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A.7.

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Post Office Engineering Department

TECHNICAL PAMPHLETS FOR WORKMEN

Subject:

Sensitivity of Apparatus.

ENGINEER-IN-CHIEF'S OFFICE,
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SENSITIVITY OF APPARATUS.

(A.7.)

The following pamphlets in this series are of kindred interest:

- A.1. Magnetism and Electricity.
- A.3. Technical Terms.
- A.6. Measuring and Testing Instruments.
- B.1. Elementary Principles of Telegraphy.
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SENSITIVITY OF APPARATUS.

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TELEGRAPHS.

SENSITIVITY OF APPARATUS.

From the point of view of the Officer who maintains the apparatus, it is not required that the laboratory tests, usually imposed under the various specifications, shall be made. It will, however, be possible with the use of a Detector No. 2 to make such tests as will enable it to be determined whether the apparatus is or is not suitable for the particular work it is required to do.

Diagram T. 102 in the Loose Leaf Series shows voltage, current and resistance tests (made by means of Detector No. 2), which will cover practically all the requirements of ordinary maintenance.

In connection with the electrical examination of Telegraph apparatus there are a few general electrical requirements that may be summarised thus, viz. :—

(1) In a complete instrument the *continuity* in every lead and connection must be practically perfect, that is, there must be no appreciable resistance except that of the coils, which is specified.

(2) The *insulation* of parts electrically separated must also be practically perfect, that is to say, there must be an insulation resistance of not less than a megohm between them. This condition must especially be observed between the coils and the cores of electro-magnets and between the two wires of differentially wound instruments.

(3) *Connections* and *joints* must be well and securely made, and, where screws are used for making connections, the lacquer must be removed (before delivery) from those surfaces upon which contact depends.

(4) All *resistance coils* and *shunts* must be double wound.

(5) The *adjustments of relays*, etc., must be examined to see that the armature of the instrument has its proper range of movement between the limiting stops, without making contact at any point with the electro-magnet cores.

(6) The apparatus must have its proper "*figure of merit.*" The figure of merit, in the case of instruments worked from a battery, is *the minimum current in milliampères with which they will work well.* Generally the figure of merit represents the current used in the tests which determine the acceptance or rejection of new apparatus delivered to the Department by the makers.

(7) *Non-polarised instruments* should work equally well with the current flowing in either direction through the coils, unless otherwise specified.

If tried with the current in one direction only, misleading results may arise, due to the presence of residual magnetism.

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(8) In all *electro-magnets* the armatures must be symmetrically placed with respect to the iron cores.

(9) *In Single Needle Coils, Galvanometers* and *Indicators*, the end of the needle, from which the reading is taken, should deflect in the same direction in which the current passes from terminal to terminal across the instrument, unless otherwise specified.

In Table 1 are shown the values of the "Figure of Merit" and other data in respect of the more important types of apparatus used in connection with telegraphy in this country.

TABLE 1.

Apparatus Constants of the more Important Items of Telegraph Apparatus.

Item.	Resistances.		Figure of Merit.
	Coils.	Shunt.	
	ohms.	ohms.	m.a.
Sounder 20w	21	420	55
Sounder 900w	1,000	9,000	11
Sounder Relaying 30w...	60	60	60
Sounder Relaying 40w...	44	440	40
Sounder Relaying 500w	1,000	1,000	20
Sounder Relaying 900w	1,000	9,000	10
Sounders Double Plate 20w	21	420	73
Sounders Double Plate 900w	1,000	9,000	10
Sounders Vibrating Military 10w	20+20	—	125
Single Needle Coils ...	200	—	3·06
Inkers Direct	300	—	4·9
Inkers Duplex ...	200+200	—	4·9
Inkers Local	40	500	69
Sounder Pold. C ...	200+200	—	2
Sounder Pold. D 100w+100w	100+100	—	6
Sounder Pold. D 500w+500w	500+500	—	3
Sounder Pold. D. 2,000w	2,308	15,000	2½
Sounder Pold. D. 4,500w	5,400	27,000	2
Relay N.P.B.	200+200	—	6
Relay N.P.C.	100+100	—	4·5
Relay N.P.C. 500w+500w	500+500	—	3
Relay Std. A	200+200	—	½
Relay Std. B	100+100	—	½
Sounders Polarised Relaying 500w+500w ...	500+500	—	½
Relay Std. G *Line Coils	100+100	—	½

* For "repeating" see notes and also remarks on Wheatstone Receiver Tests.

The following notes are intended to supplement the information shown in Table I.:—

Sounders, 20^w.—Coils 21^w with a shunt of 420^w. The armature should be so adjusted that, when in the attracted position, it is 10 mils from the cores and the limiting stop 10 mils from the lever. With this adjustment the sounder should work with a current of 55 m.a. and allow of the tension spring screw being turned through three complete revolutions without interrupting the working.

Sounders, 900^w.—Coils 1,000^w with a shunt of 9,000^w. The remarks referring to the adjustment of sounders 20^w apply also to sounders 900^w, with the exception that the operating current should be 11 m.a.

Sounders, Polarised, " B," 4,500^w.—Two coils of 2,700^w each shunted with a resistance of 27,000^w, the resistance of the instrument being 4,500^w. The coils should be joined up so that, when a battery is connected to the instrument, the striker will deflect towards that side to which the positive pole of the battery is connected.

With the striker adjusted centrally between the stop pins the instrument should work well with a current of 1 m.a., and, without readjustment, it should work well also when the current is increased to 20 m.a.

A rubber buffer should be fitted at the back of each sounding plate.

Sounders, Polarised, D, 100^w + 100^w.—The instrument should work well at maximum " key speed " when a current of 6 m.a. is reversed through the coils. It should not " polarise " with reversals of 60 m.a., and, after the passage of such a current, it should again respond to 6 m.a. of current without readjustment. The instrument should show no sign of response when reversals of 300 m.a. (total current) are sent differentially from the central terminal to the two outer terminals joined together.

Sounders, Polarised, D, 500^w + 500^w.—The instrument should work as in the case of the 100^w + 100^w type with currents of 3 m.a. and 30 m.a., and should show no sign of response to a total differential current of 200 m.a.

It should be capable of satisfactory adjustment for working currents up to 50 m.a.

Sounders, Polarised, D, 2,000^w.—The current limitations range from 2.5 m.a. to a maximum of 25 m.a.

Sounders, Polarised, D, 4,500^w.—The range of current values is from 2 m.a. to 20 m.a.

Relay, N.P.B., 200^w + 200^w.—The adjusting spiral, when fully extended, should be strong enough to prevent the armature from being attracted when a current of 12.2 m.a. is flowing through the coils, the armatures being at the same distance from the poles as for the " Figure of Merit " Test.

Relay, N.P.C., 100^w + 100^w.—The adjusting spiral, when fully extended, should be strong enough to prevent the armature being attracted when a current of 15 m.a. is flowing through the coils.

Wheatstone Receiver.—The actual figure of merit of a Wheatstone Receiver is of less importance than the question as to the most suitable tests to be applied, in order that it may be ascertained whether the apparatus is suitable for the work required of it. A scrutiny of the tests hitherto imposed will illustrate what is meant. For example, in the case of a "*Receiver Spring*" two electrical tests are given, viz. :—

(a) For working a sounder at key speed, the coils being in parallel and the tongues being in the neutral positions, the minimum current is given as 10 m.a.

(b) For Morse signals at a speed of 200 words per minute, the coils being in series, a minimum current of 17½ m.a. is required.

The conditions stipulated provide for the use of a testing battery of 60 volts with an external resistance of 3260 ohms, 1600 ohms of which is shunted by a 2 mf. condenser. The tests imposed in the case of the *weight driven Wheatstone Receiver* are similar, but, in the test (b), a maximum speed of 300 words per minute should be obtained.

Obviously, therefore, both mechanical inertia and speed of signalling have to be considered in determining the efficiency of the instruments.

Recent experiments have shown that, with the use of suitable underground loops, it is not necessary to increase the steady value of the line current beyond 10 m.a. nor the voltage beyond 40 volts when the speed of signalling is 200 words per minute, the Wheatstone Receivers being connected direct to line.

The results obtained when the Wheatstone Receivers were connected to the locals of (a) Relay Standard "B" and (b) Relay Standard "G" are worthy of notice.

(a) *Wheatstone Receiver on locals of Relay Standard "B."*	*SX.*	*DX.*	(b) *Wheatstone Receiver on locals of Relay Standard "G."*	*SX.*	*DX.*
Sending Voltage ...	40	13½	Sending Voltage ...	40	13½
Steady current value	4	5	Steady current value	4	5
Shunted Condenser... mf.	2½		Shunted Condenser... mf.	2½	
Condenser Shunt ...	8,000^w		Condenser Shunt ...	8,000^w	
Speed obtained w.p.m.	200	120	Speed obtained w.p.m.	200*	200
Current observed when transmitting reversals.	41 m.a.		Current observed when transmitting reversals.	41 m.a.	

* The limit of "G" relay not reached.

When the leakage is negligible, as in the case of an underground cable, the question of loss of current due to line leakage does not come into the problem.

Without entering too fully into the complex question of the effects due to alternating signals being sent on an underground cable circuit, it will be sufficient to say that the frequency (f) of the signals increases with the speed of working; that the inductance (L) increases with the value of the current, and that the E.M.F. of Self Induction (Es) due to the passage of alternating signals is equal to 2π times (where $\pi = 3.1416$) the product of the Inductance (L) the frequency (f) and the current (I) (where I is the virtual value of the alternating current). That is

$$Es = 2\pi f L I$$

The only point that need be considered at present in this connection is that, in order to minimise the E.M.F. of Self Induction, it is necessary to reduce the value of the current (I) to the lowest possible figure consistent with the efficient working of the receiving apparatus. That is to say, the figure of merit of the receiving apparatus may, with advantage, be more nearly approached in the case of underground wires than in cases in which leakage losses have to be compensated for. The extent to which the figure of merit is approached will depend partly on the nature of the adjustments obtainable at the terminal offices and partly on the speed of the signals.

