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PW—K.1

Post Office Engineering Department

TECHNICAL PAMPHLETS FOR WORKMEN

Subject
Electric Lighting

ENGINEER-IN-CHIEF'S OFFICE
1919

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[Continued on page iii of Cover.]

CORRECTION SLIP TABLE

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ELECTRIC LIGHTING

(K.1).



*The following pamphlets in this series are of
kindred interest :*

A.3. Technical Terms.

A.5. Protective Fittings.

A.6. Measuring and Testing Instruments.

ELECTRIC LIGHTING.

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ELECTRIC LIGHTING.

WIRING, MAINTENANCE AND METHODS OF ILLUMINATION.

1.—SYSTEMS OF SUPPLY.

The following systems of supply are provided by the various corporations and supply companies:—

- (a) Direct current, two wire.
- (b) Direct current, three wire.
- (c) Alternating current, single phase.
- (d) Alternating current, two phase.
- (e) Alternating current, three phase.

Where System (a) or (c) is provided, one pair of cables will be available for feeding the building.

Where System (b) or (d) is provided, two pairs of cables will be available for feeding the building.

Where System (e) is provided, three pairs of cables will be available for feeding the building.

2.—ARRANGEMENT OF MAIN CIRCUITS.

In every case where **payment for the supply** is based on the amount of current used, a **meter** will be fitted in one of each pair of main cables, and it will generally be situated between the supply authority's cut-outs and the main switch. In some few cases it will be found that a small cable is also provided, which makes a connection between the meter and the other cable.

In the former case the meter registers only the amount of current used, and it is assumed that the declared voltage of supply is, on the average, constant. In the latter case the meter also registers any variation in the voltage, but in both cases the reading on the dial is given in **units**.

One Board of Trade **unit of electricity** is the amount of electrical work represented by 1,000 watts used for one hour, and a watt is the name given to the amount of electrical power represented by a current of one ampère at a pressure of one volt; thus, assuming the voltage of supply to be 200 volts and the current used to be 5 ampères, the number of units consumed per hour will be:—

$$\frac{200 \times 5}{1000} \frac{1000}{1000} = 1 \text{ unit.}$$

Main Switches and Cut-outs.—From the meter the outgoing cable will be led into one terminal of a main switch, double pole, in cast-iron case, the cable from the supply authority's cut-out being led to the other terminal on the same end of the main switch. From each of the two terminals at the other end of the main switch a cable will be run to one terminal of a cut-out, single pole, in cast-iron case, and from the other terminal of each of these cut-outs a cable will run to one of the main bus bar connections of a board, distributing switch and fuse.

In large offices a main switchboard is provided on which the supply authority's cut-outs and meters are fitted, and to which all sub-main circuits for both power and lighting are connected through circuit breaker or switches and fuses.

In **connecting up the main switch** it is important that the incoming cables (one from the supply authority's cut-out and the other from the meter) are led to the **top of the switch**, when the switch is of the Post Office stock pattern. In stock pattern switches, the blades are operated by a handle at the right hand side of the case, and the switch should be so fitted on the wall that it is "off" when the handle is in a horizontal position at right-angles to the wall, and is put "on" when the handle is moved upwards to a vertical position, parallel to the wall.

All main switches and cut-outs are provided with a small screw and washer for connecting the case to "**earth.**"

The foregoing description of the main circuit applies to direct current, two wire, and alternating current, single phase. When the supply provided in the building is direct current, three wire, or alternating current, two phase, there will be two meters, two main switches, four cut-outs, and two main distributing switch and fuse boards, and in the case of alternating current, three phase, there will be two or three meters, three main switches, six cut-outs, and three main distributing switch and fuse boards.

It should be noted that in certain cases of **small offices**, where the supply is on systems (b), (d) or (e), the supply authority does not insist on the load being distributed between two or three pairs of cables, and in these cases only two wires are led into the building.

Service Boxes.—In the most recent installations the main switch and cut-outs are combined in one fitting called a service box and these are available in various sizes up to 50 ampères. The method of wiring is the same as for main switches and cut-outs, except that the connections between the main switch and the cut-outs is already provided in the box and the incoming cables are led to the bottom of the switch.

