tests of this nature are inseparable. The arc installation at the Northolt Radio Station was requisitioned, at such times as it was not required for commercial traffic, for most of the early work, which was carried out by Mr. G. T. Evans. The arc is capable of supplying to the primary circuit about 10 k.w. of high frequency power and will produce a normal voltage of 26,000 V., which can be increased if necessary to a maximum of 35,000 V at a frequency of 43,000 cycles. The oscillation circuit itself consists of a Dubilier Mica Condenser of 0.005 μ F capacity and an inductance made up of $\frac{5}{8}''$ diameter copper tubing, the coil being 6 feet in diameter and approximately 10 feet high. The material to be tested is placed between two copper plates connected across a portion of the tuning inductance, as is indicated in the diagram of Fig. 1. The high frequency

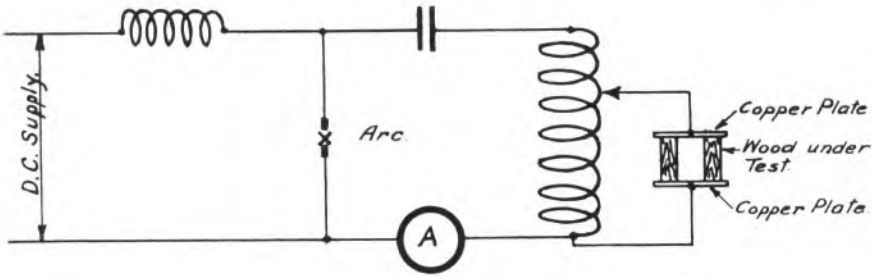

FIG. 1.—TESTING CIRCUIT.

voltage applied to the sample under test can be varied either by moving the tapping point or by the control of the D.C. supply voltage to the arc, and is known by reference to the H.F. current in the oscillation circuit, the inductance and the frequency. This voltage can also be checked by means of an electrostatic voltmeter. The temperature of the test piece is kept under observation throughout the test by means of an ordinary thermometer, the bulb being placed in intimate contact with the surface of the material and protected by means of asbestos, or (in the case of wood and similar materials) inserted into a small hole drilled into the sample. Readings of rise in temperature of similarly shaped bodies under the action of the same field give a very ready, though perhaps somewhat rough, idea of relative quality.

The tests which follow were in the nature of preliminary tests in order to ascertain the best materials for use for the insulation of the masts and stays at the Rugby Radio Station, and also to determine the most suitable material for the manufacture of high power tuning inductances. In the first mentioned case, it was necessary that good dielectric properties of the material should be combined with good mechanical properties, as some of the insulators were to be called upon to support a maximum load of 400 tons.

The following schedule gives examples of the results of preliminary tests on materials considered for mast and stay insulation, the frequency being 43,000 cycles in each case :—

Material.	Dimensions cms.	H.F. Volts, R.M.S.	Duration of Test.	Temp. rise during test.	Remarks.
British Granite	11×8×3	23,000	Few Secs.	95°F.	Broke down immediately the voltage was applied.
Norwegian Granite, coarse grain, dry	10×9.5×5	21,000	5 hrs.	59°F.	O.K. at end of test.
Do. do., after immersion in water for 30 minutes ...	10×9.5×5	3,200	3 mins.	100°F.	Test discontinued owing to rapidly increasing temperature.
Norwegian Granite, fine grain, dry	10×9.5×5	21,000	5 hrs.	48°F.	O.K. at end of test.
Do. do., after immersion in water for 30 minutes ...	10×9.5×5	3,200	3 mins.	73°F.	Test discontinued owing to rapidly increasing temperature.
Cornish Granite ...	15×15×8	17,000	10 mins.	90°F.	Test discontinued owing to rapidly increasing temperature.
Aberdeen Granite ...	10×9.5×5	21,000	5 hrs.	102°F.	—
Staffordshire Bricks, dry (*a*) Wire cut (*b*) Moulded	23×11.5×7.5 ,, ,, ,,	8,500 10,000	30 mins. 30 mins.	96°F. 75°F.	—
Staffordshire Bricks, after immersion in water (*a*) Wire cut (*b*) Moulded	23×11.5×7.5 ,, ,, ,,	7,000 7,000	2½ hrs. 2½ hrs.	160°F. 13°F.	Temperature was constant during the last hour of test.
Porcelain, dry	17 diam. 10 high solid	25,500	3 hrs.	—	Temperature out of range of thermometer at end of test.
Do. do., after immersion in water for 30 minutes ...	17 diam. 10 high solid	25,000	45 mins.	—	Became molten internally, cracked and molten porcelain exuded.
Porcelain, solid, after 20 hours immersion in water ...	30 diam. 15 high	15,000	—	130°F.	
Porcelain as above, but with central hole 10 cms diam. ...	30 diam. 15 high	30,000	—	25°F.	Temperature began to fall after reaching max. and remained steady at 20° rise for one hour.

Fig. 2* shows the results of a test on a number of different kinds of wood required for use in manufacture of large inductance coils. These samples, each 4″ × 1″ × 1″, were subjected to the test simultaneously, the voltage being gradually raised. The name of the wood is shown against the point on the graph of voltage and time at which it was necessary (owing to burning, etc.) to remove it from the test. Points A and B indicate the approximate relative merits of two well known proprietary materials of

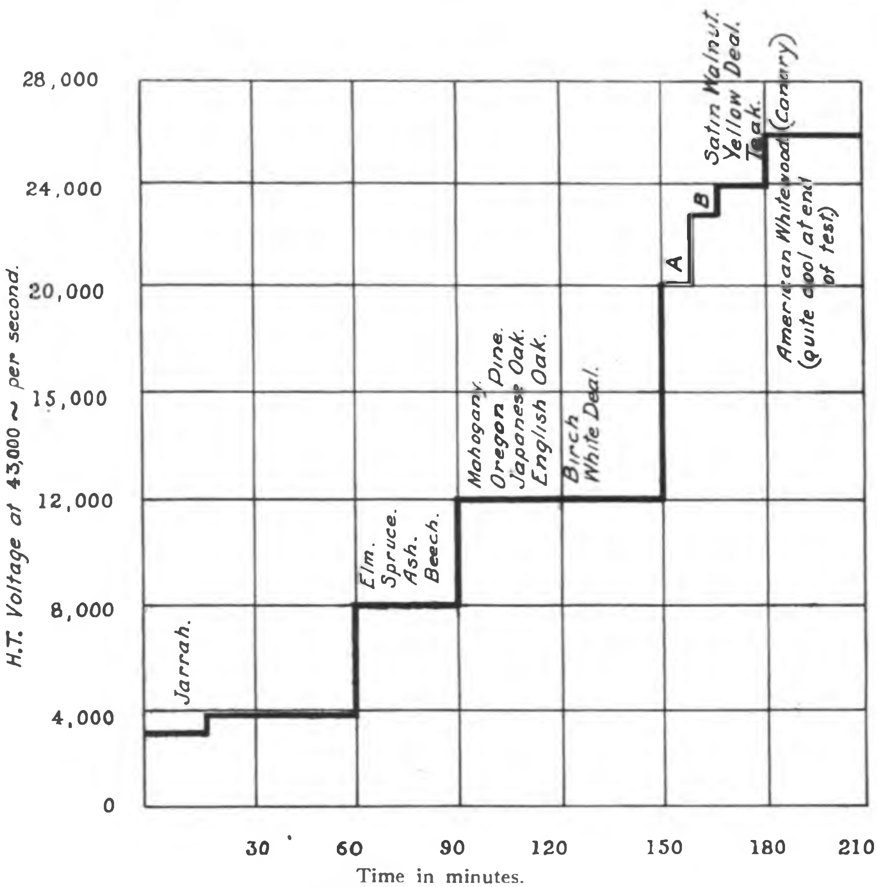

Fig. 2.—Tests on various types of wood.

synthetic resin and cellulose, which are generally regarded as of special value for high frequency work. It is now the practice of the Department to test in this manner samples of all insulators which are to be used under high frequency conditions, and many hundreds of samples have been so tested in the temporary testing plant installed on the site of the Radio station now in course of erection at Rugby. H.F.

* See also E. H. Shaughnessy, *Journal I.E.E.*, 1925, Vol. 63, p. 61.

NOTES & COMMENTS

NOTES AND COMMENTS.

Mr. Donald Murray's paper on "Speeding up the Telegraphs: A forecast of the new Telegraphy," had a favourable reception when read at the Institution of Electrical Engineers in December last. He describes it as mainly a forecast of the probable form that the telegraph will take in the next 25 years.

He who would adopt the role of prophet must needs be an enthusiast and one with strong convictions, especially on such a highly technical question as this undoubtedly is. Mr. Murray is more than this, because after advocating the "Automatic" system (high speed single channel working) for a number of years he had the courage to change his opinions and become a supporter of the "Multiplex" system. The change is entirely in his favour, as only a strong man can do this and cannot but command our respect.

Mr. Murray now advocates a telegraph exchange system. This, of course, is not a new idea, as we have seen several essays in the same direction, for example the early Umschalter system of the old Electric and International Co., the Wheatstone A.B.C. exchange at Newcastle-on-Tyne, the Intercommunication Switch at the C.T.O., designed by Colonel Purves, and the Telewriter Company's Exchange in London. The new feature in connection with Mr. Murray's proposal is the use of the "Start-Stop" printer.

The apparatus is a very suitable instrument for placing in the business man's office in order that it may be manipulated by his typing staff. As far as our experience goes it has done its work very well, but if its use be extended it will mean a considerable increase in the staff of mechanics and will create quite a new industry in the same way as the ordinary typewriter has done. Its maintenance will not be less simple, and the introduction of long distance transmission will not render this phase of the matter less difficult.

Mr. Murray states there is no shortage of telephone messages. One of the difficulties of both the telephone and telegraph services is to provide a uniform load for the plant during and after business hours. The telephone rates are varied to induce the public to distribute the existing load over a longer period, but business men are prone to confine their communications to normal working hours and even to concentrate on only a few of them. The only people who wish to use the telegraph service at night time are the newspaper proprietors and they are encouraged to do so as much as possible by cheaper rates for the use of night circuits.

Another point mentioned by Mr. Murray is that the telephone needs two costly wires while the telegraph needs only one. This may be true for aerial lines, but even in this case it is possible to provide more than one circuit on the telephone loop whereas the telegraph line does not lend itself so readily to such an arrangement. When, however, long underground cables are used the telegraph needs two wires so that in this case the comparison does not hold. Doubtless in the future all telegraphs, that is, the main circuits, will be underground in order to provide surety of communication (we have gone a long way in this direction already) which is one of the most important factors for a really efficient service.

It must be borne in mind that the diversion of an aerial circuit to the underground almost invariably leads to a reduction in the speed of signalling.

Mr. Murray refers to the great farming industry. Speaking of this country alone, the individual farmer is not a great patron of the telegraph and is not likely to indulge in private teletype circuits. The purely business messages connected with farming are few and as these alone justify typewriting telegraphs the outlook in this direction is not a very hopeful one. Even the cheap telephone which, apart from business transactions, can be used for social intercourse between farm and farm is not nearly so much utilised as it might be.

The transfer of the cost of operating to the subscriber is, of course, a very alluring one, as this is the most serious item so far as the Post Office is concerned. According to the Accountant-General, about four-fifths of the costs of dealing with a telegram are due to operating charges; this fact is enough to spur all engineers to special efforts with a view to eliminate some of them. Much has already been done and if the "Start-Stop" will assist in this direction, and there is good reason to think it will, the engineer will do his best in the matter.

Mr. Murray states plain multiplex working duplex can give twelve channels on a single wire without difficulty and there is nothing inherently impossible in working the ordinary multiplex up to twelve channels each way. This is 100% more than anything yet done on a stable underground circuit. Much, of course, depends on the length of the line, but this point is not mentioned and might mislead the uninitiated.

The calculations given by Mr. Murray on page 18 of his paper make no mention of the capital cost of the multiplex apparatus that would be required at each end of the line, nor of the attendance for running and maintaining it. This charge would be additional to the teletype exchange maintenance and operating.

At 40 words per minute twelve arms would mean 480 words per minute duplex. Between London and Birmingham we have obtained 180 words per minute duplex, six arms at 30 words per minute, so that although the teletype would be working at the lowest speed quoted by Mr. Murray, the figures are pretty high. The duplex balance would have to be exceptionally good and the phase running of the two distributors very exact. On the same page Mr. Murray mentions that so long as we don't expect too much from telegraph machinery and human nature we have good reason to be hopeful.

Speaking of the speeds at which the Start-Stop printers should be run, Mr. Murray mentions three possible speeds. Seeing that in order to get intercommunication between different circuits working on the multiplex system a common speed is necessary, it would appear that the teletype should be made to conform to it. Several advantages would be obtained, more channels per circuit would be obtained at, say, 40 w.p.m. than if the speed were higher, maintenance would be cheaper and in the long run the subscriber would be more satisfied with an instrument that ran well at low speed than with an indifferent one at a higher speed. Speed changing gears should not, it is thought, be encouraged. Time would be lost and so would tempers.