The coils of Wheatstone Receivers should be differential when tested in series with 100 m.a. and in parallel with 200 m.a.

Wheatstone Transmitters.—Good signals should be produced by the receiver when a punched slip is passed through a transmitter at any speed from the lowest to the highest. Marking and spacing contacts of equal duration should be made for "reversals."

The battery must not be short-circuited during reversal, nor must it be joined through to the receiving apparatus when the switch is being turned from one position to the other.

Relay, Std. B.—Each of the coil bobbins to be double wound in two sections with single silk-covered copper wire. Each of the wires on each complete bobbin to be of 200^w resistance, making a possible total of 800^w for the two bobbins. The similar windings of each bobbin are to be joined in multiple between the connection plates, giving a finished resistance of 100^w between terminals " D " and " U " and 100^w between terminals "Ⓓ" and "Ⓤ."

The relay to be tested differentially by connecting terminals " U " and "Ⓤ" and sending a current of 250 m.a. through the coils from terminal " D " to terminal "(D)," when the armature must remain unaffected.

Relay, Std. G.—The line coils are similar to those of the B relay. The auxiliary coil windings are connected to the terminals A, B and C, as indicated in E-in-C Diagram T.G. 261. The coils must be differential. The tests imposed are as follows, viz. :—

Line Coils. For Key Speed Working.—Four Y Cells Dry through 12,500^w external resistance and with the auxiliary coil circuit open, current $\frac{1}{2}$ m.a.

For repeating at 400 *words per minute;* a current $7\frac{1}{2}$ m.a.; auxiliary coil circuit open; 120 volts; 4,000^w external resistance and a reading condenser and shunt of $\frac{1}{2}$ mf. and 12,000^w respectively.

Auxiliary Coils.—For repeating at the rate of 300 words per minute, $7\frac{1}{2}$ m.a., the conditions being the same as in the preceding test and with Line Coil circuit open.

Galvanometers, Differential.—Resistance of Coils 50^w each. Resistance of Shunts 300^w each. Joint resistance 42.9^w each. The differential test should be 100 m.a. (series) and 200 m.a. (parallel).

The Figure of Merit, for equal deflections on either side, of not less than 40 degrees and not more than 50 degrees, is $17\frac{1}{2}$ m.a.

TELEGRAPH CIRCUITS.

Circuit Efficiency and Factors of Safety.

When polarised sounders are used at an out office in connection with Telegraph Central Battery Omnibus Circuits, the apparatus will be connected in a manner similar to that shown in Fig. 1. As there are no batteries at the out office it will not be possible to subject the apparatus to " Figure of Merit " tests. With this class of circuit the Condenser is normally charged by the Central Battery at the Head Office, and the polarised sounder at the out office is actuated by the condenser being alternately discharged and recharged under the control of the Head Office key. These circuits are usually connected with the Head Office by means of overhead wires. If the insulation of the line is perfect the voltage at the " bridge " of the key (a), Fig. 1, will be that of the Head Office battery. With low insulation conditions there will, however, be a loss in the voltage, and this loss will be greater on long aerial lines than on short ones, under the same atmospheric conditions. By means of a Detector No. 2 voltage test (see Loose Leaf Series, T. 102) the voltage reading of the potential at (a) Fig. 1 can be obtained. If with the Head Office key normal the reading is greater than the voltage drop shown in Table 2 for the given combination of Polarised Sounder and Condenser, and if the depression of the out office key does not actuate the Polarised Sounder,

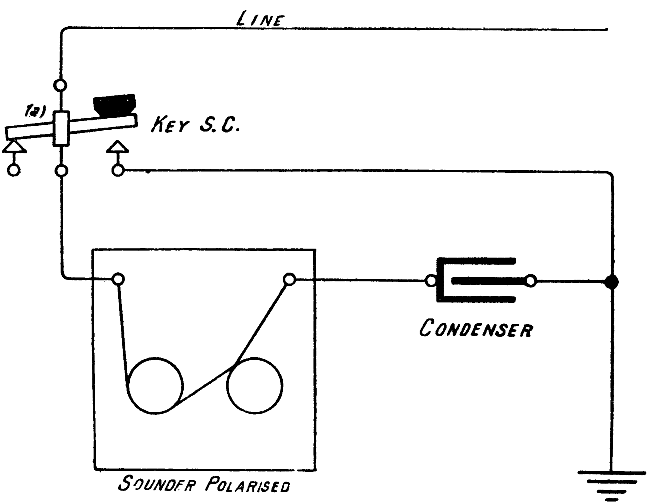

Fig. 1.

then the out office apparatus is faulty. In making these tests at the Head Office Set it is necessary that one reading be taken with the out office key normal and a second reading with the out office key depressed. The difference between the two readings should not be less than the relevant "voltage drop at key" figures shown in Table 2.

In the case of the Head Office Set both the battery and the feed resistance must, of course, remain in circuit while the tests are being made.

Table 2 shows the minimum voltage drop required for different combinations of Condensers and Polarised Sounders or Relays for normal adjustments.

TABLE 2.

Central Battery Omnibus Circuits minimum voltage drop (at the bridge of the key) to actuate different combinations of Condensers and Pold. Sounders or Relays.

Apparatus.	Condensers.	Voltage drop at key.
Sounder, Pol'd, $2,000^w$	4 mf.	11½
Sounder, Pol'd, $4,500^w$	2 mf.	20
Sounder, Pol'd, $500^w + 500^w$... ...	2 mf.	10
Sounder, Pol'd, $500^w + 500^w$... ...	4 mf.	9
Sounder, Relaying, Pol'd, $500^w + 500^v$ (two coils in series)	4 mf.	3½
Sounder, Pol'd, Relaying, $500^w + 500^w$ (one coil)	4 mf.	6
Relay, Std. B, with $1,000^w$ coils in series	4 mf.	5½
Relay, Std. B, with $1,000^w$ in series (1 coil)	4 mf.	11½

The question of working speeds on underground wires is a complex one, but empirical formulæ representing limiting conditions have been arrived at, on the basis of the time constants of the receiving apparatus.

The Time Constant of a cable wire may be regarded as being proportional to the product of the capacity (K) and the resistance (R) of the line. So that it may be said that an underground wire of 600 miles in length having a resistance per mile of 9 ohms and a capacity per mile of 0.1 mf. will have a Time Constant of :—

$$KR = (600 \times 0.1) \times (600 \times 9) = 324{,}000 \text{ microseconds.}$$

As the unit K is expressed in microfarads it will be necessary to divide the result by 1,000,000 in order to obtain the value in seconds, so that

$$KR = 0.324 \text{ second.}$$

The Time Constant of the receiving apparatus is represented by the fraction $\frac{L}{R}$, in which L represents the inductance due to a current passing through the coils and R the ohmic resistance of the coils. The ratio determines the time taken for a current to reach 0.623 of its full value, and upon the Time Constant depends the speed at which the apparatus can work. The value of L increases slightly as the current in the coils is increased.

The empirical formulæ are usually arrived at by increasing the line KR up to a point beyond which the signals obtained on the receiving apparatus become imperfect. For example, it has been shown that the Syphon Recorder will work well when the product obtained by multiplying the KR value by the speed in words per minute (W) is equal to 120×10^6. So that at 30 words per minute the maximum KR value will be

$$KR = \frac{120,000,000}{30} = 4,000,000 \text{ microseconds} = 4 \text{ seconds.}$$

Similarly the KRW for the Undulator is given as 40×10 and for Wheatstone working with copper wire as 11×10^6.

Notice also that $K = L \times k$ where L = length in miles and k capacity per mile.

Also $R = L \times r$ where r is resistance per mile.

So that $KR = L \times k \times L \times r = krL^2$.

So that, if $k \times r = 1$, which would be the case where $k = 0.1$ and $r = 10^w$, then $W = \frac{\text{constant}}{(\text{mileage})^2}$ = words per minute.

It may be added that in applying the KRW formulæ, discrimination, based upon practical experience, should be exercised.

The question of the **Factor of Safety** to be provided is largely determined by the length and composition of the line wire associated with the apparatus set.

From what has already been said in connection with Wheatstone working, it will be apparent that the "Figure of Merit" of the apparatus can be approached more closely with underground cables than in the cases in which the wire is erected on poles. In the latter case, leakage is always present to a greater or lesser extent in this country, and this is beneficial up to a certain point, in that difficulties due to capacity and inductance effects are minimised.

So far as overhead telegraphs in this country are concerned, it may be said that the predominating factor determining the mileage of long telegraph circuits is that of the loss of current due to leakage.

If a line wire be tested throughout its length, first for insulation resistance and then for conductivity, and if the length in miles of the wire and the conductor resistance per mile be known, the following values can be determined, *viz.* :—

(a) The calculated conductor resistance
$Ra = L$ (miles) $\times$ ra (the conductor res. per mile) and

(b) The Perfect Current $Cp = \frac{\text{EMF.}}{Ra}$

By means of the two tests (insulation and conductivity) it is possible to express the percentage of the "Perfect Current" lost under different conditions of line insulation.

From (a) of Table 3 it will be seen that when the Insulation Resistance (R1) is 1.01 times the conductivity reading (Rc) the percentage loss of current is 80, and that under these conditions the Insulation reading is only equal to 0.56 Ra.

Comparing (a) and (j) of Table 3, it will be clear that the percentage loss falls from 80 to 4.34, while the ratios R1/Rc vary between 1.01 and 5.76.

TABLE 3.

Overhead Telegraphs.

The percentage loss of the "Perfect Current" for different insulation conditions of the line.