3.—ARRANGEMENT OF SUB-MAIN CIRCUITS.

In describing the method in which the wiring is arranged from the main distributing switch and fuse boards onwards, it is assumed that only one pair of mains is provided by the supply authority. Where more than one pair is provided, the wiring for the second or third pair is on exactly similar lines to those described hereunder, but under no circumstances will the wires or cables which are fed from one pair of mains be connected to any wire or cable which is fed from any other pair of mains. Similarly, no main distributing switch and fuse board, lamp point, wall plug or switch connected to one pair of mains, will

be fitted at a less distance than six feet from any of the fittings enumerated which is connected to any other pair of mains.

The main distributing switch and fuse board consists of a cast-iron case with glazed door, and contains two fuses and one switch for each sub-main circuit. The two fuses and the switch for each sub-main circuit are arranged in a vertical line, and the number of lines is determined by the number of distributing fuse boards required, with the addition of one spare line for extensions. The type of board has varied during the past few years, but the general principle of two bus bars, each of which is connected to one of the cables from the cut-outs, single pole in cast-iron case, and has a fuse attached for each sub-main circuit, still holds good, as does generally the arrangement of the switch at the bottom of each line of fuses.

It is important, where the supply is on the direct current, two wire or three wire system, that **the cable on which the meter is situated is connected to the bus bar to which the switch is connected** through the fuse. The run of the cables is shown in Figs. 1 and 2. Similarly, with alternating current, two or three phase system, there is sometimes a **neutral cable** which can usually be identified by the fact that two cables in the case of two phase, or three cables in the case of three phase, will be tapped from it immediately it enters the building. (See Fig. 8.) **Switches must on no account be connected to this neutral cable** which must be connected to the bus bar on which fuses only are fitted.

The arrangement of the cabling under the various systems is shown on Figs. 1, 2, 3 and 4. (See Drawing W. 4971.)

In alternating current, single phase, two wire, it is of no importance on which cable the switches are connected.

Fig. 4 shows another method in which an alternating current three phase supply is sometimes provided, two watt hour meters only being used. In this case a main circuit is taken from each pair as shown.

The **sub-main circuits** are the connections between the main distributing switch and fuse boards and the fuse boards. The latter are of a standard **capacity of five ampères per way**, and are similar in pattern to the main distributing switch and **fuse** boards, except that they are of a smaller capacity, and are not fitted with switches. One board is shown, with its bus bars connected, in Fig. 1. All boards are provided with a **small screw and washer for earthing** purposes, in the same way as the main switches and cut-outs.

There are a number of boards in Post Office premises which are fitted in polished **wood cases**. The internal arrangement of these boards is on exactly similar lines to that in iron-cased

boards so far as the electrical connections are concerned, but the method of construction differs from the latest pattern of iron-cased boards. In the case of the wood-cased board and the earlier pattern of iron-cased board, there will be found two **slate or marble bases**, but in the latest pattern of iron-cased board these bases are not fitted. The screw and washer for earthing purposes are, of course, not provided on wood-cased boards.

4.—ARRANGEMENT OF SUB-CIRCUITS.

The **sub-circuit** is all that portion of the wiring between the fuse boards and the lamps, switches, etc., and it is therefore economical to fix the **position of each fuse board** as near as possible to the centre of the area which is to be illuminated from it.

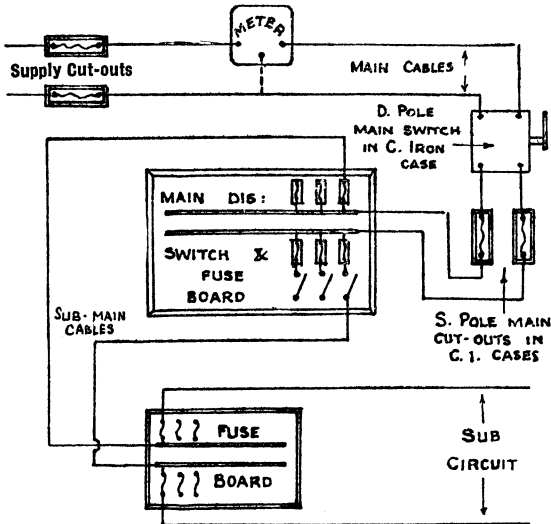


Fig. 1.