THE TRANSMISSION UNIT.

It is very desirable at the present time, when international telephony on a large scale has become a practical proposition, to establish a uniform unit of transmission in terms of which the efficiencies of telephone transmission lines can be expressed. There has been a considerable amount of discussion in the technical press and elsewhere on the choice of this unit and the matter is now under consideration by the International Electro-Technical Committee. These notes are intended as a summary of the present position. For further details reference should be made to the articles which have appeared recently in the technical papers.

1. *Alternative Systems of Transmission Units.*

(*a*) Mile of Standard Cable. In this system the transmission efficiency of a circuit is stated as being equivalent to that of x miles of standard cable. The standard cable is defined as an air-space paper-core cable with the following constants (per mile):—

$P_1 = 88$ ohms, $L = 0.001$ Henry, $G = 10^{-6}$mho., $C = 0.054\ \mu F$.

This is the recognised unit in Britain and until recently in America, except that the constants adopted in the two countries differ slightly. It is also used in the Dominions and several other countries.

(*b*) The "800-cycle mile." This unit has an attenuation equal to that of a mile of standard cable at a frequency of 800 cycles per sec. It has been used in America and Britain to fulfil the need for a unit which is independent of frequency and of a recognised magnitude. Non-reactive artificial cables calibrated in this unit have been in use for some time.

(*c*) The "Natural" Attenuation Constant β.

This system has been used until recently for all mathematical work in connection with telephone transmission. In Germany and some other countries it is also used for general engineering purposes.

(*d*) The "T.U." This unit has recently been introduced in America. In this system two points on a transmission line are stated to be 1 TU apart when the ratio of the power being transmitted through them is equal to $10^{0.1}$. It will be seen that the essential differences between this unit and "β" is that the TU is based on a Power ratio instead of on a current or voltage ratio and the logarithmic base 10 is used instead of the natural base e.

(*e*) The "Décie." This unit is one tenth the magnitude of the "natural" unit β and has been proposed as being of a more convenient size. It is not actually in use, but has been discussed at International meetings.

In order that the relative merits of these units may be compared the characteristics of an ideal unit will be examined and the merits of the various alternatives summarised with respect to their fulfilment of these requirements.

2. *Characteristics of an ideal unit.*

The unit should be:—

(*a*) Logarithmic in character.
(*b*) Independent of frequency.
(*c*) Convenient for use in theoretical investigations.

(*d*) Convenient in practical work.
(*e*) Of a suitable magnitude.
(*f*) Suitable for the expression of all types of transmission losses and gains. For example, losses due to apparatus in bridge, reflection and transformers, or gains due to repeaters.
(*g*) The unit should preferably convey a definite physical meaning.
(*h*) The transfer from existing systems should be as simple as possible.
(*i*) It should be possible to make up adjustable artificial cables calibrated in units.

3. *Compartive merits of the alternative units.*

Mile of Standard Cable (*M.S.C.*). This unit satisfactorily complies with conditions (*a*), (*e*), (*g*), and (*i*). With regard to the other conditions :—

(*b*) It is not independent of frequency.
(*c*) It cannot conveniently be used for theoretical calculations.
(*d*) Since the introduction of loaded cables and repeaters there has been considerable difficulty in applying the M.S.C. to practical work, due to the fact that it is not independent of frequency.
(*f*) Losses due to apparatus in bridge, etc., may be expressed in terms of M.S.C. and this method has led to satisfactory results in practical work. Further particulars as to the impedances and phase differences involved are necessary for a full theoretical statement of the case.
(*h*) The transfer would involve alteration of records and construction of standard cables in the case of countries where other systems are in use.

With reference to the construction of artificial cables (*i*), they are usually made containing resistance and capacity only. The error due to the omission of inductance and leakance is not appreciable when the cable is used for speech tests only. Inductance and leakance of the correct values can be added if the cables are required for A.C. tests.

The 800-*cycle mile*. This unit satisfactorily complies with conditions (*a*), (*b*), (*d*), (*e*) and (*i*). With regard to the other conditions :—

(*c*) It cannot be used conveniently in theoretical calculations.
(*f*) The remarks made in the case of the M.S.C. apply, except that the "800-cycle mile" is independent of frequency.

(g) The unit does not represent any actual type of cable.

(h) The transfer from existing systems would be fairly simple but it would involve alteration of records and standards.

The Attenuation Constant β. This system satisfactorily fulfils conditions (*a*), (*b*), (*c*) and (*i*). With regard to the other conditions :—

(*d*) The system presents no difficulties in its practical application to long uniform lines. In the case, however, of lines involving reflection losses some difficulty is experienced which is referred to under (*f*).

(*e*) The magnitude of the unit is somewhat large and it is generally necessary to employ two decimal places in expressing the attenuation length of normal telephone lines.

(*f*) Losses such as those mentioned can be investigated theoretically, but their accurate practical expression in terms of β is not simple. For the simple expression of such losses a power unit is more suitable.

(*g*) The unit does not represent any actual type of line.

(*h*) The transfer from existing systems would involve alteration of records and standards.

The "TU." This unit satisfactorily complies with conditions (*a*), (*b*), (*d*), (*e*), (*f*) and (*i*). With regard to the other conditions :—

(*c*) The adoption of base 10 for the logarithms involves the use of a factor to convert from the natural base. The theory of transmission has been built up from a consideration of the distribution of current and voltage along a transmission line and this, or its equivalent, is necessary for the full development of the theory.

(*g*) The unit does not represent any actual type of line.

(*h*) The transfer would be fairly simple but would involve alteration of records and standards.

The "Décie." This unit satisfactorily complies with conditions (*a*), (*b*), (*c*), (*e*) and (*i*). As regards the other conditions the same remarks apply as in the case of β.

To sum up, the mile of standard cable, although it has been of great value in the past, is no longer suitable for present requirements and is to be abandoned as a unit of transmission. The 800-cycle mile introduces an unnecessary factor in calculations and was only adopted as a temporary measure until a more suitable unit was authorised. It should be abandoned as soon as such a unit is decided upon.

The Décie was considered at International Conferences and the majority of nations represented preferred "β" on account of the confusion which might arise from the use of two methods of expressing attenuation.

At a recent international meeting in Paris the choice was reduced to that between "β" and "TU." The majority of nations represented preferred β and the matter was referred to the International Electro-Technical Committee. It is possible, however, that in the course of further deliberations, some compromise might be adopted, such as a "Power Unit" referred to the natural base of logarithms, *e*.

Apart from technical considerations, there is the question of uniformity of practice among different nations. America has apparently definitely adopted the "TU" and it would therefore be an advantage from this point of view if European nations adopted the same unit.

An unfortunate typographical error crept into Mr. Ragnar Holm's article on "The validity of Erlang's Trunk-Congestion Formula," which appeared in our January issue. At the top of page 320 in line 2, please read "is = x for all . . . ." in place of "is = for all . . . ." We are sorry for the slip and hope no misconception has been caused by it.

We regret to announce the death of Mr. Herbert Watson Sullivan, who died, after an operation, on the 28th January. Mr. Sullivan commenced his electrical work with the Eastern Telegraph Company. Most telegraph men have acquaintance with the Sullivan Universal Galvanometer, which he produced in 1894, but not so many are aware of the large range of testing and cable apparatus which his firm has produced for our own and other administrations. Under his personal supervision the firm of H. W. Sullivan acquired a fine reputation for accurate and careful workmanship.

The following remarks made by the Mayor of Hampstead on the occasion of the opening of a 60-line P.A.B.X., on the 23rd February, may be of interest:—

"The new Automatic Telephone Exchange installed in this Town Hall, and which is linked with the Public Service is, I understand, the first to be installed by any of the Metropolitan Boroughs, and marks a further advance on the part of Hampstead in keeping their Administration up to date. Not only is every Official Department, and indeed every official apartment throughout the Municipality, in instant automatic communication with every other one, but it can also establish immediate communication with the Public Exchange Service.

Under the previous arrangement of manual working, such Departments as the Elect. Station, the Works Dept., the Central Library, etc., had independent exchange lines, so that an official at, say, the Town Hall wishing to speak to the Elect. Station, had to put his call through the operator at the Town Hall, who passed it through the Hampstead Exchange, who in turn passed it through the operator at the Elect. Station. This took anything from 30 to 50 seconds, or more, and each call cost $1\frac{1}{4}$d.

"In the Relay Automatic Installation, which has now been provided by the G.P.O. for this Corporation, the official dials the wanted person direct and is through to him in 3 seconds, whilst the call costs nothing.

"Under the old system, when the operator had left at 5 o'clock in the evening, the telephone service was no longer available, and this was a disadvantage when Committees were sitting late. With the new Exchange, however, the instant interdepartmental service is available all night as well as day, and connection to the Public Exchange Service is available *via* certain night lines which are connected by the operator before she leaves.

"The two points which should chiefly appeal to Municipal Authorities are that all interdepartmental calls on the Automatic System are connected in 3 seconds and that all such calls *cost nothing*, and secondly, telephone operators at outlying Departments can be dispensed with.

"The nature of a Municipal organisation renders it imperative that the various buildings should be scattered throughout the district, but by centralising the telephone service on a "Relay" Automatic Switchboard at the Town Hall, as Hampstead has done, and several other Corporations are proposing to do, judging by the enquiries we have had, the members of the various staffs are enabled to speak to one another just as quickly and just as cheaply as if they were all sitting in the same room.

"From the point of view of Municipal Administrations the advantages of automatic telephony are considerable, each department has the same facilities, and co-ordination is greatly intensified."

The Mayor then made the first official call and declared the Exhange open.

Messrs. W. T. Henley's Telegraph Works Company, Ltd., owing to the expiration of the lease, are removing their Head Office from Blomfield Street, London Wall, on March 18th, to 11, Holborn Viaduct, E.C.1. Their London warehouse which has for some years been situated at 18, New Union Street, E.C., will be also transferred to the new premises at the same time. The firm has been at Blomfield Street for 21 years and the lease expires on the 25th March. For several years the accommodation at Blomfield Street has been quite inadequate to the needs of their greatly increased staff, a large part of which has occupied offices in New Broad Street and in Finsbury Circus House, No. 10, Blomfield Street, in addition, of course, to our occupation of the whole of the building at 13/14, Blomfield Street. The warehouse was transferred to New Union Street 3 or 4 years ago in order to increase the office accommodation at Blomfield Street.

The new premises at Holborn Viaduct were formerly the "Holborn Viaduct Hotel." They have been rebuilt internally and decorated to form a commodious suite of modern offices and warehouse. There is sufficient accommodation in the new premises for all departments to be housed under one roof. They are situated at the eastern end of Holborn Viaduct.

Mr. W. R. Bailey, Superintending Engineer's Office, Glasgow, is willing to dispose of Volumes I. to XVI. of this Journal, bound and in good condition.

The Fox Film Co. are releasing at the end of April a film with the title "Daughters of the Night," which deals with the life of a telephone girl and contains many scenes of large and small exchanges, as well as operations by telephone engineers. A less intriguing title might have been chosen, we submit, but no doubt the company knows its public better than we do.

HEADQUARTERS NOTES.

Exchange Developments.

The following works have been completed :—

Exchange.	Type.	No. of Lines.
Cwmbran New	Auto	66
Birkenhead New	Manual	3640
Manchester Central Extn..	,,	2100
Burndepts Ltd. Extn. ...	P.A.B.X.	10
Charlesworths Ltd. ...	,,	80
Duckworths Ltd.	,,	30
Great Western Railway ...	,,	50
Hampstead Council ..	,,	60
Higginsons Ltd. Extn. ...	,,	5
London Elec. Wire ...	,,	40
Lowthian Drake	,,	40
Philips, J. & N.	,,	100
Spillers Milling Co. ...	,,	100
Triumph Cycle Co. ...	,,	70

Orders have been placed for the following New Exchanges:—

Exchange.	Type.	No. of Lines.
Burnley	Auto	1650
Edinboro' Central... ...	,,	8720
Morriston	,,	320
Southwick	,,	110
Battersea	Manual	5500
Coatbridge	,,	600
Shipley	,,	1080
Walworth	,,	3700
Benton's Ltd.	P.A.B.X.	40
Booths Ltd.	,,	40
Bury Co.op.	,,	50
Cardiff Union	,,	50
Du Cross Ltd.	,,	50
Dunlops Ltd.	,,	50
Gardners Ltd.	,,	60
Hayes Ltd.	,,	40
Morris Motors	,,	130
Nairns Ltd.	,,	80
Robinson's Ltd. (3) ...	,,	70
Scottish Autos	,,	50
Shell Mex Ltd.	,,	30

Orders have been placed for extensions to existing equipments as follows:—

Exchange.	Type.	No. of Lines.
Chiswick	Manual	1500
Eastbourne	,,	1120
Guildford	,,	540
Huddersfield	,,	720
Ramsgate	,,	380
St. Annes	,,	540
Speedwell	,,	2100
Toll M.F.	,,	—
Uxbridge	,,	220
Woking	,,	300
Burndepts Ltd.	P.A.B.X.	10
Higginsons Ltd.	,,	5
Willis Faber Ltd.... ...	,,	10

Fenny Stratford Telephone Repeater Station (permanent) has been completed by the contractors. We hope to be able to describe the lay-out of one of the new repeater stations in an early issue.