Equivalent Res. of Resultant Leakage Path.	R1/Rc.	R1/Ra.	Rc/Ra.	Cr/Cp.	Percentage of Perfect Current lost.
(a) $\frac{1}{16}$ Ra ...	1·01	0·56	0·55	0·20	80
(b) $\frac{1}{8}$ Ra ...	1·04	0·625	0·60	0·33	$66\frac{2}{3}$
(c) $\frac{1}{4}$ Ra ...	1·125	0·75	0·66	0·50	50
(d) $\frac{1}{2}$ Ra ...	1·33	1·00	0·75	0·66	$33\frac{1}{3}$
(e) 1 Ra ...	1·80	1·50	0·83	0·80	20
(f) 2 Ra ...	2·77	2·50	0·90	0·88	$11\frac{1}{9}$
(g) 3 Ra ...	3·76	3·50	0·92	0·92	7·69
(h) 4 Ra ...	4·76	4·50	0·94	0·94	5·88
(j) 5 Ra ...	5·76	5·00	0·95	0·95	4·34

Remarks.

R1 is the reading obtained by taking an Insulation Res. test of the line wire throughout its length.

Rc is the reading obtained by taking a conductivity test of the line wire throughout its length.

Ra is the calculated res. of the line wire, equal to the length of the wire in miles multiplied by the conductor res. per mile.

Cr is the Rec'd Current.

Cp is the Perfect Current equal to $\frac{\text{EMF}}{\text{Ra.}}$

In applying the results shown in Table 3 to the conditions obtaining in this country, it is necessary to determine what percentage loss can be allowed for different types of Telegraph apparatus in use, having regard both to the lowest condition of insulation resistance on the aerial wires and to the characteristics of the receiving apparatus.

An approximation to the mileage limitations in this country is shown in Table 4.

TABLE 4.

Approximations to mileage limitations for different types of Overhead Telegraph Circuits in Great Britain.

Length in miles.	Type of Circuit and voltage.	Line conditions. Minimum value.	Percentage loss of Perfect Crt. minimum line value.
(a) 1,000/√ra	Key D.C. Morse with Relay 120 volts.	Ri/Rc 1·01	80%
(b) 700/√ra ...	Fast Speed Telegraphs 120 volts	Ri/Rc 1·04	66⅔%
(c) 490/√ra ...	Quadruplex with 40 and 120 volts	Ri/Rc 1·125	50%
(d) 316/√ra ...	Central Battery Tghs. Special Head Office Sets 80 volts secy. cells	Ri/Rc 1·33	33⅓%
(e) 223/√ra	Secondary Cells. (1) CBS ordinary Head Office Sets 80 volts. (2) Quadruplex with 24 and 80 volts (3) Central Btty. DX with Relay at Out Office 80 volts	Ri/Rc 1·8	20%
(f) 158/√ra ...	CBS Primary Batteries (2 ccts) 80 volts	Ri/Rc 2·77	11 1/9%
(g) 100/√ra ...	CBS Primary Batteries (6 ccts) 80 volts	Ri/Rc 5·76	4⅓%

As regards the values shown at (a), (b) and (c), the mileage approximations are fairly wide, as duplex conditions are assumed, and further, the conditions on East Coast and West Coast routes as well as on Road and Rail routes, differ widely. Also, the Fast Speed figures comprise "Wheatstone Receiver Direct on line," "Wheatstone Receiver on Locals of Relay," "Baudot," and other types of circuits, of which it may be said that, although classified under the one formula, there are slight differences in respect of mileage limitations, for which allowance would require to be made in practice.

From the values shown at (d) it will be seen that when a wire has a mileage represented by $316\sqrt{ra}$ only one-third of the "Perfect Current" is lost under the worst conditions of insulation resistance.

If the conductor resistance per mile (ra) is, say, 9 ohms, then the mileage will be $\frac{316}{3} = 105\frac{1}{3}$ miles. The calculated conductor res. (Ra) of the wire will be $9 \times 105\frac{1}{3} = 948^w$.

An approximation to the minimum conditions can be arrived at by assuming the lowest insulation resistance per mile to be $50{,}000^w$.

Dividing this figure by the mileage will give a resultant leakage path resistance of 474^w which, it will be seen, is equal to half the calculated conductor resistance. (See Table 3.)

Assuming the resultant leakage is acting at the centre of the line resistance a close approximation to the limiting conditions will be obtained. These conditions are represented in Fig. 2.

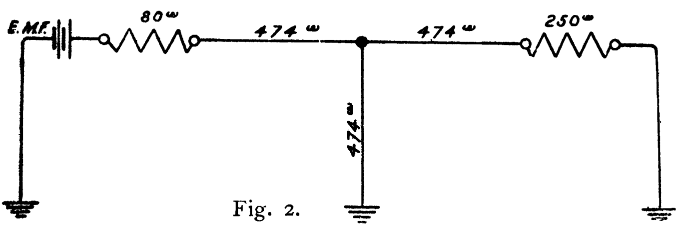

Fig. 2.

The following simple calculations will indicate the method of arriving at the E.M.F. required :—

The resistance of the circuit (including the receiving Relay Std. B), when there is no leakage present is

$80 + 474 + 474 + 250 = 1278^w$. Therefore the "Perfect Current" Cp. $= \frac{EMF}{1278}$.

The resistance of the circuit when the leakage is such as to be equivalent to a resultant leakage path resistance of 474 ohms acting at the centre of the line resistance, will be

$$(80 + 474) + \frac{(474 + 250) \times 474}{474 + 250 + 474} = 554 + 286 = 840.$$

So that the "Sent Current" under these conditions will be $Cs = \frac{EMF}{840}$ and the "Received Current" Cr will be a fraction of the Sent Current, *viz.*, $Cr = \frac{474}{1198} \times \frac{EMF}{840}$

$$Cr = \frac{EMF}{2123}$$

So that $\frac{Cr}{Cp} = \frac{EMF}{2123} \times \frac{1278}{EMF}$

$$\frac{Cr}{Cp} = 0.6 \text{ or } Cr = 0.6 \times Cp.$$

From Table 3 it will be seen with a line having a ratio of $R_1/R_c = 1.33$ that the Received Current Cr. = 0.66 Cp. Compare this with the result obtained under the conditions shown in Fig. 2.

The additional resistance due to the apparatus has diminished the received current from 0.66 Cp. to 0.6 Cp.

If duplex conditions are required the working minimum received current might reasonably be regarded as 8 m.a. and the Perfect Current in this case would be $\frac{8}{0.6} = 13\frac{1}{3}$ m.a., say 15 m.a.

The E.M.F. required will then be found, since E = CR = 0.015 × 1278 = 19.17 volts, say 20 volts, or nearest value available with a Secondary Cell installation.

Practically all overhead problems can be dealt with in this manner, and it will be possible to modify, where the circumstances require it, the values shown in Table 5, which represents the Department's standard practice.

TABLE 5.

Showing working currents for different types of Telegraph circuits, in accordance with the Department's standard practice.

Type of Circuit.	Working Currents.
Single Needle Apparatus	15 to 20 ma,
Double Sounder 20^w	100 ma.
S.C. Direct Sounder 20^w	100 ma.
Direct Inker 40^w...	100 ma.
Combined Inker 300^w	15 to 20 ma.
S.C. Sounder with Relay Std. B (coils multiple) ...	30 to 40 ma.
S.C. Sounder with Relay Std. B (coils series)	15 to 20 ma.
S C Sounder with Relay Std. A (coils multiple) ...	20 to 30 ma.
S.C. Sounder with Relay Std. A (coils series)	10 to 15 ma.
Direct Sounder 900^w	20 to 26 ma.
Combined Inker Duplex (200^w + 200^w)	15 to 20 ma.
S.C. Duplex with Relay Std. B (1 coil)	30 to 40 ma.
D.C. Duplex with Relay Std. B (1 coil)	20 to 30 ma.
D.C.S. with Relay Std. B (multiple)	20 to 30 ma.
D.C.S. with Relay Std. B (series)	10 to 15 ma.
Wheatstone Automatic News Receiving (coils in multiple)	20 to 30 ma.

TELEPHONES.

SENSITIVITY OF RELAYS, METERS AND INDICATORS USED IN MANUAL TELEPHONE EXCHANGES.

RELAY ADJUSTMENTS.

In modern exchanges the whole of the relays are of the non-polarised type—simple electro-magnets with armatures, the movements of which open or close electric circuits.

The number of such relays in an equipment for 10,000 subscribers may reach as high a figure as 30,000 It is, therefore, very important that the relays shall not be expensive in maintenance; indeed, the ideal relay will be one which, once correctly adjusted and installed, will perform its function without failure or need for readjustment for twenty years, and at the same time have a low purchase price and occupy little space.

Ten relays (five No. 127A and five No. 128B) were recently put through 1½ million operations under operating conditions representing the worst obtainable in practice. Eight out of the ten relays (four No. 127A and four No. 128B) passed the test without a single failure. The fifth (128B) developed an imperfect contact at the end of 73,000 operations, and a failure to operate due to displacement of armature, probably the result of external vibration, at the end of 603,800 operations. The fifth (127A) relay developed a recurring fault only at the end of 705,800 operations.

In these relays the air gap between the armature and the pole piece, either in the normal or in the energised condition, was not capable of adjustment, and as the tension of the contact springs was not interfered with, **the test affords conclusive evidence that, assuming accurate and invariable adjustment to start with, and reasonable care to keep the relay covers in position, the failures should be extremely few.**

When an internal fault is reported there is often a tendency to assume too readily that a relay is out of adjustment, especially if the relay is provided with facilities for readjustment. Once the adjustment has been altered unnecessarily it is difficult to readjust to the precise original condition, and failures begin to occur when, say, the voltage varies or changes take place in the character or length of the circuit in which the relay is called upon to operate. Further adjustments have then to be under-taken, which cause wear to the threads of adjusting screws and render permanency of adjustment difficult to obtain.