One wire from any sub-circuit is taken from one of the fuse terminals on the fuse board, and the other wire from the corresponding fuse terminal on the other side of the fuse board, as shown in Fig. 1.

The number of points on any sub-circuit is limited to a maximum of ten, and the total number of watts must not exceed 600; thus **the maximum current** is determined by dividing 600 by the voltage of supply, the result obtained being the current in amperes.

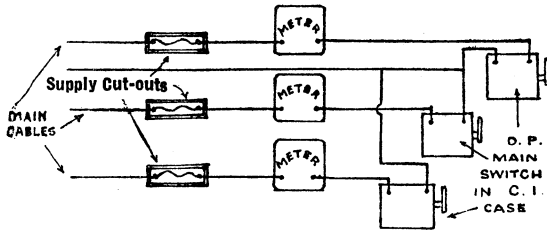


Fig. 8.

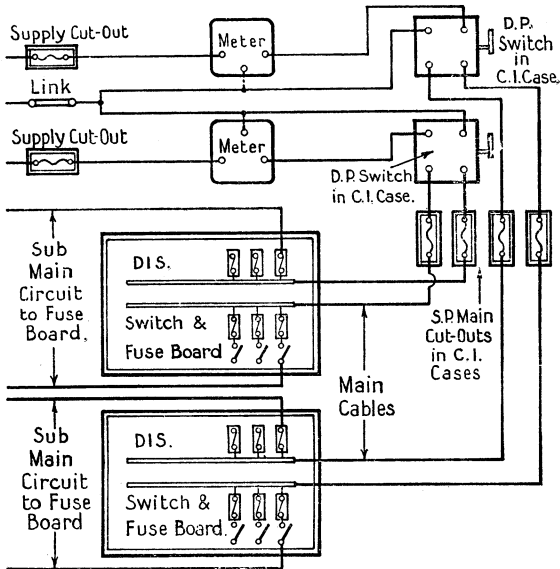


Fig. 2.

In all except the oldest installations the sub-circuit is then wired on the "looping-in" principle, in which all the connections between wires are made at the terminals of the ceiling roses and switches, thus doing away with joints in the wires, and this principle is shown in Fig. 5 which gives the wiring connections for four points in one room, two points in a second room, and a single point in, say, a corridor, all the points being separately controlled. In practice these wires are protected by conduit or casing, but in order to make the figure clear the protective covering has been omitted. The figure is also intended to show that it is not necessary for the wire which feeds the

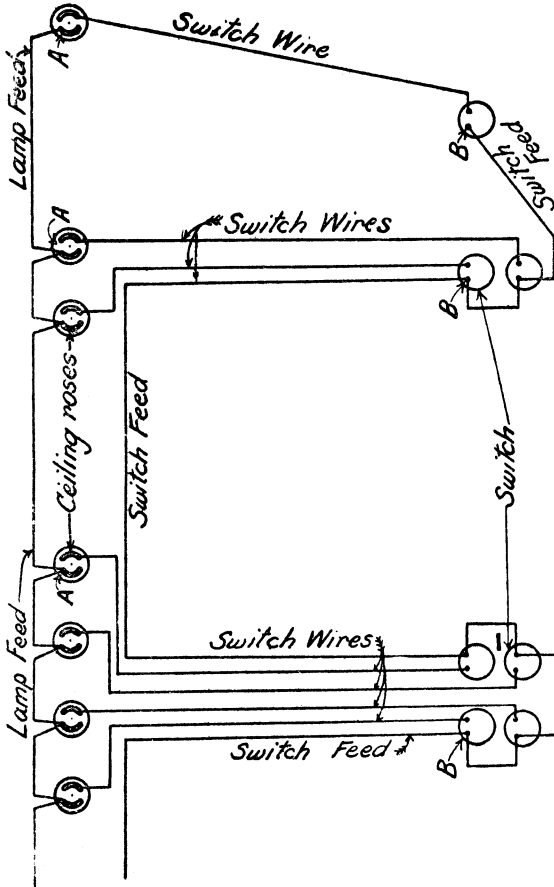
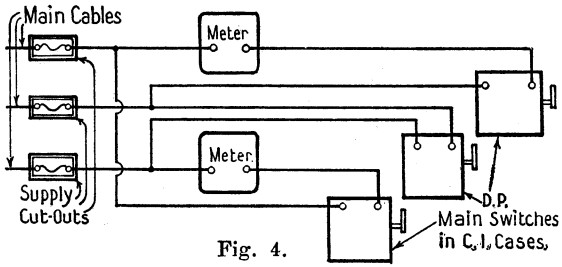