*The Engineer-in-Chief had a crowded audience at the Institution of Electrical Engineers on Thursday, the 12th March, when he read his paper on "The Post Office and Automatic Telephones." In printed form, the paper runs to 42 pages of the Journal of the Institution and constitutes a complete history of the development and progress of automatic telephony in this country.

* A limited number of copies of the paper is being obtained for Journal subscribers who do not obtain it from the I.E.E. in the usual manner.

MR. E. H. SHAUGHNESSY.

We have pleasure in announcing the appointment of Mr. E. H. Shaughnessy, O.B.E., to the newly created post of Assistant Engineer-in-Chief in charge of Wireless Services.

Edward H. Shaughnessy, O.B.E., M.I.E.E., M.I.R.E., needs no introduction to the readers of this Journal, as he has been for several years a member of the Board of Editors, over which body he has presided for the past three years.

Mr. E. H. Shaughnessy, the new Assistant Engineer-in-Chief.

He was born in 1871 and entered the Post Office in 1887. After several years of service in the C.T.O. he joined the Engineering Department in 1896 as a Sub-engineer. He passed rapidly through the ranks of 2nd Class Engineer (1898), 1st Class Engineer (1901), 2nd Class Technical Officer (1903), doing service in the Experimental, Test, Telegraph and Cable Sections of the Engineer-in-Chief's Office. He also served as third Cable Engineer on board the S.S. "Faraday" during the laying of a new submarine cable across the Gulf of Mexico from Galveston to Coatzacoalcas, and in the repair of deep sea cables.

In 1908 he was transferred as Assistant Superintending Engineer to the Eastern District, and early in 1913 he returned to

Headquarters as a Staff Engineer to take charge of the Wireless Section of the Engineer-in-Chief's Office. He entered this section at a very important period in its history. The Coast Stations for dealing with Ship and Shore traffic had been taken over from Marconi's Wireless Telegraph Company in 1909 and a complete engineering reorganisation was being undertaken. Negotiations were also proceeding with Marconi's Wireless Telegraph Company for the erection of the stations which were to form the Imperial Wireless Chain. This contract was duly entered into in 1913, but was cancelled on account of the War in 1915, the cancellation resulting in the arbitration case in which the Company were awarded £590,000 damages for Breach of Contract, their claim being for some £7,000,000. Mr. Shaughnessy acted as expert technical witness for the Crown in this case. He has also acted as technical adviser in several patent litigation cases.

At the commencement of the War Mr. Shaughnessy was solely responsible for the organisation for the detection of unauthorised Wireless Transmissions, the menace of which loomed so large in the columns of the Press and in the minds of the Public in those early days. In spite of the many scares investigated no case of a serious nature came to light. Later, he was responsible for the control of a system of Direction Finding Stations for Home Defence, which performed the invaluable service of tracing the Zeppelins across the North Sea on their bombing expeditions. It was not until after these stations were in operation that the first of the Zeppelins was brought down in this country, and it cannot be doubted that the system of direction finding stations was one of the principal agencies which caused the ultimate abandonment of this nefarious campaign.

For these services Mr. Shaughnessy was awarded the honour of being made an officer of the Order of the British Empire.

The close of the War found the Wireless Section in possession of two sites for High-power Wireless Stations, *i.e.*, at Leafield and Cairo, with mast systems erected or in course of erection, and in spite of shortness of staff, Mr. Shaughnessy, with characteristic energy, set about the equipment of these stations. At this period the high frequency alternator had hardly passed the experimental stage, thermionic valves had not been developed for greater ratings than about half a kilowatt, and the Marconi timed-spark system, which had been developed during the War and which was an advance on the synchronous spark system proposed for the original scheme, was to all intents obsolescent. The Elwell Poulsen Arc System was, however, a good commercial proposition and Mr. Shaughnessy recommended its adoption. Although much criticism was levelled against this decision, events have abundantly justified its wisdom.

In 1919 a Committee, under the Chairmanship of Sir Henry Norman, was appointed by the Government to conduct an enquiry into Imperial Wireless Communications and, as a result of their recommendations, a Wireless Telegraphy Commission, under the Chairmanship of the Rt. Hon. Viscount Milner, with three technical members, was appointed by the Cabinet in 1920. Mr. Shaughnessy has been a member of this Commission since its inception. Although the original recommendations of the Norman Committee could not be brought to fruition owing to the non-participation of the Colonies in the scheme, the erection of a high power station in this country was decided upon and this is now in course of erection at Rugby.

In 1921, Mr. Shaughnessy acted as a British delegate at the Inter-Allied Technical Conference on Wireless Telegraphy which was held in Paris and lasted six weeks.

Mr. Shaughnessy is a man of very many activities. He will be well remembered by a large number of his old students as a lecturer in Electrical Engineering, Telegraphy and Telephony at various London Technical Institutes. At the present time he is the Examiner in Telegraphy for the City and Guilds of London Technical Institute, a member of the Radio Research Board, of several committees and panels of the British Engineering Standards Association, and of the Royal Society's National Committee of the International Research Council. In 1922 he was selected by the Royal Society to act as one of their delegates at the Second Assembly of the International Research Council, held at Brussels, for the Union Internationale de Radiotelegraphie Scientifique. For the past two years he has occupied with distinction the Chair of the Wireless Section of the Institution of Electrical Engineers, and last year he was elected unopposed as a member of the Council of that Institution. He is also a Vice-President of the Radio Society of Great Britain and the Schools Radio Society.

Mr. Shaughnessy hides beneath an apparently casual manner an eye for detail, whether it be for specification, drawing, or minute, which gives to his staff the assurance that no error of importance is likely to escape his notice. The sphere of Radio patents he has made particularly his own, and here his wonderful grasp of the situation, combined with a remarkable memory for its details, has won him general acknowledgement as an expert.

No one who has come into contact with the Wireless Section of the Engineer-in-Chief's Office can have failed to have noticed the regard in which Mr. Shaughnessy is held by his staff, and how he has impressed his spirit of cheerful optimism upon them.

We are sure Mr. Shaughnessy has the best wishes of his many friends, both inside and outside the service, on the occasion of his promotion.

OLIVER HEAVISIDE, F.R.S.

From *The Electrician*, February 13th, 1925.

It is with great regret that we have to record the death of Mr. Oliver Heaviside, F.R.S., which occurred at Torquay, on February 4th, at the age of 75.

Heaviside's death marks the passing of one who had a great influence in increasing our knowledge of the scientific principles upon which much of the recent progress in telegraphy, telephony and radio communication has been based, for he established a connection between Maxwell's electro-magnetic theory and "weak current" practice whose full possibilities we are only now beginning to realise. He established this connection, however, in a way which not only shocked pure mathematicians of the rigid

Oliver Heaviside, F.R.S.

school, but brought upon him criticisms from the practical men whom he desired to help. These two results at first made his recognition difficult, but it has now been recognised for some years that what he did was of fundamental importance. We may, therefore, be allowed some self-gratification in recalling that publicity was given to his work in the columns of *The Electrician*. A large part of his well-known work on the "Electro-Magnetic Theory," which is now published by Ernest Benn, Ltd., first appeared in the form of articles in our columns, and though its publication raised a good deal of criticism on account of its being intelligible to only a small proportion of our readers, those responsible for the conduct of the journal in those days have been amply justified by events.

It is difficult to write a suitable obituary notice of Heaviside because the manner in which he lived during many years of his life, and his great age have made it impossible to obtain any details of his early life and practical work. We do know, however, that he was born in London on May 13th, 1850, and was for a few years in the employment of the Great Northern Telegraph Co., at Newcastle-on-Tyne. At the early age of twenty-four, after a short time spent in London, he retired to Torquay where practically all of his subsequent work was done. He lived practically the life of a hermit, seeing few people, but corresponding with one or two with whom he had ideas in common, notably, Sir Oliver Lodge and Dr. G. F. C. Searle, of the University of Cambridge.

The result of this existence, which he chose for himself and which probably suited him, was a legend that has grown up round him and which probably only his death will disperse. The important thing about Heaviside, however, was not his life but his work. What this work was and the results that have been obtained from it are fully elucidated by Sir Oliver Lodge on p. 174 of this issue. Although Heaviside took up the attitude that what he had done had not received due recognition, there was, at any rate in recent years, no real basis for this opinion. He was elected a Fellow of the Royal Society in 1891, became the first Faraday Medallist of the Institution of Electrical Engineers in 1922 (having been elected an honorary member in 1908) and received the recognition of Honorary Membership from many learned foreign and scientific societies.

His earlier papers were published by Macmillan in two volumes under the heading of " Electrical Papers," in 1892, and his principal work, " The Electro-Magnetic Theory," was published by *The Electrician* Printing and Publishing Co., in three volumes, in 1893, 1899 and 1912, respectively. It was reprinted in 1922 by Benn Bros., Ltd., and it is interesting, as an indication of the value that is placed upon the arguments and results given in it, that a further edition is now in preparation by Ernest Benn, Ltd.

The funeral took place on Friday, February 6th, at Paignton Cemetery, in the family grave in which his father and mother are also buried.

The following were present: Mr. B. B. Heaviside, Mr. C. Heaviside, Mr. and Mrs. F. Heaviside, Miss Heaviside, Mr. and Mrs. Williams, nephews and nieces, and Mr. R. H. Tree, who represented the Council of the Institution of Electrical Engineers. The American Telephone Co. and the Western Electric Co. were also represented.

AN APPRECIATION: THE PERSONAL EQUATION: THE WORK OF A GENIUS ELUCIDATED.

By Sir Oliver Lodge, F.R.S.

From *The Electrician*, February 13th, 1925.

Occasionally a remarkable genius arises, we know not how nor whence. Such an one runs the risk of being misunderstood and neglected in his lifetime; partly perhaps because he has not gone through the ordinary processes of education, and has therefore not attracted the attention of his contemporaries in the regular way, and partly because his insight may be of an unorthodox and exceptional type, and his utterances personal and peculiar in style. He is also apt to be more or less in advance of his time, so that it is sometimes left to posterity to discover the brilliance and notable character of his achievement. Such an one was Waterston, who evolved the kinetic theory of gases years before the scientific world was ready to receive it; with the result that his communication to the Royal Society on the subject was turned down by the referees; and we are now told that among Waterston's papers will be found other striking anticipations of the course of scientific progress, though they have not as yet been made public.

A Genius of Exceptional Ability.

Such an one again was Oliver Heaviside, a mathematical genius of exceptional ability, who flooded the columns of *The Electrician* with remarkable but ill-understood Papers, the value of which was, however, recognised long before his death (partly by Kelvin, partly by Fitzgerald, Dr. G. F. C. Searle, and others), but which for all practical purposes had been turned down by the telegraphic authorities of his time, and regarded as nonsense by no less a personality than Sir William Henry Preece, that genial orator, for many years engineer-in-chief to the Telegraphic Department of the British Post Office. Indeed I was told that a practical Paper by his brother, A. W. Heaviside, of Newcastle-on-Tyne, was rejected by the Society of Telegraph Engineers, because it embodied in more practical form the results of his brother's mathematical researches. There is no doubt that Oliver Heaviside felt this neglect and contumely very keenly, and he gave expression to it in humorous and sarcastic fashion on many occasions.

All this is now ancient history, but reference to it cannot properly be omitted, for it loomed large in Heaviside's mind and saturates many of his lighter Papers. Besides, when serious mistakes are made, it is only just that for a time they should be remembered. Recognition, though tardy, came at length—perhaps too late to be altogether consoling. The Royal Society made him a Fellow; the Institution of Electrical Engineers awarded him their most distinguished medal; and their President took the trouble to convey it personally to him at his solitary home in the depths of the country.

Part of the difficulty of recognising his achievements lay no doubt in his own personality; he was of very retiring disposition with no social gifts. He lived alone, in what appeared to be a state of considerable poverty, cooking his own food, waiting on himself, and suffering from indifferent health. He was visited from time to time by occasional admirers of his genius, in his dismal lodgings at Kentish Town. But as soon as he began to be recognised he fled to Devonshire, and thence emerged no more; never, so far as I know, attending the Royal Society, nor the Electrical Engineers, nor coming to hear the congratulations which might—late in life—have been showered on him; and living to the end the life of a recluse.