A safe course to take is to assume that where facilities are provided for adjustment, in 99 cases out of 100 they are there for the manufacturer to correct for slight dimensional variations in the metal used, variations which are unavoidable in the best factories.

The following notes may be useful in dealing with the adjustment of relays before they are brought into use or in readjusting subsequently, although, as previously mentioned, cases in which readjustment is necessary will be very few if the initial adjustment has been carefully carried out and made permanent.

RELAYS—TYPES.

Western Electric Knife Edge Relay with "make" action.—A relay of this type has an armature with a base shaped like a knife edge. The edge rests in a groove cut into an iron piece which forms an extension of the core from the rear. The groove acts as a fulcrum for the armature movement. Two adjustments are provided for :—

(i) Regulation of the distance between the armature and core when the armature is in the normal or unattracted position.

(ii) Regulation of this distance when the armature is attracted.

The screw which provides for adjustment (ii) is fitted with a contact point, so that when the armature is attracted the local circuit is completed *viâ* the armature itself. It will be found most convenient to make adjustment (ii) first, regulating the contact screw until the minimum distance is obtained between armature and core consistent with the armature falling back when the specified releasing current flows in the winding. Adjustment (i) follows, which consists in bringing the normal position of the armature towards the core until the contact clearance is about 20 mils, when the specified operating current in the winding should cause the armature to be attracted and close the contacts. The ordinary line relay used in 22v. manual exchanges is representative of this type.

Western Electric Knife Edge Relay with "break and make" action.—An example of this type is to be found in the Department's relay No. 28. The knife edge in this case is formed at the end of the core extension, whilst the groove into which it fits is in the armature near its base. Both adjusting screws are provided with contact points to give a break and make action, and a spiral spring is fitted in order to secure a reliable pressure on the break contact and, at the same time, to provide a means whereby the value of the releasing or non-operating current may be varied. One end of this spring is anchored underneath the core extension, the other is attached to a threaded pin passing through a slot in the base of the armature. That portion of the pin which protrudes in front of the armature receives a nut, the turning of which varies the releasing or non-operating tension on the armature and the "break" contact pressure. In adjusting the 28A relay the "make" and "break" contact screws and spring adjusting nut are regulated until the armature, with not less than 10 mils clearance between "make" contacts, does not move to separate the "break" contacts while the specified non-operating current is flowing in winding, but will move towards the core with the specified operating current.

Western Electric Type Cut-off Relay.—P.O. relay types Nos. 30 and 23 are representative of this design. The core of the electro-magnet is extended at both back and front by means of iron "L" pieces. The armature, which is about 2½ in. long, is hinged inside the rear "L" piece by means of a thin flexible iron plate clamped to the "L" piece and fixed to the middle of the armature by two screws. The front "L" piece forms the pole to which the front end of the armature is attracted. The armature is normally kept away from this pole by the pressure of the "break" or movable contact springs upon ebonite studs fixed on the outer surface of the armature.

The front end of the armature is cut obliquely, and the point of an adjusting screw, threaded through the front "L" piece, bears on the oblique surface. Giving the head of the screw a clockwise rotation brings the end of the armature nearer to the pole and *vice versâ*. The pressure between contacts with the armature in its normal position should not be less than 28 grammes and, subject to this condition being met, the operating current can be reduced by bringing the armature closer to the pole. A very thin non-magnetic separation between armature and pole is sufficient to provide reliable release, as the tension of the deflected contact springs acts in a direction to restore the armature to its normal position. This non-magnetic separation is not adjustable.

Automatic Telephone Manufacturing Co.'s Sensitive Double Break and Make Relay.—P.O. relays Nos. 6 and 7 are of this type. The core of the relay is extended by means of two soft iron flanges, one at the back near the mounting, the other at the front. Two pins projecting from the rear flange penetrate holes in the armature forming a hinge for movement. The front flange forms the pole to which the front end of the armature is attracted when the relay is energised. The armature carries two insulated contact springs, the contact pieces in which normally rest upon the points of two adjustable contact screws with capstan heads. When the armature is attracted the contact pieces in these springs are brought against the points of two other adjustable contact screws giving the double break and make action. Several adjustments are provided for, *viz.* :—

(a) *The regulation of the restoring tension on the armature.*—A spiral spring is suspended between a pin in the rear flange and the point of a screw threaded through a post on the upper rear surface of the armature. The head of this screw is accessible from the front of the relay if a long thin screwdriver is used, and rotating the head in a clockwise direction extends the spiral spring, thereby increasing the restoring tension on the armature. Turning the head in the reverse direction will, of course, decrease the tension.

(b) *Variation of the air gap between the armature in its normal position and the pole.*—This may be accomplished in either of two ways, depending upon whether or not the " break " action of the contact springs is in use. *If the " break " action is in use,* the air gap will be regulated by the adjustment of the upper capstan heads. *If not in use,* then the adjustment may be made either by means of the upper capstan heads, as already explained, or by the rotation of the nut threaded upon the screw shank which passes through a slot in the front end of the armature. Adjustment at the upper capstan heads would be more permanent.

(c) *Variation of air gap between pole and armature when the latter is in its attracted position.*—This is possible by adjustment of the lower capstan heads, which varies the positions of the " make " contacts with respect to the pole.

British L.M. Ericsson Co.'s Relay.—The Department's No. 1 relay is representative of this type. It is provided with two flat coils, one on each limb of a soft iron " U " shaped piece of about 1 in. × $\frac{1}{8}$ in. section. The " U " piece is fixed to an iron disc, which is mounted upon a wooden base 3 in. × $2\frac{5}{8}$ in., provided with four coil and three contact terminals. The iron of each limb protrudes about $\frac{1}{16}$ in. from the upper cheek of the coil, forming the two polar surfaces which act upon a rectangular armature $1\frac{7}{16}$ in. × $1\frac{3}{16}$ in. mounted above.

The local circuit of the relay has a break and make action. The moving contact or tongue is in two sections, one fixed to the upper, the other to the lower surface of the armature. The play of the tongue is between two adjustable contacts. A pin projects from the rear of each pole and penetrates a hole in the armature. The hole has a slightly greater section than the pin, so that the armature is free to move within the limits of the contact points. The clearance between the rear of the armature and the poles is regulated by two small adjusting screws fitted in the armature as near as possible to the holes previously mentioned, whilst the clearance between the front of the armature and the poles may be varied by adjusting the position of the lower contact screw. Tension, opposing the attraction of the armature and determining the normal contact pressure, may be varied by regulating the length of a spiral spring acting upon the rear of the armature. This regulation is effected by rotating the milled nut which bears upon a bracket fitted to, and projecting from, the rear upper surface of the armature, and holding the pin which carries the spring and threads into the nut.

The adjustment necessary for satisfactory operation will depend upon the requirements of the circuit in which it is fitted. The pressure between contacts (armature normal or attracted) should not be less than 10 grammes, and the clearance not less than 10 mils. The releasing current will depend (1) upon the air gap between armature and poles when the armature is attracted and (2) upon the restoring tension exerted by the spiral spring at the rear. Where the releasing current is high the adjustment should be such that the movement of the armature takes place as far as possible away from the poles—consistent, of course, with the armature moving in response to the minimum operating current, and the pressure on the normal contact not being less than 5 grammes. If the releasing current is low, greater sensitiveness may be obtained by bringing the armature nearer to the poles.

Peel Conner Single Spool Relay.—This relay is used extensively in 40-volt exchanges. Nos. 70 to 75 inclusive in the Department's stock list are typical. The core is of circular section and extends $\frac{7}{16}$ in. beyond the front spool cheek. The extension forms the pole to which the armature is attracted. At the rear, an "L" shaped piece of $\frac{1}{16}$ in. iron forms, on the one side, a mounting for the contact springs and, on the other, a hinge for the horizontal armature movement. The armature is $3\frac{3}{8}$in. long and at the front presents a curved surface to the core extension for attraction. To prevent actual magnetic contact with the core and consequent "sticking" after the operating current has ceased to flow, the curved polar surface of the armature is covered with a thin brass sheet. A light nickel silver stamping connects the front of the armature with the contact springs on the other side of the coil. The only adjustment provided for is one by means of which the air gap between the armature in its normal position and the core can be regulated. This is done by rotating a conical nut, the conical surface of which engages with the stamping previously mentioned.

Peel Conner Double Spool Relay.—This type is represented by Nos. 66 and 69 in the stock list. It has two cores and two spools, the winding on each spool being brought out to a separate pair of tabs. Both cores extend $\frac{7}{16}$ in. beyond the front spool cheek and the armature pivoted above the upper core extension is shaped so as to present maximum surface to each pole. The position of the armature, with respect to the poles (a) normally and (b) attracted, is controlled by two brass adjusting screws mounted between the upper and lower spools. The lower end of the armature carries a hinged rod by means of which the armature movement is communicated to the contact springs. The latter are mounted to the left of the lower spool on an extension of the soft-iron yoke which connects the two cores in the rear.

This relay is more sensitive than the single spool type, and is used as a junction line relay and as a pilot relay in 40-volt exchanges.

Siemens Type Relay.—Examples of this type are to be found in relays Nos. 128 and 130. The front of the core is provided with a pole piece which acts upon the vertical portion of an inverted "L" shaped armature. The inside of the bend in the armature rests upon an inverted knife edge formed at the front of a heavy yoke brought out from the rear of the core. Only the vertical portion of the armature is acted upon magnetically. The horizontal portion, normally resting upon the upper surface of the yoke, is used to lift the contact springs above. No facilities are provided for adjustment. A brass cheese-headed screw is threaded through the vertical portion of the armature with the view of preventing the armature becoming detached in transit. Where it is necessary to provide for a high releasing current following heavy saturation, the section of the vertical portion of the armature is reduced between the surface opposite the pole piece and the front of the yoke. A case of this kind is the Department's relay No. 127A.