Fig. 5.

switch to be run in the same conduit or casing as that which contains the wire which feeds the lamp, and it is sometimes possible to **effect an economy in the amount of wire** used, in cases where switches are situated on opposite sides of the same wall, by means of running a short wire through the wall, protected by conduit. This arrangement also does away with the necessity for the run of conduit or casing between the ceiling rose and the switch. It will sometimes be found that the **wires from two pairs of fuse terminals** are run **in one conduit or casing**. This is done in cases where two sub-circuits are required to illuminate a certain portion of the building which is some distance from the fuse board, and an **economy in conduit or casing is effected** thereby. The two circuits are in this case kept entirely separate electrically. It will also be found, in a few cases, that **two wires are connected to each of a pair of fuse terminals**, and this occurs when an **economy in wire is effected** by looping-in at the fuse board instead of at a lamp point and switch; but the number of lamps on the two portions of the circuit is still limited to ten, and the total load to 600 watts.

It is essential that the **local switches** are connected to the same side of the supply as the switches in the main distributing switch and fuse board.

To connect up a **wall plug**, a wire from each of the connections "A" and "B" (Fig. 5) is necessary, and these wires will be run in the most convenient manner, protected by conduit or casing, to the point at which the wall plug is required. A local switch is connected in the wire which comes from the connection "B," and is situated immediately beside the wall plug. It is usual to mount the wall plug and the switch on the same box or tablet. Except for portable table standards and in telephone exchanges 3-pin wall plugs with earth connection are used.

5.—PROTECTION OF CABLES AND WIRES.

Protection is effected either by means of **enamelled steel tubing** (conduit) or **wood casing**, the former being the up-to-date method. Lead covered cables are used in battery rooms generally and in small installations only.

The conduit must be in good electrical and mechanical connection throughout the building, and in order to ensure this, it is the Post Office practice to instal **screwed conduit**, the connections at the boards being effected by nuts and back nuts. The conduit must be "**earthed**" to a water-pipe at convenient points **by means of a copper conductor of a size not less than 7/·029 cable for each 50 amps. of normal working current. No smaller conductor than 7/·029 shall be used. Wherever an open end of the conduit occurs, a bush of ebonite or hard wood will be fitted** to prevent the insulation of the cables or wires being damaged.

Where conduit is liable to **internal condensation**, it is desirable to slope it to a point for drainage. The drainage is effected by drilling a small hole on the under-side of the conduit near the end of a length, in order that the burr on the inside may be removed after drilling. **This drilling of the conduit must be done before the cables or wires are drawn in.**

In positions exposed to the weather and in lavatories, etc., **galvanised conduit** and **watertight switches** will be used. Galvanised conduit will also be used where it is concealed. If the galvanising shows signs of deterioration, the conduit should be cleaned and then painted with two coats of aluminium paint.

All **conduit will be fixed** by means of saddles or pipe-hooks at intervals not longer than three feet, and all parts of a lighting installation must be kept clear of gas and water fittings and pipes, also telegraph, telephone, bell and other wires.

Wood casing must be screwed to the surface of the walls or ceilings, and **must not be buried** in plaster or cement. It must not be fixed immediately below nor in contact with water-pipes. The **cover** must be screwed to the casing on the outer fillets.

Lead covered I.R.V. insulated cables are fixed direct to the walls and ceilings and must be supported by a sufficient number of clips to prevent sagging of the conductors. Conduit boxes are used for mounting the ceiling roses, switches, etc., and continuity between these boxes and the lead sheath is obtained by bonding nipples.

6.—SYSTEMS OF LIGHTING.