He was a voluminous correspondent, however, and both FitzGerald and myself received innumerable letters from his pen. Dr. Searle also must have received many, and probably continued to know him personally better than anyone else. He it is who would be able to tell us more about Heaviside's life and education. How he acquired his mathematical knowledge I do not know; I hope that Dr. Searle does, and will tell us. But the outcome of his singular mind is embodied in several volumes of "Electrical Papers" (published by Macmillan in 1892) and other volumes on "Electromagnetic Theory" (published by *The Electrician* Printing and Publishing Company in 1893, 1899 and 1912). A recent reproduction of these last, in three volumes, with the same title, has been recently issued by Benn Brothers (now Ernest Benn, Ltd.).

The fact that these early Papers were accepted (I presume paid for) and published by *The Electrician,* for many years, redounds greatly to the credit of that organ; for there could have been but few of its readers who really understood them: by the majority they must have been regarded with more or less awe, perhaps with some suspicion, but with certainly less than adequate attention.

Heaviside had, however, a peculiar vein of humour, and sometimes his writings amused, even though they did not edify. He had a wonderful instinct for grappling with the difficulties of a subject and giving it symbolic expression. Probably no one in his time had an equal grasp of the present and future outcome of Maxwell's theory. He expressed the generation of electric waves in his own style: he treated of the motion of electric charges at different velocities, including those which equalled or even hypothetically surpassed the velocity of light. Everything relating to electrical induction, and the energy of electric currents, and the forces and fluxes of energy in the electromagnetic field, the self-induction of wires and the generation of waves, was elaborately worked out in these early Papers. He invented a special system of vectorial algebra with which to deal with them. His mathematics often aroused the admiration of John Perry and other competent judges. And the three volumes on "Electromagnetic Theory" may be taken as a summary of his matured views on these subjects.

It seems probable that workers on the science of the ether will make more use of his methods and results than they have at present done; though the peculiarity of his modes of expression rather alienated, for a time, and perhaps even to this day, the majority of Cambridge mathematicians; for, though there is much originality, there is little orthodoxy in his manner of presentation.

Cable Theory.

The chief subject on which his fame rests at present, the subject also which at the time aroused rather bitter controversy, was his development of the theory of cable signalling. This theory was (as all the world knows) begun by Kelvin: and it may be truly said that Kelvin's theory of the propagation of pulses along cables, taking into full consideration their resistance and their capacity, rendered the Atlantic cable of 1865 and 1866 possible: and it may be said that it was neglect of that theory which slaughtered the first cable in 1858. Kelvin's theory, however, was incomplete: it proceeded on the analogy of conduction of heat: it applied Fourier's analysis of heat conduction to the electrical case: and the results, though most helpful, indeed invaluable, were by no means the last word on the subject. Self-induction, though doubtless partially understood by Kelvin (he called it electrodynamic capacity), was not introduced into his theory, it was probably considered a negligible factor for a long straight wire. Heaviside recast and remodelled the theory in the most general form: he invented the terms "inductance" and "reluctance," "reactance," "permeance," "permittance," and the like, on the lines of the term "resistance"; and some of these terms have come to stay. He showed that the propagation of signals along wires was in all essential respects identical with the laws of propagation of electric waves in free space. So that when I had the pleasure of detecting electric waves along wires, in or about 1888, at the same time as Hertz detected them in free space, Heaviside hailed both observations as practically one and the same—though there is no doubt that Hertz's investigations eclipsed mine altogether, in thoroughness, as well as in practical results.

The Theory of Wave Transmission.

The theory of the transmission of waves along free aerial wires is simple enough. The equations are much the same as for waves anywhere else: they are given in my "Philosophical Magazine" Paper for August, 1888, near the end of a disquisition on lightning conductors. But Heaviside did not stop at waves along aerial wires: he applied the theory to impulses along cables, where the combination of capacity and resistance exercised its deleterious effect, and constituted the great difficulty in efficient signalling. He showed that by taking self-induction into account, the results could be much more accurately expressed, and further, that self-induction was not the hindrance or bugbear which Sir William Preece thought it was, but that it was the most essential help. And, indeed, without inductance it is difficult to see now how any transmission theory could be satisfactory. Heat has no rate of propagation: it is merely diffusion; and Kelvin's theory of cable signalling was entirely on diffusion lines. The waves, as it were, soaked through, and the time of arrival was quite indefinite; it depended merely on how sensitive the receiving instrument could be. If you had to signal by heat, along a rod of copper, to a thermometer at one end, by applying to the other end, first a flame and then a block of ice, alternately, so that the distant thermometer could experience pulses of temperature and respond to the signals (which in imagination might be dots and dashes), no rate of propagation could be specified. An infinitely sensitive thermometer would feel the influence at once; any practicable thermometer would feel it after considerable delay. But the delay could be reduced by making the thermometer still more sensitive: and that is what Kelvin did; his mirror galvanometer and syphon-recorder were instruments far more sensitive than any of their predecessors: and accordingly the very beginnings of diffusion were felt, and could be stopped, before they had accumulated, by an opposition pulse. That was, and to some extent still is, the system of cable signalling.

The Effect of Inductance.

But when inductance is taken into account it is seen that there is a definite velocity involved—viz., the velocity of light. No instrument could respond instantaneously, even if infinitely sensitive. True waves are passing along the cable, though greatly modified by the distortional effect of diffusion, which has the effect of transmitting waves at different paces, and smoothing out sharp signals; after the same sort of fashion as a coach spring smooths out the bumps and irregularities of a road. Such smoothing out is to some extent tolerable, when dots and dashes, and especially when right and left deflections, are used. A dash is not suitable for transmission, it lasts too long; but right and left deflections, that is positive and negative signals, may be quite brief—the briefer the better, for then there is nothing to accumulate; the positive pulse is curbed by the immediately following negative pulse. All this was applied by Fleeming Jenkin and other telegraphic experts; but no one contemplated the possibility of telephonic speech through a long cable, even after the telephone had been invented. The smoothing out of consonants would reduce them to nonsense; and on Lord Kelvin's theory speech would be unintelligible and impossible of transmission on any cable longer than, say, that across the Irish Sea.

But Heaviside's theory modified all that: he showed that the effect or tendency of inductance was to add momentum to the signals, to give them a real speed, to wipe out much of the deleterious effect of capacity, to transmit waves of all lengths at the same speed; so that if only sufficient inductance could be employed, signals could be transmitted even along a cable of Atlantic length without distortion. He gave in fact the theory of the distortionless cable.

He showed also that a certain amount of leakage, lateral escape of electricity, would improve the signals: it would weaken it, of course, but the attenuation might be more than compensated by the absence of distortion.

The Influence of the Magnetic Field.

Put into words, by way of exposition of one aspect of the theory, one may say that for the transmission of true waves—not diffusion waves like heat, but waves like light, waves such as exist in free ether, and approximately along an aerial line—the electric and the magnetic energies are required to be equal. If one overpowers the other we have distortion, varying rates of transmission, or no rate of transmission at all, nothing but diffusion if the overpowering is excessive. In Kelvin's theory it was excessive, because there the inductance was considered zero, that is to say, the magnetic field was neglected; the electric field alone was taken into account. Heaviside pointed out that the magnetic field was really doing the work, though greatly overpowered by the electric, especially in cables of large capacity. By adding self-inductance, magnetic energy could be increased and made more equal to the electric energy; by leakage the overplus of electric energy could be still further reduced, though less economically. If the two energies could be made quite equal we should have true distortionless waves, with every feature of the signal reproduced at the far end, subject to nothing but attenuation.

Such a state of things can only be approximated to in practice. Silvanus Thompson advocated the construction of cables with added inductances, so as to carry out into practice Heaviside's views; and everyone knows that Prof. Pupin, in America, succeeded in influencing capitalists to make such cables according to his design; and they were found to have just the properties predicted for them. Moreover, in America successful enterprise has gone further. They really have long-distance telephony there (they say that we have not got any long distances, and therefore have not attended to it so fully); they apply extra inductance to their land lines. And in that way I am told that the General Electric Co. (or perhaps it is the Western Electric C., I am not sure) by applying extra inductance at regular intervals along their extensive continental lines, find it possible to transmit clear and distinct telephone speech from New York to California, and beyond.

Practical Results of Heaviside's Theory.

I am now trespassing on subjects concerning which practical experts are more fully informed than myself. But I have said enough to indicate that these interesting and extensive developments (of which we have not as yet by any means heard the last) owe their origin and inception to the genius and perspicacity of the subject of this memoir. That he failed to derive any pecuniary benefit (at least as far as I know) is to be lamented; but under the present system of scientific recognition (or non-recognition) it was probably inevitable. It was not an easy matter to help Heaviside pecuniarily: I believe that FitzGerald, and probably others, tried once or twice; but he had a pride which discouraged such attempts. A Government pension he was ultimately prevailed on to accept, provided it was so put as to recognise his work for Science, so as to remove it from anything of an eleemosynary character.

He has left his name on the atmosphere in the form of a "Heaviside layer," which is considered responsible for the transmission of electric waves to the Antipodes round the curvature of the earth.

Another little excursion of his is noted in the "Philosophical Magazine" for January, 1925, where a Japanese Professor describes a method for making an electret by electrising a dielectric, on the analogy of magnetising a permanent magnet; and finds that his idea was anticipated by Oliver Heaviside in "Electrical Papers," Vol. i., §xii., under the title "Electrisation, Natural Electret."

Heaviside was fond of tracing magnetic analogies to electric phenomena: hence his name "reluctance" for the magnetic analogue to resistance. He even introduced a pseudo-magnetic coefficient in some equations, so as to make them more symmetrical and therefore more pleasing to mathematicians. His theory of the distortionless cable is very complete and beautiful; he knew how to avoid reflections at distant ends and how to design a cable of any desired properties. His brother worked practically, and accumulated data, in the same direction; but he was suppressed.

I do not think the man was unhappy; though at one time he was rather embittered by the misunderstanding and hostility of those in authority—an attitude which a genial man like Sir William Preece would have been the first to lament had he been better informed. Heaviside lived an independent, self-contained life: and no doubt his insight into Nature (whether recognised by his contemporaries or not) must have given him moments of sincere pleasure. The least we can do now is to recognise his genius, and wish that it had been earlier recognised and more widely known.

THE VOCATION OF THE ELECTRICAL ENGINEER.

By THOMAS BOYES JOHNSON, Member,
Superintending Engineer, North Midland Section.

Extract from the Chairman's Address, I.E.E. North Midland Centre.

(*Address delivered at Leeds, 11th November,* 1924. *The extract is taken from the Journal of the Proceedings of the Institution*).

No one can read the reports of the proceedings* at the Commemoration Meetings of this Institution held in February, 1922, without being struck by the enormous development of engineering during the last 50 years. Dealing with electrical engineering, it seems incredible that at the time of the birth of many of us electric lighting was practically unknown, the telephone had not been invented, electric trams and railways had not been thought of, whilst wireless telegraphy and telephony—which have now attained such universal prominence—were not even dreamt of. The dynamo entered the area of commercial use less than 50 years ago, and it still seems almost miraculous that the turning of a mass of iron enclosed in wire in an electromagnetic field should give us lighting, heating, traction and power in such various ways and to such an enormous extent as we have to-day.

There is no reason to think that there will be any slackening in the field of discovery or in that of practical application. As Prof. Howe remarked at the meeting of the British Association in August last:† "We can look forward with confidence to an ever-

* *Journal I.E.E.*, 3922, vol. 60, p. 377.

† *Electrical Review*, 1924, vol. 95, p. 239.

increasing application of electricity to the utilization and distribution of the natural source of energy for the benefit of mankind."

Telephony.

It seems almost incredible that the first telephone exchange was established so late as 1878, while to-day there are well over 20 million telephone exchange stations in various countries, nearly $1\frac{1}{4}$ millions being in Great Britain. The first multiple exchange was established 10 years later, and by means of these multiple boards one operator can have access to 10,000 lines. It is physically impossible for one operator to obtain access to a greater number. With the development of the automatic system, however, this limitation disappeared. The first automatic exchange in this country was opened at Epsom in May, 1912, and several others were completed in 1915 and 1916. The first large city to be provided with an automatic exchange was our own city of Leeds, where, in spite of serious difficulties owing to the war, a 5-figure exchange constructed by the Automatic Telephone Manufacturing Co. was opened in May, 1918. This was the largest automatic exchange in Europe, and the largest in the world to be transferred from the manual to the automatic system. It is still the only 5-figure exchange in Great Britain, but a similar one is being constructed in Sheffield, other automatic exchanges are being provided in various towns, and the conversion of the London system to automatic working has been commenced. A 4-figure exchange at Grimsby constructed by Messrs. Siemens was opened in September, 1918, and proved equally satisfactory. Another 4-figure exchange has just been opened at York, and the conversion of the Leeds suburban exchanges to automatic working is proceeding steadily. A 4-figure exchange at Harrogate has been commenced, one at Halifax will be started as soon as the building is ready, and others will follow at Wakefield, Keighley and other places within the area of the North Midland Centre. The Hull Corporation have also opened two automatic suburban exchanges. We are glad to know that the system in Leeds has proved the advantages of automatic telephone working, and that the Post Office authorities are now definitely committed to the establishment of automatic working as the standard method for large exchanges.