RELAYS—FUNCTIONS.

Line Relay.—This is the title given to the relay which, on being actuated, closes the circuit of the Line or Calling Lamp. It should operate in series with the highest resistance line, which may be joined up to it at the Main Distribution Frame —taking the common battery voltage at minimum value. The armature should be released if the subscriber restores his receiver before the operator inserts the answering plug into the answering jack—this time taking the voltage of the common battery at a maximum, as the current through the insulation resistance is then a maximum. In the 22-volt system the line relay winding has a resistance of 60 ohms, and should operate with 20 m.a. and release with 2.8 m.a. after saturation with 280 m.a. The pressure between the contacts, with the operating current flowing, should not be less than 10 grammes, and the clearance between contacts when the armature is in its normal position not less than 20 mils. The standard line relay for the 22-volt system is No. 25B.

In the 40-volt system the line relay has a resistance of 200 ohms, and the operating, saturation and releasing currents are 33, 130 and 5 m.a. respectively; minimum contact pressure 15 grammes, and minimum contact clearance 10 mils. The standard for the 40 volt system is No. 70 A.

Cut-Off Relay.—The circuit of the line relay winding is normally completed through the contacts of the cut-off relay. The winding of the latter is connected between multiple and answering jack sockets and earth. The entrance of a plug into either multiple or answering jack causes a current to flow which energises the cut-off relay, its contacts opening to disconnect the line relay. The winding of the cut-off relay may be shunted by the windings of—

(1) Subscriber's Meter, 500 ohms.

(2) Registration Relay (Service Testing Circuit).

(3) Operator's Relay (Service Testing Circuit).

Shunted in this way, the relay should operate even though the C.B. voltage is a minimum, and the further shunting effect due to an engaged test in another section of the switchboard should not cause the release of its armature. Its windings should carry without damage or change in adjustment the heavy current which flows during the registration of an originated call; and when, after registration, the answering plug is withdrawn from the answering jack, disconnecting the cut off relay, its armature should be released, re-establishing the line relay circuit. The following figures meet these requirements :—

	22v. System.	40v. System.
	Relay No. 30A.	Relay No. 62A.
Resistance within 5%	30 ohms.	50 ohms.
Min. Operating Current	73 m.a.	66 m.a.
Min. Retaining Current	37 m.a.	49 m.a.
Max. Saturation Current (applied for not longer than 10 secs.)	1·25 amp.	1·04 amp
Max. Releasing Current	Disconnection	Disconnection.
Contact pressure not less than ...	28 gr.	28 gr.
Contact clearance not less than ...	10 mils.	10 mils.

Supervisory Relay.—The conductivity and insulation resistance of the supervisory relay circuit changes with each connection. It must operate reliably whether connected to a short subscriber's line or to a comparatively long junction circuit. The following operating figures apply to the standard relays cited :—

	22v. System.			40v. System.		
Rate Book No.	39*J*	1008*AB* *	127*A* *	143*A* *	144*A* *	148*A* *
Res. within 5% ...	21*w* †	50*w*	50*w*	150*w*	200*w*	200*w*
Min. Operating Current (m.a.)	17·8	15	15	15	15	15
Max. Saturation Current (m.a.)	175	31 volts	280	130	130	130
Max. Releasing Current (m.a.)	1	2·8	2·8	5·0	5·0	5·0
Contact Pressure not less than (gr.)	1	14	10	10	15	15
Clearance between Contacts not less than (mils)	10	10	10	16	16	10

* These relays are stocked and maintained only in association with retardation coils. See paragraph on "Relay and Coil."

† This resistance is that of the magnet winding 30 ohms in parallel with a non-inductive shunt of 70 ohms, the object of the latter being to reduce the impedance of the relay so that the transmission loss due to the presence of the relay in the talking circuit is a minimum.

Relay and Coil.—If the twisting or transposition of conductors in the external plant is to succeed in eliminating inductive interference, it is essential that any internal apparatus connected to it shall not alter the state of balance between the impedance from *A* conductor to earth and that from *B* conductor to earth. Whenever, therefore, a supervisory relay is connected between one of these conductors and earth a corresponding impedance, usually of relay of like design *minus* contact springs, is placed between the other conductor and earth. The relay without springs is listed in the Rate Book as a retardation coil. The relay and its coil are selected so that the value of the impedance of one shall be as close as practicable to that of the other. After selection they are combined and mounted together to form one pair, not to be separated either in the store or in maintenance.

Typical relay and coil combinations are given in the following list:—

Relay No	*Coil Ret'rd'n No*	*Relay and Coil No.*
127 A	17 A	9 AN
143 A	10 B	11 AN
144 A	10 C	12 AN
148 A	10 C	13 AN

Pilot and Night Alarm Relays.—These relays have respectively the pilot lamp and night bell in their local circuits. The winding of the pilot relay is in series with the line lamp, and that of the night alarm relay in series with the pilot lamp. In order, therefore, that the presence of the relay shall not diminish unduly the voltage available for the lamp, the resistances of the relays are as low as satisfactory operation in series with the lamp will permit. Typical of the relays used in the 22-volt system are Nos. 39C. and 1008B. Both operate with 80 m.a. and release upon disconnection after saturation with 3 amp; minimum contact pressure 10 grammes, (2 grammes for No. 39C) and clearance 10 mils. In the 40-volt system Nos. 69A and 156A are typical. They operate with 54 m.a. and release upon disconnection after saturation with 2 amp.; minimum contact pressure and clearance 10 grammes and 16 mils respectively.

Incoming Junction Line Relay.—This relay, as its title implies, is actuated by current *viâ* the external line conductors of the incoming junction circuit. In the latest circuits it takes the form of a supervisory relay balanced with a retardation coil, but many circuits are in use in which the relay has two windings, one of high and the other of low resistance.

Under ordinary working conditions the relay is first energised by current in the high resistance winding, and is kept energised when, later, the two windings are brought in parallel. In each case the current is drawn from the battery at the distant exchange, and flows *viâ* the winding of the supervisory relay at that exchange. This supervisory relay is not energised while only the high resistance winding of the incoming junction line relay is operative, but is energised when high and low resistance windings are in parallel—a condition set up when the required subscriber at the incoming end of the circuit removes his receiver.

The undermentioned relays are typical :—

Relay No.	43 A.	48 A.	66 B.
Action.	Single Make.	Single Make.	Sgl. Bk. & Mk.
Resistances of Windings (ohms)	12,000 + 27	12,000 + 27	12,000 + 50
12,000ʷ Winding.			
Operating Current ...	1·5 m.a. —	1·5 m.a. —	1·5 m.a. —
Releasing Current ...	0·5 m.a. —	0·5 m.a. —	0·3 m.a. —
Saturation Current...	2·3 m.a. —	2·3 m.a. —	1·7 m.a. —
Windings in parallel.			
Operating Current...	20 m.a.	20 m.a.	20 m.a.
Releasing Current ...	1 m.a.	1 m.a.	1 m.a.
Saturation Current...	120 m.a.	160 m.a.	30 m.a.

Tripping Relay.—The function of the tripping relay in machine ringing and keyless incoming junction circuits is to bring about automatically, and as soon as the required subscriber raises his receiver to reply, (a) the disconnection of the ringing generator from the required line, and (b) the restoration of the talking circuit.

The connection between the ringing generator and the subscriber's bell includes the winding of the tripping relay, and the design and adjustment of the relay are such that it is not energised by the current which actuates the bell, but is energised immediately the receiver is raised. A copper block fitted friction tight at the armature end of the core, or, as in the case of the 146A type, a copper shell over the whole core, assists in the adjustment against alternating current. An increase in the strength of the current in the winding induces in the single turn copper block or shell a current which, following "Lenz's" Law, is in such a direction as to tend to set up a magnetisation opposite to that being set up by the inducing current, with the result that in the operation of the relay an alternating current is at a disadvantage.

Diagram C.B. 588 F. gives the connections of a circuit by means of which the operator may test the ringing and tripping circuits. It is found that the requirements, as regards not operating with ringing current yet operating when the subscriber on a line of 600ʷ resistance removes his receiver, are adequately met if the relay works under the following direct current conditions :—

	Operating Current. m.a.	Non-Operating current. m.a.	Normal voltage of battery connected during the non-ringing interval.
Western Electric Co.'s types.			
28 A — (Outer winding)			
98 A	29	25	30
108 A	20	18	22 or 24
146 A			
A.T.M. Co.'s types.			
51 A	29	25	30
91 A	20	18	22 or 24
1012 A	29	25	22 or 24
Peel Conner Co.'s types.			
55 A			
68 A	36	25	40
74 A			

RELAYS—MISCELLANEOUS TYPES AND FUNCTIONS.

The following brief notes have reference to miscellaneous relays met with in standard 22v., 24v. and 40v. systems.