Individual lighting consists of lamps of low candle-power in opal or enamelled iron shades, and it is provided in small clerical and other offices immediately over the tables or desks, and about three feet above them. Individual lighting is also provided in some of the older sorting offices by means of brackets fixed to the sorting tables. The term "individual lighting" may, in fact, be applied to any arrangement of the lighting points, except those dealt with under general lighting, direct and indirect.

General lighting, direct, consists of a high-power lamp, or cluster of lamps, either in a large opal shade or other reflector or in a fitting with a semi-opaque globe. These fittings are suspended at standard heights which vary from 9 ft. 6 in. to 18 ft. 6 in., according to the candle-power contained in each fitting. The horizontal spacing is also dependent on the candle-power.

General lighting by enclosed diffusing fittings or by semi-indirect fittings. The standard system of lighting Instrument Rooms, Switch Rooms, Sorting Offices and Clerical Offices which exceed 200 sq. feet in area, is now by means of

totally-enclosed fittings with diffusing glass bowls. This system is employed in all new installations and replaces the former standard semi-indirect system. The totally enclosed fittings are less dependent on the quality of the decorations and are cheaper to maintain than semi-indirect fittings. The height and spacing of the fittings depends on the local conditions.

The semi-indirect fittings Nos. 3 and 3A which are fitted with large overhead reflectors will still be employed where the ceiling is not flat or is broken up by skylights or exceeds 14 feet in height.

7.—MAINTENANCE.

It is most important that all the **fittings and switchboards are kept in a clean condition**, also that all **contacts are making good connection**. To ensure this, it is necessary to examine the blades of the main switch from time to time to see if there is any discoloration from overheating. This will be done at a time when no light is required in the building, and when, therefore, the switch may be opened. If there is any discoloration, the blades will be cleaned up at the points of contact, also the corresponding surfaces of the clips into which the blades enter. **Fine glass-paper wrapped round a flat stick of wood should be used** for cleaning, and the resultant dust blown out, and the clips should then be slightly squeezed together in order that they shall make a better contact with the blades. **Care must be taken**, in giving attention to the main switch, **not to touch with the hand, or any metal tool, any of the internal parts of the switch**; the squeezing together of the clips should be done by means of a stout stick of wood, through which pressure can be applied to the outer sides of the clips.

The contacts of the main cut-outs should be examined and cleaned if necessary at the same time as attention is given to the main switch, the latter being left in the "off" position to remove any risk of shock. The type of contact between the terminals and the fuse varies with the sizes of the cut-out; in the smaller sizes it is of a pattern similar to that of the main switch, and in the larger sizes the contacts are held together by a stud and washer, but the attention required is similar to that given to the main switch—that is, the surfaces must be clean and be firmly fitting together.

With regard to the **main distributing switch and fuse boards, and the fuse boards**, here again the **type of contact** between the terminals and the fuses differs in the various makes of board, but the essential points are cleanliness and firmness of the contacts. It is desirable to have two spare fuse holders, fitted with a suitable fuse, in each board for replacement purposes.

The conduit runs and fittings should be examined from time to time to ensure that all the fixing points are holding firmly, **particular note** being made of the **firmness of the boxes or blocks** on which the switches are fitted.

The condition of the **flexible wire** immediately above the lampholders and where it enters the wall plugs should be kept under close observation, and when showing signs of wearing out, the flexible wire must be renewed in the case of pendant lights, or, usually, shortened by cutting off the faulty piece, in the case of wall plugs.

The frequency of the **cleaning of the fittings** which contain the lamps will vary in different localities, and the period between cleanings will generally be fixed locally, but it should be noted that a very thin layer of dust will considerably reduce the amount of light given, especially in the case of semi-direct lighting fittings.

8.—LOCATION AND REMOVAL OF FAULTS.

In the instructions which follow it is assumed that the **correct size of fuse wire** has been inserted in the fuse holders of the boards, distributing switch and fuse and the fuse boards. These should be as follows:—

On the fuse boards, the fuse wire fitted should be of a capacity of 50 per cent. greater than the maximum current taken by the sub-circuit, and on the main distributing switch and fuse board of a capacity 75 per cent. greater than the maximum current taken by the sub-main circuit.