Another important development in telephony has been in the distance over which speech can satisfactorily be transmitted. In Graham Bell's first business circular it was stated that telephones could be furnished for the transmission of speech through instruments not more than 20 miles apart. With the improvement of lines and apparatus the distance was largely increased, but was still limited. Continued attempts were made to devise a telephonic relay to repeat telephone currents in the same way as the well-known telegraphic relay, but all these proved unsatisfactory. With the invention of the thermionic valve or repeater, however, the difficulty disappeared, and there is now practically no limit to the distances over which speech can be transmitted. Speech is already carried from East to West of the American continent, and there is no technical reason why it should not be carried equally well between the extremes of North and South America.

Improvements in the condition of the lines used for telephone working have been remarkable. For many years it was necessary to use aerial wires, owing to the limited distance possible with gutta-percha-covered or rubber-covered conductors. Air-space cables increased the distance considerably, and the invention of the loading coil straightway enabled the distance to be increased about threefold. In 1913 the first balanced cable for both telegraph and telephone wires in this country was laid between Leeds and Hull, and proved so successful that the laying of such cables for long-distance telephony became the standard practice. This balancing enables thermionic repeaters to be used, and telephonic communication by means of balanced cables, loading coils and thermionic repeaters can be carried on from one end of the country to the other.

International Telephony.

It will be remembered that Mr. Gill during his presidency of the Institution devoted great attention to the development of international telephony, and the development of this phase of telephony will undoubtedly occupy a prominent position in future. Here, again, the invention of the thermionic valve opened up a new era. By its means the British military authorities were enabled to have telephonic communication between London and the Expeditionary Force Headquarters in France. The Germans with the great advantage of land frontier had circuits from Berlin to the Army Headquarters in Northern France and Russia, and also right across Austria and the Balkans to Constantinople. Owing to its geographical position, as well as for other reasons, Germany is bound to occupy a large place in any scheme of European intercommunication. At the international conference held in Paris last year, at which Belgium, England, France, Italy, Spain and Switzerland were represented, much work was done in getting unanimous approval to many important technical proposals which were officially confirmed by the Governments of those countries, and further progress was made at a record conference in Paris in April last when no fewer than 21 European countries were represented. It is much to be hoped that Mr. Gill's plan of an international board for constructing, maintaining and operating long-distance circuits will be adopted. The influence of such an association and of international telephony would extend far beyond the boundaries of telephone working, and be of great service in creating and maintaining good feeling between the peoples of different countries, thus removing national misunderstanding, inspiring confidence and removing friction.

The Vocation of the Engineer.

If the electrical engineer has so much influence over the lives of fellow citizens and the conditions under which they live and work, it follows that whether employed by the State, a municipality or a limited company, he is in the best and most complete sense of the term a public servant, and he should realize the obligations which this places upon him. The education and training of the engineer are of great importance and have been dealt with in various addresses to the Institution. The pay of the engineer is also of importance, and the Institution should, without undue interference in wages questions, use its influence to raise the general standard of remuneration of engineering officers and men. In this connection reference is gratefully made to the letter sent by the presidents of the professional and technical institutions to the Prime Minister in February last, in which the greater recognition of scientific and technical men in the Government service was urged. It is wrong, for instance, that engineering workmen of long experience and training, and of great skill, should be receiving less wages than unskilled labourers in some occupations.

Of greater importance is the character of the engineer and the spirit which animates him. Realizing that the public depends upon him to so great an extent, the engineer will look upon his work not merely as an occupation by which he can earn a certain amount of money, but as a vocation. The public is entitled to the best service he can give, and a high ethical conception must be put on his duties.

There is one way, in particular, in which the electrical engineer can be of very great service in an important direction. Writers and speakers generally refer to capital and labour as if these were the only two classes affected in industrial matters, whereas the great bulk of the members of the Institution do not come within either of these categories, but are supervisors, etc. The ownership of factories in the North of England has changed in such a way as to alter largely the character of local life: whereas formerly the great productive concerns were owned and conducted by strong, shrewd men who had climbed out of lower ranks, their descendants have largely sold out to company promoters. Many men who still continue to be directors have mostly gone to reside at a distance, and their interest in the place of their origin, and in the community from whom they have derived their ample means, is ended, except for the limited duties of the board-room. With the decrease of private ownership which goes on at an increasing rate year by year, the old relations between the employer and his workmen are practically dead, with the result that there is a large amount of misunderstanding, distrust and fear between them. The engineer, whatever his supervising grade may be, can do a great deal towards filling the gap. He can represent the requirements of the employers to the men in a reasonable light, instead of simply issuing orders, and can receive suggestions or, if necessary, remonstrances, from the workmen, and represent them to the employers or directors. Many of the most serious industrial troubles of recent years have undoubtedly been due to misunderstanding and suspicion, and the engineer who shows himself worthy of trust by both parties, and loyal both to those above him and those below him, can exercise a very valuable influence in minimizing trouble. Engineers stand between capital and labour, and also between the public and its safety, and by their education, training, and sympathy with all classes seem specially competent to work out a solution of the industrial problem.

The engineer must look upon himself as a trustee and cultivate a high sense of the importance of his duty—which is not a question of self-importance—to his superiors, his subordinates, and the public. Employees must not be treated as machines or " hands " but as brother men engaged in improving the conditions of life and furthering the progress of mankind. There must be a spirit of real comradeship, which will have a high spiritual value and help to inspire the spirit of service in others. As has been well said, " The greatest service a man can do is to carry out his daily work in a spirit of service to God and man."

LONDON DISTRICT NOTES.

Mileage Statistics.

During the three months ended 31st December, 1924, the following changes have occurred :—

Telegraphs.—Nett increases in open wire and underground of 27 miles and 100 miles respectively.

Telephone (Exchange).—Nett decreases in open wire and aerial cable of 229 miles and 969 miles respectively and a nett increase of 19,070 miles in underground.

Telephone (Trunks).—Nett increases of 100 miles and 1,720 miles in open wire and underground respectively.

Pole Line.—Nett increase of 78 miles, bringing the total to date to 4,984 miles.

Pipe Line.—Nett increase of 149 miles, the total to date being 5,757 miles.

The total single wire mileages at the end of the period under review were:—

Telegraphs	23,871
Telephone (Exchange)	1,556,197
Telephone (Trunks)	51,652
Spares	49,474

EXTERNAL CONSTRUCTION.

DURING the quarter ended December 26th, 1924, 10,278 exchange lines, 6,183 internal extensions and 1,105 external extensions were provided. In the same period 4,175 exchange lines, 2,740 internal extensions and 506 external extensions were recovered, making nett increases of 6,103 exchange lines, 3,443 internal extensions and 599 external extensions.

INTERNAL CONSTRUCTION.

New Exchanges.—A new C.B. Exchange of No. 1 type, to which the name of Franklin has been given, was opened for service on February 5th. The Exchange is located within the Victoria Exchange building and is equipped for 1,000 lines.

New Manual Exchanges are in course of construction at New Malden, Albert Docks, Palmers Green, Mill Hill, Tilbury, Sloane and Enfield. The Exchanges at New Malden and Sloane are being constructed by the Department's staff.

The installation of the Holborn Mechanical Tandem Exchange and the Holborn Automatic Exchange is proceeding. It is anticipated that the installation of the Bishopsgate Automatic Exchange will be started in the near future.

Extensions of Exchange Equipment.—A considerable amount of work of this nature is in progress and it has been necessary to augment the staff to meet the demands. Most of the Exchanges in the District are affected.

P.A.B.X.'s.—Private Automatic Branch Exchanges are being installed by Messrs. Siemens Brothers for the Port of London Authority at the various Docks, and for the Prudential Assurance Company. These are the first P.A.B.X.'s of Siemens type to be constructed in the District.

TELEGRAPHS.

Intercommunication Switch.—The first of the smaller concentrators, intended to replace the Intercommunication Switch, has now been installed and is working. A second portion of the old I.C.S. has been dismantled, amid the regrets of many lady operators who have worked on it from the first. They are asking for souvenirs in the form of scraps of the ornamental woodwork; but they agree that the new arrangements are more favourable from an operating standpoint.

The Central Telegraph Office is in the throes of building operations from the foundations upwards. Much shifting of engineering plant is involved, including pneumatic carrier-tubes, pressure and vacuum mains, and some useful clearances are being effected. For example, wrought iron pipes, originally containing G.P. wires, derelict for a quarter of a century, are being recovered, and those which are straight and in good condition will be re-issued.

THE NEW RADIO ROOM.

A Concentrator has recently been installed on the second floor at the C.T.O. for the purpose of receiving and transmitting wireless messages, audible by telephone and loud speaker and on tape by means of Machine Telegraphs. The lines are terminated on Jacks. Telephones and Telegraph Sets are terminated on Cords and Plugs and all wires are connected *via* a small I.D.F. by the side of the Concentrator, giving facilities for re-arrangement of circuits to meet traffic requirements. This Concentrator will operate in conjunction with a smaller one which has been installed in the Wireless hut on the roof of the C.T.O. In the case of the latter Concentrator, both lines and apparatus terminate on Jacks and are connected by looping cords. With a view to avoid interference from other circuits in the building, and having in mind the removal of the Wireless hut to a more suitable locality necessitated by local conditions, special cables have been installed to the C.T.O. Test Room, and connected by means of Jumpers, etc., to the Concentrator on the roof. All rectifying is carried out in the Wireless hut and signals are passed down to the new Wireless Receiving Room; the speed determines whether the message shall be received by Machine Telegraph or by Telephone. In the case of telegraphic reception, the signals are received on a suitable relay, the telegraph apparatus being in a local circuit.

MR. E. H. FARRAND.

MR. E. H. FARRAND, Executive Engineer in charge of the Leeds (External) Section of the North-Eastern Engineering District, retired on 31st December, 1924, after completing 46 years' service in the Post Office.

Mr. Farrand commenced his career at Worksop in 1878 and, coming under the notice of the late Mr. G. H. Comport, Superintending Engineer of the North Midland District, was transferred to the latter's Headquarters at Nottingham in 1885. He was promoted subsequently to the position of Chief Clerk at Leeds, but his natural bent was towards an active share in the construction work of the Department and he received his appointment as Second Class Engineer at Middlesborough in 1895. Afterwards he served under the late Mr. G. M. Carr, Superintending Engineer of the North Eastern District, who had many similar personal characteristics, including an earnest desire to improve the methods of open line construction and maintenance, and Mr. Farrand had a great deal to do with various improvements relating to the construction of open lines.

MR. E. H. FARRAND.

In 1904 Mr. Farrand was appointed 1st Class Engineer at Leeds, taking over three second class Engineers' Sections. It was in this capacity that he became widely known not only in Leeds and the West Riding of Yorkshire but to engineers in different parts of the Country, as Leeds has always been an important Telegraph and Telephone Station. His activities have been many, but, to the last day of his service, his energy, cheerfulness, and goodwill remained unimpaired. It made no difference whether the work at the moment related to the efficiency of a leading-in insulator or to a complicated rearrangement of wires for a change over from "Manual" to "Automatic"—his enthusiasm and experience overcame all difficulties.

The years from 1911, following the acquisition of the late N.T. Company's plant, have been strenuous ones for most Post Office Engineers due to the need for developing the local telephone system by providing plant to meet the increasing demands of the service. Here, again, Mr. Farrand set an example by devoted attention to the many schemes of development in his Section and, at the same time, carried out an extensive re-arrangement of local underground plant to facilitate the conversion of Leeds Exchange from Magneto to Automatic Working. Much more might be written, but it is sufficient to state that Mr. Farrand's high ideals of construction and maintenance methods were a great asset to the Post Office in the first trial of Automatic Telephone working in a large industrial city.

Mr. Farrand in his leisure hours turned to the country side. His knowledge of the old roads—particularly Roman—was extensive, and his love of nature showed him to be a disciple of Borrow, although his trusted cycle carried him at greater speed than was accomplished by the East Anglian Master in his day. Towards the close of his official career Mr. Farrand combined with his first love the cultivation of an allotment and the exhilaration of driving a small car.

His colleagues wish him happiness in his retirement and as he is in good health and spirits no doubt his energy will follow new paths. He will be remembered as one ever ready to serve the Department and to assist his colleagues.

G.M.B.

MR. C. H. CHAPMAN.