22-Volt and 24-Volt Systems.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
$0 \cdot 1^{w}$	Control Relay Lamp Flashing Circuits.	39 L (W.E. type) 40 L (A.T.M. type) 1008 H	To operate with 330 m.a. and release with 30 m.a. after saturation with 1·3 amp. 39L—Minimum contact pressure 2 grammes, clearance 10 mils. 40L—Minimum contact pressure 5 grammes, clearance 20 mils. 1008H—Minimum contact pressure 14 grammes, clearance 10 mils.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
40^w (45^w magnet winding shunted by 360^w non-inductive winding).	Ringing or Ringing-Release Relay, Keyless juncs. or Relay operating in parallel with 12 volt lamp.	22 J (W.E. type) 24 D (A.T.M type) 128 A (Siemens type) 161 F	Windings in parallel. Relay to operate with 68 m.a. and release upon disconnection after saturation with 160 m.a. (except for 161 F. for which the figures are 45 m.a. and 180 m.a.). Minimum contact pressure and clearance 20 grammes and 10 mils respectively.
$75^w + 75^w$	Sensitive Line Relay.	26 A (W.E. type) 41 B (A.T.M. type) 1010 B	Windings in series to operate with 8 m.a. and release with 0·6 m.a. after saturation with 100 m.a. Windings connected differentially and in multiple to release with 120 m.a. after saturation. 26 A—Minimum contact pressure 1 gramme, clearance 20 mils, 41 B—Minimum contact pressure 5 grammes, clearance 20 mils. 1010 B—Minimum contact pressure 14 grammes, clearance 10 mils.
80^w	Sounder Relay-Test Desk.	39 Q (W.E. type)	To operate with 18 m.a. and release with 2·8 m.a. after saturation with 350 m.a. Minimum contact pressure and clearance 2 grammes and 10 mils respectively. This relay may be connected across the common battery for long periods and should withstand the application of 28 volts for 2 hours without damage or need for readjustment.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
83^w	Sleeve Conductor Relay-Cord Circuits (Double Break and Make action)	22 A (W.E. type) 24 A (A.T.M. type) 161 C	To operate with 57 m.a. and release upon disconnection after saturation with 196 m.a. (except for 161 C for which the figures are 40 m.a and 217 m.a.). Minimum contact pressure and clearance 20 grammes and 10 mils respectively.
83^w	Sleeve Conductor Relay-Cord Circuits (Triple Break and Make action)	88 B (W.E. type) 50 A (A.T.M. type) 1011 A	To operate with 63 m.a. and release upon disconnection after saturation with 196 m.a. (except for 1011 A for which the figures are 45 m.a. and 217 m.a.). Minimum contact pressure and clearance 20 grammes and 10 mils respectively.
120^w	Retaining Relay (in series with 12-volt lamp)	39 R (W.E. type)	To operate with 10 m.a. and release with 1·3 m.a. after saturation with 120 m.a. Minimum contact pressure and clearance 2 grammes and 10 mils respectively.
140^w	Sleeve Conductor Relay, Howler Cord Circuit.	88 D (W.E. type)	To operate with 40 m.a. and release upon disconnection after saturation with 140 m.a. Minimum contact pressure and clearance 20 grammes and 10 mils respectively.
300^w	Operated in multiple with Cut-off Relay, Service Testing Circuits.	39 F (W.E. type)	To operate with 5 m.a. and release upon disconnection after saturation with 130 m.a. Minimum contact pressure, 2 grammes, clearance 10 mils.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes
350^{w}	Local Relay	22 D (W.E. type) 24 B (A.T.M. type) 161 D	To operate with 29 m.a.; not to operate with 21 m.a.; and release upon disconnection after saturation with 80 m.a. (except for 161 D for which the figures are 20, 15 and 90 m.a.). Minimum contact pressure and clearance 20 grammes and 10 mils respectively.
500^{w}	Local Relay	88 C (W.E. type)	To operate with 25 m.a. and release upon disconnection after saturation with 60 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.
500^{w} + 250^{w}	Generator Call Relay.	34 C (W.E. type) 41 F (A.T.M. type) 155 B (Siemens type)	To operate and lock when the 500^{w} winding is connected to a ringing generator at 70v. 16~ in series with a non-inductive resistance of 12,000^{w} (for 155 B, 6000 ohms and a 2 mf. condenser), the locking winding being (a) shunted by a non-inductive resistance of 240^{w}, and (b) connected to a voltage of 20 when the armature is attracted. To hold without interruption to the local circuit, when the 500^{w} winding is connected to or disconnected from a ringing generator (16~ and up to 100v.) in series with a 2 mf. condenser. Pressure and clearance between contacts to be not less than 10 grammes and 10 mils respectively.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
500^w + 500^w	Supervisory Relay, etc. Trunk Exchanges.	6 D, for metal mounting. 7 A, mounted on wooden base. (A.T.M. type)	Windings in series to operate with 4 m.a. in either direction and release upon disconnection after saturation with 25 m.a. Windings in parallel to operate with 9 m.a. in either direction and release with 3 m.a. after saturation with 40 m.a. Windings connected in series and in opposition not to operate with 100 m.a. Windings connected in parallel and in opposition not to operate with 200 m.a. Pressure and clearance between contacts not less than 4 grammes and 10 mils respectively.
500^w + 500^w	Locking Cut-off Relay.	137 A (W.E. type) 94 B (A.T.M. type) 1013 A	137 A and 94 B—Either winding to operate with a current of 36 m.a. and retain with 22 m.a. With the windings in series to release with 2·54 m.a. after saturation with 28 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively. 1013 A—Either winding to operate with a current of 30 m.a. and retain with 22 m.a. With the windings in series to release with ·2·54 m.a. after saturation with 31 m.a. Pressure and clearance as above.
1,000^w	Meter or Local Relay.	22 F (W.E. type) 24 G (A.T.M. type) 161 B	To operate with 19·6 m.a. and release upon disconnection after saturation with 39 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
2,000w	Sleeve Relay Jack-ended Junction Cord circuit.	128 B or 130 A (Siemens type)	128 B to operate with 7 m.a. and 130 A with 7·5 m.a. Both to release upon disconnection after saturation with 17 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 16 mils respectively.
1,025w	Alternating Current Relay.	100 A	Armature of comparatively great inertia and should maintain an uninterrupted local circuit when the winding is connected to a ringing generator at 70v., 16·7 frequency in series with a 2 mf. condenser and 4,500w non-inductive resistance. Pressure and clearance between contacts to be not less than 5 grammes and 10 mils respectively.

40-Volt System.

50w	Marginal Sleeve Conductor Relay	143 B, 148 B, 143 C or 148 F	To operate with 60 m.a., retain with 50 m.a., not to operate with 24 m.a., and to release upon disconnection after saturation with 300 m.a. (except 143 C —120 m.a.). Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
150^w (75^w+75^w)	Sounder Relay, Test Desk.	69D	To operate with 28·5 m.a. and release with 5 m.a. after saturation with 130 m.a. To withstand the application of a voltage of 52 for 2 hours without damage or necessity for readjustment. Pressure and clearance between contacts to be not less than 10 grammes and 10 mils respectively.
350^w	Sleeve Conductor Relay	148 D or 148 E	To operate with 12 m.a. and release upon disconnection after saturation with 105 m.a. Pressure and clearance between contacts to be not less than 10 grammes and 10 mils respectively.
400^w	Incoming Junction Sleeve Conductor Relay	65 F 73 H 64 G 72 H	To operate with 78 m.a., not to operate with 23 m.a., and to release upon disconnection after saturation with 116 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.
500^w	Local Relay.	53 A etc.	To operate with 66·6 m.a. and release upon disconnection after saturation with 104 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
500ω + 500ω	Generator Call Relay.	69 B 155 A	To operate and lock when the line winding is connected to a ringing generator at 70v. 16~ in series with a non-inductive resistance of 6,000ω and a 2 mf. condenser, the locking winding being (a) shunted by a non-inductive resistance of 450ω and (b) connected to a voltage of 36 when the armature is attracted. 155 A to hold without interruption to the local circuit when the line winding is connected intermittently to a ringing generator (16~ and up to 100v.) in series with a 2 mf. condenser. In the case of 69 B the 2 mf. condenser is replaced by a resistance of 600 ohms. Pressure and clearance between contacts to be not less than 10 grammes and 10 mils respectively
500ω + 500ω	Operates (windings in series) in parallel with Cut-off Relay, Service Testing Circuits.	69 B	Windings in series to operate with 3·3 m.a. and release upon disconnection after saturation with 48 m.a. Pressure and clearance between contacts to be not less than 5 grammes and 10 mils respectively.
1,000ω	Local Relay or Meter Relay, Service Testing Circuits.	64 D, etc.	To operate with 29 m.a., not to operate with 16 m.a. and release with 9·2 m.a. after saturation with 48 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.

Resistance of Winding.	Function of Relay.	Post Office Rate Book Description.	Notes.
2,000^w	Sleeve Conductor Relay, Jack - ended junction.	67 C etc.	To operate with 14 m.a. and release upon disconnection after saturation with 27 m.a. Pressure and clearance between contacts to be not less than 20 grammes and 10 mils respectively.
2,000^w + 400^w (400^w winding non-inductive).	Alternating Current Relay.	153 A	Armature of comparatively great inertia and should maintain an uninterrupted local circuit when the 2,000^w winding is connected to a ringing generator at 70 volts 16·7 frequency in series with a 1·5 mf. condenser and 6,000^w non-inductive resistance. Pressure and clearance between contacts to be not less than 5 grammes and 10 mils respectively.
16,000^w + 400^w	Line Relay Incoming Plug - ended junctions from Trunk Exchange.	121 B	16,000^w *winding.** To operate with 2·1 m.a. in either direction and release with 0·5 m.a. after saturation with 3·1 m.a. 16,000^w + 400^w *windings in multiple*. To operate with 22 m a. in either direction and release with 3·6 m.a. after saturation with 125 m.a. Contact pressure and clearance to be not less than 5 grammes and 10 mils respectively.

* Comprised of two portions always connected in series, 12,000^w on one spool and 4,000^w on the other.

METERS.

The meter in the manual telephone exchange is the apparatus upon which the *A* operator registers—

(a) the effective calls originated by a subscriber, or

(b) the effective or ineffective calls handled upon the operator's own position.

The apparatus is comprised of an electro-magnet and armature, the latter having attached to it a ratchet by means of which the units disc of a cyclometer is drawn round one step with each attraction. The mechanism of the cyclometer provides that the *units* disc is in gear with the *tens* disc as it passes from "9" to "0," taking the *tens* disc round one unit during this step. The *tens* disc acts similarly on the *hundreds* disc, and the *hundreds* disc similarly again on the *thousands* disc. The cyclometer therefore registers up to 9,999 attractions of the armature.