On the 14th December, 1924, Mr. C. H. Chapman, the Executive Engineer in charge of the Engineer-in-Chief's Instrument Testing Branch, Studd Street, retired at the age limit, having completed 43 years' service. Being attached for 32 years to the Testing Branch, a training ground for many Engineers who have risen to prominence, Mr. Chapman will be remembered by colleagues now scattered all over the country as a genial and true friend.

A large number of past and present members of the Testing Branch assembled in the dining room at Studd Street to bid him farewell. The presentation of a silver salver, suit case and autograph album was made by Mr. F. L. Henley, Staff Engineer, Test Section, who, in the course of a felicitous speech, thanked Mr. Chapman for the great and valuable assistance he had rendered, and instanced the phenomenal growth of the work of the Section, the staff of which in his early days numbered less than a dozen officers now amounted to several hundreds.

The Album bore the inscription as follows:—

"This Album contains the signatures of those colleagues of

MR. CHARLES HENRY CHAPMAN,

who were associated with the presentation to him of a Silver Salver and a Suit Case on the occasion of his retirement from the Engineering Department of the Post Office at the age of 60 years.

His colleagues desire to express to him their cordial good wishes for a long and happy life. They recall with satisfaction the amicable relations that have always subsisted between him and them during his long service of 43 years and they regret that the time has come when their official relations with him must cease. In bidding him farewell they wish him the best of health to enjoy his well earned leisure."

I.P.O.E.E. LOCAL CENTRE NOTES.

NORTH WALES CENTRE.

At the meeting at Shrewsbury on 16th December, 1924, the Centre was favoured with a visit from Mr. J. E. Statters, A.M.I.E.E., of the Engineer-in-Chief's Office, who read a paper on "Telephone Transmission." Mr. T. Plummer, M.I.E.E., Chairman of the Centre, presided.

The paper dealt in detail with the methods used at Headquarters in calculating the impedances of circuits made up of different classes of conductor, and with the effects of changes of line impedance upon the final transmission efficiency of the whole circuit. The question of the design of a telephone which would meet efficiently the widely different combinations of line and terminal impedances through which it is required to operate from minute to minute, was touched upon. The lecture was illustrated by many lantern slides and blackboard calculations and an animated discussion followed.

The Centre met on 13th January, 1925, to hear a paper read by Mr. J. C. Spiers on "The Advantages of the Universal Fault Locator compared with the Wheatstone Bridge or Bridge Megger."

The paper was introduced by a description of the Slide Wire and the methods of localising faults. Each class of fault was dealt with and the accuracy of each method compared. The double loop test was also referred to. Dealing with disconnections, examples of capacity tests with the Slide Wire on short or on long distances were given. Finally, Mr. Spiers touched on the localisation of high resistance loop faults, and explained by means of lantern slides the theory of the tests taken.

On 10th February, 1925, a discussion was opened by Mr. W.

Dunnet, who read a paper on "Departmental Regulations and Present Day Practice."

He was critical of the issue of the large number of books, instructions, pamphlets, cards, etc., for the guidance of the staff, and doubted the wisdom of the new form of Regulations. The lecturer considered that the publication of so many shortlived circulars tended to bewilder and confuse the staff, and to undermine initiative, and instanced the number of circulars on the subject of the provision of Rural Exchanges. Standard Tool Lists present and prospective were held to be ineffective.

The intricacy, complexity, and minuteness, of the accounting system in his opinion directly retarded output, and the workmen grades were called upon to do too much writing. It was considered that the attempts which were made to cover every contingency by an instruction of some character stood condemned. The examinations of District Accounting procedure were also in his opinion far too microscopic. He stated that records showed that the annual increase in motor vehicles in this country exceeds the yearly addition to the number of telephones installed, despite the cost of the respective services.

To effect improvements in some of these matters he advocated the automatic cancellation of every circular after 12 months from the date of issue, or alternatively its reissue and redating. Systematic Tool Checks which were costly and raised interminable correspondence should be abolished, the workmen being held responsible for the surrender of his kit intact at any time. Greater facilities for the loan of tools from Stock was also recommended.

Extension of the "Small Stores" schedule to reduce accounting transactions and the use of average prices for certain classes of inexpensive stores were also advocated.

To simplify the staff records it was suggested that increases of wages particularly of the unestablished Staff should be granted on 1st January.

Finally, the lecturer recommended serious consideration of a proposal to reduce the number of forms issued in connection with Advice Notes.

SOUTH MIDLAND CENTRE.

Although the opening meeting of the 1924-25 Session was held on the day of the general election (29th October, 1924) the large number of 69 members and visitors were present at this, the 46th meeting of the South Midland Centre.

The Vice-Chairman, Major G. H. Comport, took the chair, and the Chairman of the Centre, Mr. J. E. Taylor, read a paper entitled "Some Electrical Fallacies."

Misconceptions commonly held about the alterations in the magnetic field of telephone receiver magnets, the actual function of induction coils and condensers in telephone subscribers' sets and the real purpose of heat coils were cleared up. The lecturer, passing on to wireless fallacies, dealt with this section of his subject under the headings of the damping of the plain aerial transmitter, spark gap resistance, counterpoise substitutes for earth, coupling waves, defective earthing methods, land and sea wave-absorption, the Heaviside layer and conduction by gases.

The theory of high frequency alternators and harmonics was set out and the paper ended with an account of some difficulties which appeared to the lecturer to be encountered in the full acceptance of the electronic theory of electric currents. Alternative views were explained. The lecture was illustrated by lantern slides and numerous blackboard sketches.

Opinions were offered and questions asked by Messrs. J. S. Brown, Dwyer, Atkins, Wakefield, Halton, and Major Comport, to each of whom the lecturer replied.

Major Comport aptly concluded a most successful and instructive meeting by assuring the lecturer that the enthusiastic applause had conveyed to him the thanks of the audience in a more pleasing manner than a formal vote of thanks.

On the 26th November, Mr. A. B. Eason, of the Equipment Section, Engineer-in-Chief's Office, lectured on "Power Plant in C.B. and Automatic Exchanges."

The author dealt with the following items seriatim—standard voltages, battery capacity, counter E.M.F. batteries, meter and booster batteries, types of battery "boxes," control of charge of batteries, cabinets for battery fuses, distilled water and storage of water, oil on batteries, charging machines, piers of charging machines and ringers with special reference to anti-vibration devices, earthing brush on flexible coupling, power board and switch gear, knife switches, discharge circuit, voltage drop in fuses, instruments on power board, power cables to fuse panels, ringing machines and interrupters. The lecture, which was illustrated by 26 lantern slides, was closely followed by the audience, and the following members joined in the discussion or asked questions: Messrs. Halton, Wood, Gravill, Wakefield, Atkins, and the Chairman. Mr. Eason suitably replied, and the meeting closed with a cordial vote of thanks.

A large number of members and some specially invited visitors were present on the 31st December to hear Captain P. P. Eckersley, Chief Engineer of the British Broadcasting Company, speak in a humorous and extremely interesting manner about "The Troubles of Broadcasting." The lecturer outlined the progress of wireless telephony since 1913, making particular reference to the advent of the B.B.C. in November, 1922. The problems solved and unsolved which come before the Company were described in a racy manner.

Captain Eckersley spent some time in explaining the apparatus at the studio used in conjunction with the Post Office in order to give a simultaneous broadcasting service. He admitted that without the co-operation of the Post Office Engineers simultaneous broadcasting would not be possible and expressed the hope that the sympathetic consideration uniformly given by Post Office officials to the B.B.C. staff would continue. A number of slides showing the special apparatus at the studios was exhibited on the screen.

Captains Horton and Pope, Messrs. J. S. Brown and A. Gwilliam and the Chairman contributed to the discussion. The vote of thanks to Captain Eckersley, which was proposed by Major Comport and seconded by Mr. J. S. Brown, was endorsed by the audience with loud and lengthy applause.

Mr. J. E. Statters, of the Telephone Section, favoured the Centre on the 28th January by reading his paper entitled " Telephone Transmission." He explained the table of constants for equivalent " T " and " Π " circuits which he had prepared for use in cases of lengths up to the equivalent of 15 miles of standard cable.

Mr. Statters continued by describing the arrangement for comparing the volume of speech received over circuits under test. The differences between the British, Continental and American transmission units were explained and interesting details were given of the efforts which are being made to obtain international uniformity. The values of terminal losses in various types of circuits were computed and examples of mathematical investigations into transmission efficiency given.

The lecture was illustrated by diagrams, blackboard sketches and slides projected on to the screen.

Mr. Statters expressed himself as willing to endeavour to answer any question relating to telephone transmission, even if the points raised had not been touched upon in his lecture and he replied to the questions asked by Messrs. Beaumont, Atkins, Halton, Captain Linsell and the Chairman.

The Chairman cordially thanked Mr. Statters on behalf of the audience.

At the February meeting, held on the 25th of that month, Mr. J. S. Brown, of Southampton Section, gave an interesting account of some part of his official experiences in a discourse entitled " Submarine Cable Work in Tidal Waters."

The lecturer, adapting a breezy conversational style which obviously gained and retained throughout the close attention of the audience, commenced by explaining the method of laying new cables and recovering an old cable across the comparatively short width of the River Medina at Cowes. He continued by demonstrating how the Hayling Island cable was laid from a sand lighter across Langston Harbour, where the flow of the tides is exceptionally strong. Mr. Brown next described the more extensive work at the Itchen Ferry of laying two temporary cables, recovering old cables, laying the permanent cables and recovering the temporary cables. The description of the ingenious use of the Floating Bridge cable in the recovery of the old telegraph and telephone cables gained expressions of appreciation.

The next point dealt with was the arrangement adopted for repairing faulty submarine cables, and Mr. Brown showed clearly by demonstration with the aid of short lengths of cable the manner in which this work was accomplished.

The description of the repairing of the cables at Horseand Fort was so realistic that the audience in their lecture-room seats shared long after the event a weird and eerie adventure which Post Office Engineers rarely have an opportunity of experiencing.

The lecture concluded with a few maxims which Mr. Brown had found to be necessary in carrying out submarine work successfully. A large number of fine slides was shown on the screen.

Captain Pope, Mr. Gravill, Mr. Halton and Major Comport asked questions and each congratulated Mr. Brown on the success of his effort. The Chairman, in closing the meeting, aptly stated that the discourse carried with it a tang of salt breezes. Mr. Brown was thanked by enthusiastic applause from the audience.

(Mr. Brown's paper is dealt with more fully elsewhere in this issue).

A.W.L.

SOUTH LANCS. CENTRE.

Since the last notes were written four papers have been read before this Centre, viz. :—

December 8th. "The Importance of Detail in Radio Reception." J. H. Reyner, B.Sc., Engineer-in-Chief's Office.

January 12th. "The Baudot Telegraph System." R. J. Vernon.

February 9th. "Telephone Transmission." J. E. Statters, Engineer-in-Chief's Office.

February 23rd. "Automatic Telephones." H. H. Harrison, M.I.E.E., of the Automatic Telephone Co.

March 9th. "Cutting in Working Circuits on Underground Cables." J. W. Thompson.

In each case the papers were of an exceptionally high order of merit and have been followed by keen discussions. The latter feature is particularly gratifying not only as a tribute to the ability of the lecturer, but as showing that the subjects were well chosen from the point of view of general interest and utility. Frequently the discussion produced further contributions of value.

Thanks to the lecturers were suitably voiced by proposers and seconders on each occasion and were cordially endorsed by the members and visitors present.

On February 23rd arrangements were made, by the courtesy of the Automatic Telephone Co., for a visit to their works at Milton Road, Edge Lane, Liverpool. The Company spared no pains to make the visit a success and the members who were privileged to participate spent a very enjoyable and profitable afternoon. The demonstration set which had been on view at Wembley, showing the working of the director system, proved to be particularly interesting.

In the January issue of the Journal mention was made of an invitation received from the Institution of Electrical Engineers to attend a lecture by Prof. G. W. O. Howe, of the University of Glasgow, and of the Radio Research Board, on "World Wide Radio Telegraphy," to be delivered on January 6th. The invitation met with a generous response from this Institution and the large hall hired specially for the purpose was well filled. The Chairman, Mr. H. C. Lamb, M.I.E.E., in his opening remarks, stated that it gave the I.E.E. special pleasure to be able to attend a joint meeting with the Post Office Engineers and thus to make some return for the interesting lecture which the I.P.O.E.E. had, last year, provided when Capt. P. P. Eckersley, M.I.E.E., Chief Engineer of the B.B.C., visited Manchester. He expressed the hope that a similar event would become an annual feature.

NORTHERN CENTRE.

Since writing the last notes two of our members, Major G. A. Blackwell and Mr. J. H. Clark, have left this District on promotion. Both officers took an active interest in the activities of the local centre and we are sorry to lose them. Mr. Clark served on the Local Committee as the Draughtsmen's representative.

At the December meeting of the Centre, Mr. J. Irvin Smith read a paper entitled, "A Village Automatic Exchange." The lecturer described the recently erected Exchange at Marton, in North Yorkshire, which is one of the five unattended exchanges at present in this country. The paper was fully illustrated with slides and the lecturer was complimented upon his instructive, interesting and well written paper.

The members of the Centre were invited by the Institution of Electrical Engineers to a Faraday Lecture on the 17th December, when Professor B. W. O. Howe gave a lecture on "World Wide Radio Telegraphy."

On the 17th January, the Centre had the pleasure of entertaining a party of visitors from The Junior Institution of Engineers. The visitors were shown over the Instrument Room at Newcastle P.O., and were afterwards entertained to refreshments. A full account of the visit is recorded in the current issue of the Journal of the Junior Institution of Engineers.

Mr. J. M. Markey read a paper on "Faults—Their Prevention and Cure," at the January meeting of the Centre, and a spirited discussion ensued. The paper was practical, original and well delivered.

On February 18th, Mr. C. H. Lunn read a paper entitled, "Drawing Office Methods and their relation to the special work of the Department." The paper provided a good discussion and several of the suggestions made respecting Drawing Office conditions are being considered for adoption by the Chairman.

The Junior Institution of Engineers has extended a cordial invitation to I.P.O.E.E. members to attend a lecture to be delivered on March 20th, at 7.15 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle, by Mr. R Dowson. The subject will be "Steam Turbines," and the lecture will be illustrated by a Cinematograph Film showing the construction of a 50,000 K.W. Turbine. This will be the first occasion on which the film has been publicly exhibited.

NORTH EASTERN DISTRICT CENTRE.

A most successful Session terminated on the 9th March last, when the Centre was favoured with a visit from the Council.

On this date Mr. Hunsworth read a paper on "Annual Estimates," and between the reading of the paper and the discussion tea was taken and this proved an opportunity to mingle.

Mr. T. B. Johnson welcomed the Council, specially referring to Mr. De Lattre and Mr. Shaughnessy. The latter in replying for the Council was in his happiest mood. The whole Centre rocked with laughter at the delicious humour, whilst the sound commonsense contained in the speech won admiration on all sides. Never in the history of the local Centre has a speech been so thoroughly enjoyed. This is saying a great deal, when it is recollected that in this Centre we have a Chairman who is a past master at the game, one who knows what to say and when and how to say it.

After tea Mr. De Lattre opened the discussion and in characteristic language gave us some Headquarters views on the subject of

"Annual Estimates," which were very illuminating and helpful.

Mr. Wilby in joyous mood is always worth a hearing, and in his sonorous style he explained how in his travels he found men following lonely trails in the hunt after elusive details which they considered necessary to the make up of Annual Estimates.

We have often wondered what Hansford was like, and when a dark sharp-featured young man got on his feet we at once realised there was a new force behind the Council. He appeared to be made of springs of the best quality, capable of taking a lot of jarring and of returning to the original position in readiness for the next jar. Always wound up and ready to do all the work in a pleasant noiseless fashion.

Altogether it was a great evening, enjoyable and helpful to the good feeling amongst men who do not meet frequently but who are known to each other on paper. We saw through a glass darkly (incidentally the meeting was held at the Y.M.C.A.) and now we see face to face . . . we are known and they are known as they really are.

During the Session we have had papers on "Contracts," "P.O. Engineering Department 1885-1925," "Drawing Office Organisation," "Responsibilities and Outlook of Electrical Engineers," "Telephone Transmission," and "Annual Estimates," and the lecturers have been a Superintending Engineer, two Executive Engineers, a Principal Clerk, a Supplementary Clerk, and a Draughtsman, and therefore, it will be seen that the Committee of the Centre has been alive to the requirements of the members.

SCOTLAND WEST CENTRE.

For our fixture on 2nd February the lecturer was Mr. Arnold. The subject originally selected "Local Baudot Developments" was departed from in favour of "Tester No. 42 and Oscillator, No. 2A," it being thought the latter subject would appeal to a wider circle. The lecturer first of all described the features of the apparatus, then explained by means of diagrams the circuit of the set, and showed how it should be used to measure transmission losses in apparatus and circuits; also for the location of faults. The lecturer, in the clearest possible manner, gave the meeting the benefit of the experience gained by him from the making of tests. Experience with the apparatus in this District being, in the meantime, restricted there was little criticism, but the general opinion was that such a piece of apparatus was necessary and that it would go far towards assisting to eliminate transmission losses in exchanges.

Mr. Statters, of the E.-in-C's staff, was the lecturer at our meeting on 2nd March, the subject being "Telephone Transmission." As the lecture is being repeated at other Centres there is no need for lengthy reference here. The lecturer proved himself a master of the subject and sustained the interest of the meeting throughout. Several questions were raised and these the lecturer disposed of. On conclusion, the Chairman congratulated Mr. Statters on his lucid treatment of the subject and a hearty vote of thanks was accorded.

BOOK REVIEWS.

"Mathematics for Technical Students." By E. R. Verity, B.Sc., A.R.C.Sc. Longmans Green & Co., London. Price 12*s*. 6*d*. net.

This book is written primarily to meet the needs of students in the evening classes of Technical Institutions. It covers the usual groundwork of Algebra and Trigonometry, and the fundamental principles of the Differential and Integral Calculus are simply explained. One of the prominent features of the book is the large number of worked examples in illustration of the text. A large number of unworked examples is also given, the solutions of which are to be found at the end of the book. The practical examples will in general appeal rather to the Mechanical than the Electrical student. Although it cannot be said that the book fills any new rôle, it can, nevertheless, be recommended especially to the home student as a good guide to the elementary principles of its subject.

"Junior Technical Electricity." By Robert W. Hutchinson, M.Sc., A.M.I.E.E. W. B. Clive. University Tutorial Press, Ltd. 382 pp. 4*s*. 6*d*.

This book has been designed to provide a first year course in Electrical Engineering for students at technical schools and colleges. Special stress is laid upon the clear presentation of the fundamentals of electrical theory, and this the author has certainly succeeded in doing. No previous knowledge of the subject is assumed, and the student is led step by step from the most elementary ideas of magnetism and electricity to the stages where the knowledge acquired in the course of his reading is applied in a practical manner to the electrical appliances now in every day use. Numerous worked examples are interspersed throughout the work, and the various chapters are followed by questions and exercises on the preceding matter. The treatment of Telegraphy and Telephony is, however, of the most meagre description; but wireless theory and circuits are fairly satisfactorily dealt with in the thirteen pages allotted to them. Students reading for the City and Guilds Examinations in these subjects will find this volume a helpful adjunct to their usual class text-books.

The book is excellently printed and the many diagrams and illustrations are clearly reproduced.

A.F.

"Alternating Current Rectification." L. B. W. Jolly, M.A. (Cantab.), M.I.E.E., Assoc.M.Inst.C.E. Chapman & Hall. 25*s*. net.

The subject of Alternating Current Rectification covers practically the whole field of Electrical Engineering, and it is a matter of wonder that Mr. Jolly has managed to confine himself to one volume of 350 pages of a reasonable type and to find room for 244 splendid clear figures. The book touches on such diverse subjects as harmonic analysis, the choice of type of instrument to be used in a rectfiied current circuit, commutation, the testing of rotary converters, synchronous commutator rectifiers, the theoretical analysis of the mechanical vibration of a reed, Mercury vapour rectifiers, smoothing circuits for a rectifier installation, Neon tube, vitrating flame and corona rectifiers, electrolytic rectifiers, triode and crystal rectifiers in wireless receivers; but although such a wide range is covered the author has concerned himself strictly with his subject and has produced a splendid concise volume on present day electrical engineering practice written from the particular new point of "Rectification." The author is to be thanked also for a very good bibliography, well arranged with cross references to Science Abstracts.

The author, however, in his introduction, leaves his mathematical and practical facts and expresses opinions which will not be generally accepted without question. He states, "it is apparent that where one requires a large high voltage, direct current output of more than one or two kilowatts no immediate solution of the problem exists." The difficulties of insulation are *not* sufficient to justify the statement :—' High voltage direct current generators are anathema on account of the necessity of insulated bedplates for series operation," and there seems to be no practical reason why the system so condemned should not be a sound commercial proposition. And the thermionic rectifier *is* a good and reliable method of providing power to a wireless transmitter, although the author states: "its short life, . . . comparative uncertainty in action, and its inefficiency combine to render it unsuitable for high power conversion." It is suggested that the very short introduction might well be reconsidered and written more explicitly before the issue of a second edition.

The reviewer has a profound admiration for the scientific engineer who is also a Greek scholar, but he hopes that this book will not set a fashion of dedicating engineering books in Greek (without a translation!). The engineer has by nature a curious and enquiring mind and it is thought that his curiosity might well be spared this whetting.

R.V.H.

BOOKS RECEIVED.

"A Four-Valve Combination Receiver." W. James. 2*s*. The Wireless Press, Ltd. A 4-colour wiring diagram and complete working lay-outs facilitate the construction of this set. Switches are provided for two, three or four valves to be used at will.

"Four First Steps in Wireless." H. S. Pocock. 9*d*. The Wireless Press, Ltd.

"The Wireless Annual for Amateurs and Experimenters, 1925. 2*s*. 6*d*. The Wireless Press, Ltd.

"Post Office Technical Instructions, V.—The Wheatstone Telegraph System." New edition. 3*s*. 6*d*. net, postage extra. H.M. Stationery Office, Adastral House, Kingsway, W.C.2. Copies may be obtained from the following:—

U.S.A. The British Library of Information, 8th Floor, 44, Whitehall Street, New York.

Canada. Messrs. Wm. Dawson & Sons, Ltd., 19, Bisson Street, Montreal.

India. Messrs. Thacker, Spink & Co., Calcutta.

New Zealand. The Government Printer, Printing & Stationery Dept., Wellington.

South Africa. Messrs. Wm. Dawson & Sons, Ltd., 29/31, Long Street, Cape Town.

"The History of the Telephone in the United Kingdom." F. G. C. Baldwin. 42s. net. Chapman & Hall.

"Wireless Valve Receivers and Circuits. Tuning Coils and Methods of Tuning. The Home Constructive Easy-to-build Sets." Iliffe & Sons, Dorset House, Tudor Street, E.C.4.

"Mechanical Design of Overhead Transmission Lines." Painton. Chapman & Hall.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

Promotions.

Name.	Grade.	Promoted to	Date.
Shaughnessy, E. H. ...	Staff Engineer, E.-in-C. Office.	Asstant Engineer-in-Chief, (Wireless Services).	1-1-25
Lee, A. G., Major ...	Asst. Staff Engineer. E.-in-C. Office.	Staff Engineer, E.-in-C. Office.	1-1-25
Angwin, A. S., Major	Executive Engineer, E.-in-C. Office.	Asst. Staff Engineer. E.-in-C. Office.	9-3-25
Bassett, S. W. ...	Assistant Engineer, N. Mid. District.	Executive Engineer. East. District.	To be fixed later.
Taylor, J. L.	Assistant Engineer, E.-in-C. Office.	Executive Engineer. E.-in-C. Office.	1-4-25
Hansford, R. V. ...	Assistant Engineer, E.-in-C. Office.	Executive Engineer. E.-in-C. Office.	9-3-25
Aldridge, A. J. ...	Assistant Engineer, E.-in-C. Office.	Executive Engineer. E.-in-C. Office.	9-3-25
Gill, A. J.	Assistant Engineer, E.-in-C. Office.	Executive Engineer. E.-in-C. Office.	9-3-25
Blackwell, G. A., Maj.	Chief Inspector, N. District.	Asst. Engineer. N. Wales District.	24-2-25
Macleod, J. D. ...	Chief Inspector, E.-in-C. Office.	Asst. Engineer. Scot. West District.	21-1-25
Cook, A. G.	Chief Inspector, S. Lancs. District.	Asst. Engineer. S. Mid. District.	6-1-25
Munro, D.	Chief Inspector, Scot. West District.	Asst. Engineer. Scot. West District.	24-2-25
Bucklitsch, A. A. K. F.	Inspector, S. Lancs. District	Chief Inspector. S. West District.	To be fixed later.
Stewart, R. T. ...	Inspector, Scot. West District.	Chief Inspector. N. District.	do.
Cunninghame, R. J. Mc.	Inspector, Scot. West District.	Chief Inspector. N. Wales District.	do.
Cowles, H. M. ...	Inspector, East. District.	Chief Inspector. East. District.	20-2-25
Shearer, J.L.	Inspector, Scot. East District.	Chief Inspector. Scot. East District.	15-2-25
Gifford, H. W. ...	Inspector, S. Wales District.	Chief Inspector. S. Wales District.	25-8-24
Dixon, W.	Inspector, N. Mid. District.	Chief Inspector. N. Mid. District.	25-2-25
Cranfield, W.	Inspector, East. District.	Chief Inspector. East District.	4-2-25
Guy, W. H.	Inspector, S. Lancs. District	Chief Inspector. S. West. District.	
James, F. G. H. ...	Inspector. S. East. District.	Chief Inspector. S. East District.	25-8-24
Bull, W. J.	Inspector. S. Wales District.	Chief Inspector. S. Wales District.	25-8-24
Johnson, F. J.... ...	Repeater Officer, Class II. East. District.	Repeater Officer, Class I. N. Wales District.	15-11-24
Knox, A.	S.W.1. Scot. East. District.	Inspector, Scot. East District.	31-3-24
Brien, A.	S.W.1. Scot. East. District.	Inspector, Scot. East District.	25-8-24
Shaw, W. A. J. ...	S.W.1. Scot. East. District.	Inspector, Scot. East District.	26-11-24
Burgher, H.	S.W.1. Scot. East. District.	Inspector, Scot. East District.	28-2-24

PROMOTIONS.—continued.