The following schedule gives the Rate Book Numbers and resistances of the meters which are standard for the two systems :—

	22v. and 24v. systems.		40v. system.	
	Rate Book No.	Resistance.	Rate Book No.	Resistance
Subscriber's Meter	1 A	$500^w + 40^w$	1 B	$500^w + 50^w$
Meter for Effective Calls. *A* position	2 B	$0{\cdot}27^w$	2 C	$0{\cdot}4^w$
Meter for Ineffective Calls. *A* position	2 A	500^w	2 A	500^w

OPERATING REQUIREMENTS.

Meter No. 1 A.—1. Reading to advance from 9,999 to 0000 and local contacts close with 40 m.a. in 500^w winding. *Units* disc when not in gear with *tens* disc not to move with 37 m.a. in 500^w winding.

2. Armature to be released under the following conditions :— 500^w winding of meter connected in parallel with 30^w cut-off relay or resistance spool winding; 30-volt battery, in series with a resistance of 85^w, connected to the 30^w and 500^w in parallel. Short circuit 85^w for one second, armature should be released when the short circuit is removed.

Meter 2 B.—As for No. 1 A, paragraph 1, except that the operating current is 1·1 amp. and non-operating current 1·0 amp.

To release upon disconnection after saturation with 2.2 amp.

Meter 2 A.—As for No. 1 A, paragraph 1.

To release upon disconnection after saturation with 78 m.a.

Meter 1 B.—3. Reading to advance from 9,999 to 0000 and local contacts close with 60 m.a. in 500^w winding. *Units* disc when not in gear with *tens* disc not to move with 30 m.a. in 500^w winding.

4. The armature should be released under the following conditions:—With the 500^w winding of the meter connected in parallel with a 50^w cut-off relay or resistance, and a voltage of 48 in series with a resistance of 205^w applied across the combination, the armature should be released after the 205^w has been short-circuited for one second.

Meter 2 C.—Resistance 0·5 ohm. Reading to advance from 9999 to 0000 when a current of 1·1 amp is passed through the winding. To release upon disconnection after saturation with 2·17 amp. To register correctly when 1·1 or 2·17 amp. are applied for half a second per second ten thousand times.

To release upon disconnection after saturation with 2.17 amp.

INDICATORS.

The characteristic features of the more important indicators in the Department's stock are given below under the respective Rate Book numbers :—

No. 1.—A non-polarised hand-restored drop indicator. The shutter (circular and of about $1\frac{3}{4}$ in. diameter) is normally held in an almost vertical plane by means of a catch at the end of a nickel silver arm extending from the armature. An operating current passing through the electro-magnet winding brings down the armature and with it the nickel silver arm and catch, releasing the shutter. Four capstan head screw adjustments are provided.—

I. To adjust the air gap between the armature in its normal position and the electro-magnet cores.

II. To adjust the position of the catch with respect to the armature.

III. To adjust the releasing tension on the armature.

IV. To adjust the air gap between the armature and electro-magnet cores, when the armature is in its attracted position.

The screw giving adjustment IV. is insulated and provided with a contact point, and as the nickel silver arm is similarly fitted immediately above this screw, a local circuit is formed when the electro-magnet is energised.

The shutter is hinged about ¼ of its diameter from the lower periphery and, when released, the latter ascends and brings a light frame connected spring into contact with an insulated contact point fitted in the pillar which supports the electro-magnet.

The electro-magnet is wound to four different resistances listed in the Rate Book as C, G, E and J, viz. :—

C.	$50^w + 50^w$ Minimum operating current for each coil	32 m.a.
G.	$500^w + 500^w$ Minimum operating current for each coil	10 m.a.
E.	100^w Minimum operating current	11·5 m.a.
J.	$1{,}000^w$ Minimum operating current	5·0 m.a.

Nos. 4 and 22.—Both these numbers represent indicators of the self-restoring type. Each indicator is comprised of two independent non-polarised electro-magnets, one fitted at the front of an iron mounting, the other at the back. Each electro-magnet is provided with an armature and an iron jacket, the latter forming both a return for the magnetic flux and a cross-talk proof cover. The electro-magnet fitted at the back of the mounting is about twice as long as the other and is designed for operation by currents from a comparatively long line, whilst the shorter electro-magnet at the front of the mounting is usually designed for operation by current in a circuit of internal wiring. The former electro-magnet is known as the *line coil* and the latter as the *restoring coil.* The armature of the *line coil* has attached to it a light brass arm extending the whole length of the two coils to a point immediately above the rather heavy armature associated with the *restoring coil.* Here it terminates in a catch suitable for engaging the top of the restoring coil armature and keeping it in an almost vertical position. When the line coil is energised, the armature of that coil is attracted, the brass arm and catch raised, and the restoring coil armature released. The last mentioned armature falls through an angle of about 20 degrees and, in so doing, throws a light aluminium shutter upwards through an angle of about 60 degrees, displaying the number of the line on the front surface of the restoring coil armature. The operator attending to the call will cause a current to pass through the restoring coil, and its armature is then attracted and held by the catch at the end of the brass arm previously referred to. At the same time the shutter is released and falls into a vertical plane.

The line and restoring coils have the various resistances indicated below :—

4 A	Line Coil 50^w + 50^w Minimum operating current windings in series	22 m.a.
	Restoring Coil 450^w Minimum operating current	12 m.a.
4 B	Line Coil 500^w + 500^w Minimum operating current windings in series	5 m.a.
	Restoring Coil 50^w Minimum operating current	60 m.a.
22 A	Line Coil 600^w Minimum operating current ...	8 m.a.
	Restoring Coil 45^w Minimum operating current	40 m.a.
22 B	Line Coil $1{,}000^w$ Minimum operating current ...	5 m.a.
	Restoring Coil 100^w Minimum operating current	35 m.a.
4 D	Line Coil $1{,}000^w$ Minimum operating current ...	5 m.a.
	Restoring Coil 450^w Minimum operating current	20 m.a.

No. 100.—This indicator is invariably used as a drop actuated by ringing current and restored by hand. The shutter is nearly a square inch in size and is hinged at the front of a vertical iron mounting $1\frac{5}{8}$ in. deep. The shutter is kept from falling forward by engaging with a detent at the end of a brass arm extending through a slot in the mounting from the armature at the back. A movement of the armature towards the core of the electro-magnet causes the detent to rise, releasing the shutter, and exposing the number of the circuit on a label previously hidden by the shutter. This label covers the counter-sunk head of an iron screw which, passing through the mounting and the iron jacket containing the electro-magnet, fixes the latter and the jacket to the rear of the mounting. The iron jacket is in the form of a tube $\frac{1}{16}$ in. thick and about $\frac{7}{8}$ in. external diameter. It is closed at the mounting end and open at the other. The surface of the open end and the polar surface of the core are in the same plane and have the armature suspended in front of them. The armature is an iron disc $\frac{3}{16}$ in. thick and of the same diameter as the jacket. The distance between the armature in its attracted position and the core can be adjusted by means of a brass screw threaded through the centre of the armature. A nut is provided on the screw so that the adjustment may be locked. The iron jacket acts (1) as a magnetic return for the flux (2) as a cross-talk proof magnetic shield.

The electro-magnet has two windings, 500^w each, brought out to four connection plates mounted on an ebonite platform underneath the iron jacket. With the windings in series the shutter will be released with 6 m.a.

Nos. 400 and 500.—Indicators of these types are known as eyeball signals. They are extensively used in private branch exchanges and small main exchanges. As electro-magnetic signals they are very efficient. Normally, the front of the indicator presents a vertical rectangular plate ($1\frac{1}{4}$ in. × $1\frac{3}{8}$ in.) of blackened brass with a circular aperture $\frac{7}{8}$ in. diameter in the centre, the surfaces seen through the aperture being also blackened. When the indicator is energised, the aperture is completely filled with a hollow spherical segment or "eyeball" of aluminium which is readily seen either in front or at a reasonable angle sideways. The electro-magnet has a single core extended from the rear on two sides by a "U" shaped piece of iron which not only acts as a magnetic return, but, projecting beyond the spool cheek and core at the front, forms a framework for the support of (a) the front rectangular plate and (b) the bearings in which the combined armature and eyeball system may rotate.

The armature is tongue shaped, the tip of the tongue being normally $\frac{1}{16}$ in. approximately from the end of the core. The eyeball is fixed to the armature as a counterweight. When an operating current flows in the winding the tongue is attracted to the core and moves in an upward direction until the wider end of the tongue is opposite the core—or through an angle of about 90 degrees. As the armature travels upwards the eyeball moves downwards, closing the aperture in the front plate, and giving the signal. The armature is a little heavier than the eyeball, so that, when current ceases to flow in the winding, the unbalance will take both armature and winding to their normal positions. A small contact arm is attached to the armature so that, when attracted, a local circuit is closed for a bell or other audible signal.

The difference between the 400 and 500 types is that the latter, being for use as a supervisory signal, is provided with a copper cover. The function of the cover is to prevent interference or cross-talk between the circuits of adjacent indicators. A conversation taking place in one circuit would vary the leakage magnetic field of the indicator associated with that circuit and, if the varying leakage field is allowed to act upon the winding of the adjacent indicator, corresponding induced electro-motive forces will be set up in the circuit in which that indicator is connected. If, however, the indicators are provided with covers, the currents induced in the covers by the varying leakage fields will, by Lenz's Law, be in such a direction as to oppose the variations and render the circuits immune from interference.