Name.	Grade.	Promoted to	Date.
Falconer, A.	S.W.1. Scot. East. District.	Inspector, Scot. East District.	25-8-24
Rudger, J.	S.W.1. Scot. East. District.	Inspector, Scot. East District.	22-9-24
Swain, T. B.	S.W.1. S. Wales District.	Inspector, S. Wales District.	20-12-24
Ballett, S.	S.W.1. S. Wales District.	Inspector, S. Wales District.	21-12-24
Ives, B. J.	S.W.1. S. Wales District.	Inspector, S. Wales District.	25-8-24
Bowles, J. T.	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	18-11-24
James, W. H.... ...	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	24-12-24
Rees, H. W.	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	5-1-25
Winson, T. H. ...	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	5-1-25
Courtis, F. J.	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	5-1-25
Coote, F.	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	5-1-25
Dilkes, G. H.... ...	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	5-1-25
Skeet, T. S.	S.W.1. N. Mid. District.	Inspector, N. Mid. District.	18-2-25
Holden, G.	S.W.1. N. West. District.	Inspector, N. West. District.	25-8-24
Edwards, F.	S.W.1. N. West. District.	Inspector, N. West. District.	14-12-24
Gregson, A.	S.W.1. N. East. District.	Inspector, N.E. District.	1-1-25
Taylor, W. H. ...	S.W.1. S. Mid. District.	Inspector, S. Mid. District.	14-2-25
Knight, E. W. ...	S.W.1. S. Mid. District.	Inspector, S. Mid. District.	28-12-24
Harknett, W.	S.W.1. S. Mid. District.	Inspector, S. Mid. District.	14-2-25
Branson, J. W. ...	S.W.1. S. Mid. District.	Inspector, S. Mid. District.	4-1-25
Fletcher, J.	S.W.1. N. District.	Inspector, N. District.	1-1-25
Biggs, F. J.	S.W.1. Met. Power District.	Inspector, Met. Power District.	8-12-24
Martin, W. G. B. ...	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25
Brayley, J. W. ...	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25
Franklin, E. C. J. ...	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25
Jenkins, W. J. ...	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25
Scott, T. A.	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25
Williams, A. J. ...	S.W.1. S. Wales District.	Inspector, S. Wales District.	27-2-25
Dixon, A. S.	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25
Wooles, F. E.... ...	S.W.1. S. Wales District.	Inspector, S. Wales District.	5-1-25

STAFF CHANGES.

TRANSFERS.

Name	Grade.	Transferred. From	Transferred. To.	Date.
Mercer, C. J....	Executive Engineer.	S. Lancs. Dist.	E.-in-C. Office	15-3-25
Shea, J. ...	Executive Engineer.	S. Lancs. Dist.	N. East. Dist.	1-3-25
Leigh, J. H. ...	Executive Engineer.	E. District.	S. Lancs. Dist.	8-3-25
Dawson, C. E.	Assistant Engineer.	Irish Free State.	N. Mid. Dist.	1-2-25
Spink, E. ...	Assistant Engineer.	N. Mid. Dist.	S. Mid. Dist.	15-2-25
Hill, R. J. ...	Inspector.	S. West. Dist.	E.-in-C. Office	1-3-25

RETIREMENTS.

Name	Grade.	District.	Date.
Hunter, G.	Assistant Engineer.	do. E.-in-C. Office.	2-2-25
McLeish, J.	Chief Inspector,	London District.	6-2-25
Paynter, A. W. ...	Inspector,	S. Lancs. District.	1-1-25
Kirkham, F.	Inspector,	London District.	3-1-25
Ireland, J.	Inspector,	S. Mid. District.	22-1-25

DEATHS.

Name.	Grade.	District.	Date.
Guthrie, R. E.... ...	Inspector	Northern District.	1-1-25
Stevens, A. W. ...	Inspector	London District.	18-1-25

RESIGNATIONS.

Name.	Grade.	District.	Date.
Barthel, W. R. ...	Inspector	N. East. District.	25-1-25

APPOINTMENTS.

The undermentioned have been appointed Probationary Assistant Engineers as a result of the *Limited* Competitions held in November, 1924.

Name.	Grade.	Office alloted to.
Jolley, E. H.	Probationery Inspector.	Research Section.
Pidgeon, J. E.	Chief Inspector.	Research Section.
Taylor, T. A.	Probationery Inspector.	Research Section.
Jackson, J. M.	Chief Inspector.	Research Section.
Williams, Ll. E.	Chief Inspector.	Power Section.
Wallcroft, F. E.	Probationery Inspector.	Research Section.
Bedford, J. G.	Chief Inspector.	Research Section.
Missen, E.	Repeater Officer, Cl. II.	Wireless Section.
Chinn, W. E.	Draughtsman, Cl. II.	Equipment Section.

STAFF CHANGES.

The undermentioned are due to be appointed Probationary Assistant Engineers as a result of the *Open* Competition held in November, 1924.

NAMES.

Beer, H. G.	Bryden, J. E. Z.	Gray, W. D.
Britton, F. T.	Brent, W. H.	Davis, T. A.
Moffatt, C. E.	Farnes, G. H.	Bewick, T. A.
Ryall, L. E.	Gemmell, W. T.	Barker, P. L.
Semple, L. G.	Hines, R. J.	
Manning, F. E. A.	Dixon, G. J. C.	

CLERICAL ESTABLISHMENT.

APPOINTMENTS AS CLERICAL OFFICER.

Name.	District.	Date.
Edwards, W. J.	E.-in-C.O.	25-1-1925
Calnan, J. J.	do.	1-2-1925
Martin, H. J.	London	7-1-1925
Stanbury, G. R. W. ...	S.Wa.	1-1-1925
Lee, R.	S.Mid.	1-1-1925
Milne, J. T.	Scot. East	1-1-1925
Jackman, C. G.	S.East	4-1-1925
Moore, F. W.	S.West	4-1-1925
Kent, O. A.	S.East	4-1-1925
Livingstone, A. S. ...	N.	7-1-1925
Cameron, A.	N.Wa.	11-1-1925
Cowie, W.	Scot. East	11-1-1925
Gifford, R. J.	Eastern	11-1-1925
Postlethwaite, R. R. ...	N.W.	11-1-1925
Hamilton, J. McL. ...	N.Wa.	11-1-1925
McKenna, A. R.	Eastern	18-1-1925
Waddington, H.	N.W.	18-1-1925
Long, C. H.	S.Mid.	25-1-1925
Jones, G. H.	N.Mid.	31-1-1925
	(on return from Colonial	Service).
Roberts, P. M.	S.W.	1-2-1925

TRANSFERS (Clerical Officers).

Name.	Transferred.		Date.
	From.	To.	
Murphy, W. H. C. ...	S. West. District.	S. Wales District.	4-1-25
McGill, J. C.	N. Wales District.	S. East. District.	4-1-25
Stanley, F. A.... ...	Eastern District.	Ireland.	7-1-25
O'Loughlin, L. J. ...	Ireland.	London District.	25-1-25
Deacon, S. J.	E.-in-C. Office.	Met. Police Receiver's Office.	25-1-25
Martin, E. N.... ...	Admiralty.	S. Mid. District.	2-2-25

STAFF CHANGES.

TRANSFERS.

Name.	Transferred.		Date.
	From.	To.	
Crossley, E.	N. East. District.	S. East. District.	1-3-25
Hoyle, J.	S. Lancs. District.	N. West. District.	1-3-25
Moore, R. H.	N. West. District.	N. Wales District.	1-3-25
Harding, H. J. ...	N. Wales District.	S. Mid. District.	1-3-25
Grattan, G. C. ...	Ireland.	London District.	1-3-25
Maguire, E.	N. Mid. District.	Ireland.	1-3-25
Hallam, G.	Ministry of Pensions.	N. Mid. District.	2-3-25

DEATHS (Clerical Officers).

Name.	District.	Date.
Wright, J. McD.	N.E.	25-1-1925
Croft, W. H.	London	7-1-1925

COMMUNICATIONS.

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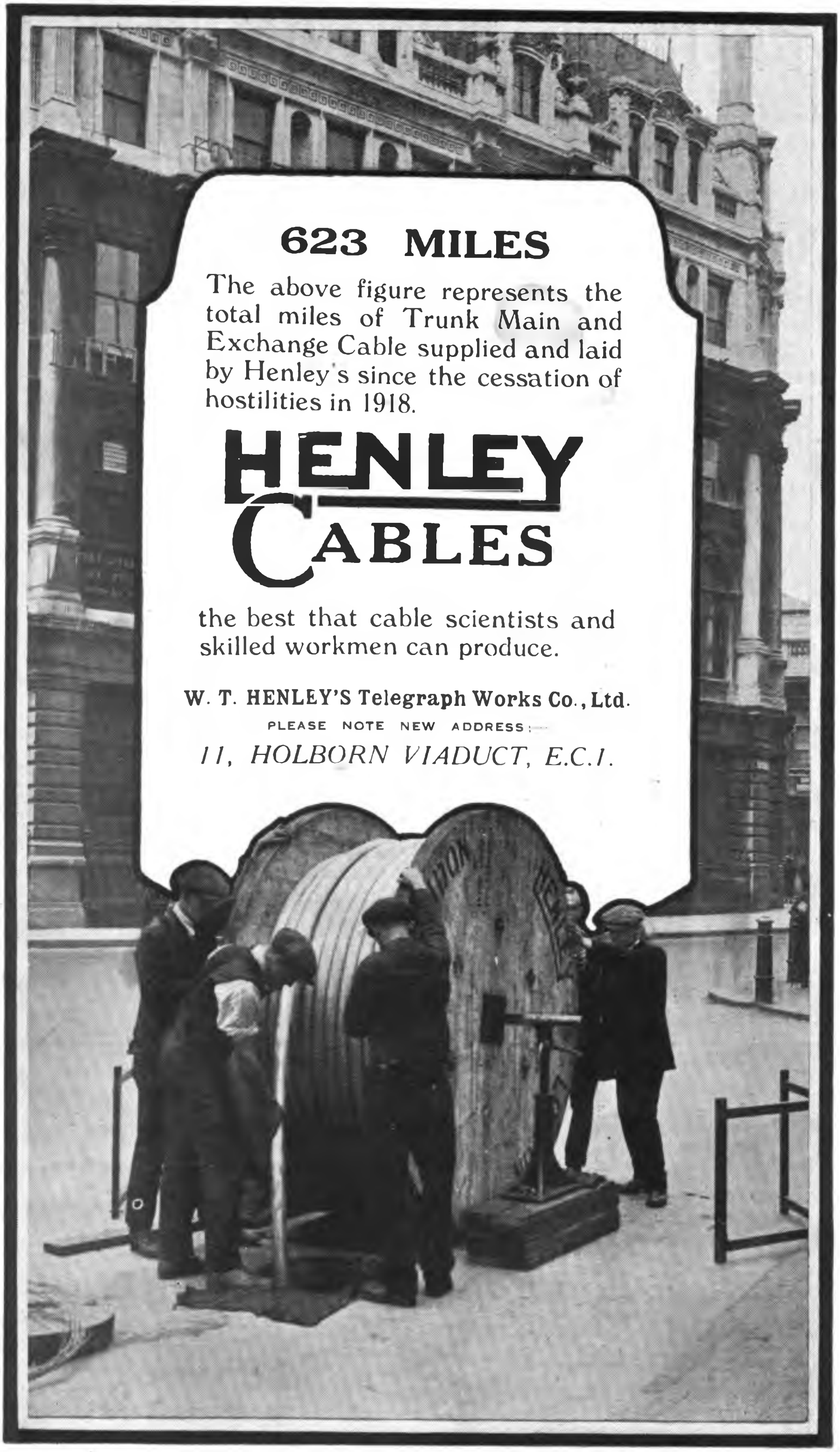
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