The following table gives the minimum operating currents corresponding to the resistances to which indicators of the eye-ball type are wound :—

Resistance, ohms.	Rate Book Title.	Minimum operating current, m.a.
8	400 D	75
50	400 H	24
80	400 A	20
300	400 G	12
500	400 AA & E	9
900	400 J	7·5
1,000	400 C or K	7·5
3,500	400 L	4·5
50	500 C	24
100–100	500 A	30 each winding
200–200	500 D	20 each winding
1,000–1,000	500 B	10 each winding

No. 600.—Familiarly known as the "sixpenny" indicator—arising from the fact that the Western Electric Company, by whom it was designed, gave to it the title, "Signal 6D." It is used as a negative keyboard signal on the larger C.B. private branch exchanges, and is energised by the current which serves the transmitter of the connected telephone. The indicator has a total length of about 4¼ in., but that part of it which concerns the operator is a circular window, ⅞in. in diameter, fitted into her keyboard, through which only blackened surfaces are seen normally. While the circuit with which the indicator is associated is engaged, a thin aluminium disc, with its upper surface painted red, is brought into contact with the inner surface of the window. The operator, seeing this red surface, knows that the circuit is engaged and that, when the red surface disappears, the subscriber has completed his conversation and restored his receiver to its rest.

Fitted under the keyboard in a vertical position is the iron-jacketed electro-magnet and horizontal armature which control the movement of the red disc. This control is obtained by means of a long arm or finger, fixed at its lower end to the armature, and, at its upper end, terminating in front of an aluminium lip which extends from and underneath the red disc. When the armature moves upwards under force of attraction, the finger end presses on the lip and forces the red disc into contact with the window. The normal position of the armature can be adjusted by means of the screw mounted underneath the armature.

In the older private branch exchanges the magnet winding has a resistance of 50^w, with a non-inductive resistance of 100^w in parallel with it to reduce impedance to telephonic currents. In later exchanges the magnet winding is 33^w and the reduced impedance is obtained by a condenser shunt. The indicator having the 50^w winding with 100^w non-inductive resistance in parallel is known as the 600 A, and that with the 33^w magnet winding as 600 C. A requires a current of 30 m.a. to operate and C 25 m.a.

No. 900.—The outstanding feature of this indicator is the small space it occupies in the switchboard panel—actually $\frac{9}{16}$ in. × $\frac{13}{16}$ in. The overall length is about 5 in., of which 3 in. approximately is taken up by a single core electro-magnet. At the rear end, the core is fixed to an iron extension piece which passes underneath the spool to the front to form a framework, which, (a) is tapped to receive the screws fixing the indicator in the panel, (b) forms a support for the bearings in which the combined armature and drum signal may rotate, (c) provides a magnetic return for the flux acting on the armature.

A tongue-shaped soft iron armature and an aluminium rectangular plate are joined end to end and bent around to form a drum of about $\frac{1}{4}$ in.. radius. The panel mounting to which the indicator is fixed has an aperture of approximately $\frac{5}{16}$ in. × $\frac{7}{16}$ in., and, normally, this aperture is filled with a portion of the outer drum surface, which is blackened. When the armature moves so that its wide end is near the core, the bright surface of the aluminium plate is brought into view—giving the signal. There is sufficient unbalance in the drum to restore the armature and plate to their normal positions when current ceases to flow in the electro-magnet winding.

A local circuit is provided by means of a pin, projecting from the drum, making contact with a spring when the armature completes its movement.

Wound to $1{,}000^w$ (Indicator 900A) the minimum operating current is 8 m.a.

No. 1,000.—An indicator of the drum type—similar to No. 900, but occupying frontal space of $\frac{7}{8}$ in. square, and having an overall length of $3\frac{5}{8}$ in. With a magnet winding of 75^w shunted by a non-inductive resistance of 150^w a current of 40 m.a. is required to operate it, and, wound to a resistance of $4{,}000^w$, a current of 3.5 m.a.

The indicator is used at the Main Instruments of subscribers' systems having one extension with intercommunication. It gives an engaged signal at the Main Instrument while conversation is proceeding between the extension and exchange. It is de-energised to give a negative clearing signal when the receiver at the extension point is restored.

No. 1,300.—This indicator is used as a supervisory signal with two windings 1,000 ohms each. It is the No. 1,000 "drum" type, provided with four tabs for the windings and a cross-talk proof copper sheath. The indicator operates with a current of 10 m.a. in either coil.

No. 1,400.—A compact non-polarised hand-restored drop indicator with two spools wound to 50 ohms each, connected in series. The overall dimensions are : length 2¼ in., width 1¼ in., depth 1 in. It is used on Magneto boards as a line signal, and, owing to its low impedance and the absence of a cover, has to be disconnected during conversation. The two cores are screwed to the back of an iron mounting, which forms the yoke between them. The armature is suspended in front of the poles from a brass block fitting the rear ends of the cores. A brass arm fixed to the upper portion of the armature passes through a slot in the mounting and terminates in a detent, which normally engages with the top of a shutter hinged at the front of the mounting. When the shutter falls a white surface is disclosed bearing the number of the line. At the same time, the weight of the shutter, bearing upon a light frame connected spring, forces the latter into contact with an insulated pin, providing a local circuit for bell or buzzer. No facility for adjustment is provided, the design of the indicator being such as to suit any circuit with which it may be associated.

With the windings in series a current of 25 m.a. is required to release the shutter.

No. 1,800.—In this type of indicator the armature and shutter are both at the front of the electro-magnet. The latter has a single core and is enclosed by a cross-talk proof tubular cover which, at the front, is extended and cut so as to form a suspension for the armature and a means whereby the indicator may be fixed to the frame carrying the shutter. A small arm about ½ in. long extends from, and at right angles to, the armature. This arm passes through small apertures in the frame and shutter and terminates in a detent which keeps the shutter in position. A good magnetic junction between tubular cover and core at the rear is made by means of an iron disc fitting tightly round the end of the core and closely inside the tubular cover to which it is screwed. A light spiral spring is let into the core at the armature end and, in moving under the force of attraction, the armature has to overcome the pressure of this spring.

No. 1,800 A is wound to a resistance of 1,000 ohms and requires 12 m.a. to operate.

When the shutter is released its weight acts upon a light spring fitted underneath the cover, bringing the cover and frame into connection with the insulated contact spring of the bell circuit.

The shutter is restored by hand.

No facilities for adjustment are provided.

No. 2,200.—In general design this type of indicator is similar to No. 100. The ebonite platform which, in No. 100 type, carries the coil connection tabs, is not fitted, the ends of the coils being brought out by means of tabs passing through four holes in the armature. The amount of space occupied by the indicator has thus been considerably reduced, and all new boards requiring magneto drops of this description will be fitted with the No. 2,200 type.

With the two 500 ohms coils in series the minimum operating current is 6 m.a.

The minimum operating currents of indicators not included in the foregoing are given in the following schedule :—

Rate Book Title.	Resistance. ohms.	Min. operating current. m.a.
2 A	1,000	3
1,500 A	100	22
1,600 A	1,000	9
1,900 A	500+500	12 (coils in series)
2,000 A	1,000	10
2,000 B	100	25
N.T. No. 4	50+50	25 (coils in series)
N.T. No. 10	1,000	6
N.T. No. 11	500+500	6 (coils in series)
N.T. No. 12	100	25
N.T. No 1,001	1,000	6
N.T. No. 1,002	500+500	12 (coils in series)

INDICATOR JACKS.

The most important combined jack and indicator in the Department's stock is that bearing No. 300 B, which now supersedes both Nos. 100 and 200.

In the switchboard panel the jack of the combination has above it an aperture of about $\frac{1}{16}$ in. square normally filled with the blackened surface of a hollow sphere. The hollow sphere is weighted so as to be out of balance about the axle upon which it can rotate. The tendency to rotate is prevented by the end of an arm (screwed to the armature in the rear) engaging with a lip raised from the sphere. When the armature moves under the attraction from the electro-magnet, the arm is raised and the unbalanced sphere released. By the action of gravity the sphere rotates through an angle of about 95 degrees, the blackened surface moving upwards out of the aperture, giving place to a bright red surface, which forms a signal to the operator. To reply, the operator will insert a plug into the jack below the signal. The tip of the plug, in passing between the long springs of the jack, pushes forward a lever which, in turn, throws a finger in the reverse direction, and as this finger is presented to another raised lip on the sphere when the latter is showing red through the aperture, the movement of the finger pushes the sphere back to its original position.

The framework of the indicator is of zinc-plated iron stampings $\frac{1}{16}$ in. thick, and is so designed as to provide :—

At the front—

I. A cross-talk proof tubular shield around the windings.

II. Bearings for the coloured sphere.

III. Bearings for the axle upon which the restoring lever moves.

Between front and rear.

IV. A mounting of double thickness of metal, $\frac{1}{2}$ in. × $1\frac{3}{4}$ in. approximately, for the assembly of the jack springs and coil connection tabs immediately below the tubular shield.

At the rear.

V. A support for the bracket in which the armature with its horizontal release arm is hinged.

The core is also a stamping and of the same metal. It is bent so as to form a tube and provided with two windings each of 500 ohms. Fixed friction tight to the outer surface of the tubular core at the armature end, is a circular block of iron, $\frac{3}{16}$ in. thick and diameter about $\frac{11}{16}$ in. The armature itself is a ring of zinc-plated iron $\frac{3}{32}$ in. thick and $\frac{5}{16}$ in. wide, surrounding the circular block but separated from it by an annular air space of about $\frac{1}{32}$ in. A round-headed iron screw about $2\frac{1}{2}$ in. long, passed along the inside of the core for the whole of its length and threaded into a socket in the front framework, keeps the core and windings in position. The windings are brought out to four pins upon the front spool cheek, and these pins, penetrating four holes in the front framework, press upon four springs which are connected to tabs conveniently assembled with those of the jack below. By merely withdrawing the screw, the core and windings can be removed without unhinging the armature.

The polar surface to which the armature is drawn is the annular end of the tubular shield.

A current of 8 m.a. flowing through the windings in series will release the sphere.

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