The fusing current of the various fuse wires is given in the Rate Book, and when the current taken has been calculated and the percentage added, the next larger size of wire is to be used. For example:—

A sub-circuit consists of two 100-watt lamps, two 60-watt, two 25-watt and two Lamps, Glow, of 8 c.p. each. The voltage of supply is 200.

In the case of Lamps, Glow, the watts taken per c.p. may be taken as 4, thus we have—

$$\begin{array}{r}
 2 \times 100 \text{ watts} = 200 \\
 2 \times 60 \quad \text{,,} = 120 \\
 2 \times 25 \quad \text{,,} = 50 \\
 2 \times 32 \quad \text{,,} = 64 \\
 \hline
 434 \text{ watts.} \\
 \hline
 \end{array}$$

$$\frac{434 \text{ watts}}{200 \text{ volts}} = 2.17 \text{ amps., add } 50\% =$$

3.25 amps. fusing current of wire.

It will be found from the Rate Book that Wire, Fuse, Tin No. 22, is rated at 3.85 amps., and this wire should be used as it is the next larger. No smaller size of fuse wire than No. 24 tin need, however, be used in any of the Department's standard 5 amps. per way fuse boards.

One lamp fails.—Probably the lamp has burnt out. Substitute it by another which is known to be in good order. If this lamp fails to light, remove the lamp, and after switching off at the local switch, **examine the lamp holder** to see that the two plungers therein are working freely and are of equal length, also see that they are in approximately the position shown in Fig. 6, the essential point being the relative positions of the plungers and the bayonet slots.

If these points are satisfactory, replace the lamp and remove the cover from the local switch; put the switch in the "on" position and make certain that the **blades are making contact**.

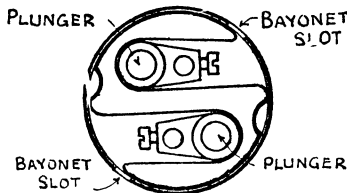


Fig. 6.

Another fault which sometimes develops at a local switch is the **working loose of the screw which clamps the wire** in the socket. This fault can be located by pressing the wire against the side of the socket. It sometimes happens that a wire has been cut too short behind the switch, and in this case it will be liable to slip back if the clamping screw works loose. This fault can be seen on removing the cover of the switch and it is remedied by dismantling the switch and jointing a short piece of bare wire on to the short end. The joint should be soldered as detailed on page 19 and the switch replaced. In making these investigations the **use of a screwdriver is to be avoided** and a piece of wood should be used as when dealing with main switches in cast iron case.

If all the above points are in order, the failure will probably be found either in the flexible wire itself or in its connection to the lamp holder, or, less frequently, in the ceiling rose. Put the local switch in the "off" position, remove lamp and shade and take the lamp holder to pieces. **Note that the wires of the flexible are firmly clamped in the sockets**, and if all is in order, reassemble the lamp holder. Examine the flexible throughout its entire length, and if in order, remove the ceiling

rose cover and see that both the flexible and the wire connections are good. If no fault is apparent it will now be necessary to prove that the circuit is in order between the fuse board and the ceiling rose, and to do this a lamp holder is wired up to one end of a short length of flexible wire and the insulation removed from the other end, exposing the two bunches of wires. The local switch is put in the "on" position, a sound lamp put in the holder and each bunch of wires held in contact with the small brass plates in the ceiling rose, one bunch being held to one plate and the other bunch to the other plate. If the lamp fails to light, there is a broken wire or other fault further back on the circuit.

A group of lamps (10 or less in number) fails.—The fuse board from which the lamps are fed can be located by tracing the conduit or casing back to the board. This may show that one of the fuses in this fuse board has blown. Sometimes both fuses will be found to have blown. If **the fuse wire has completely disappeared**, a short circuit is indicated, but if **it has only melted**, and short ends of fuse wires remain in the fuse holder, an overload is indicated.

Assuming the evidence indicates a **short circuit**, put all the local switches which control the affected lights in the "off" position, rewire the fuse holders (or substitute by the spare holders) and replace them in position on the board. Unless the design of the fuse holders is such that **the hand is completely protected from being burnt** by the fuse if it should blow directly it is replaced, it is necessary to **hold the fuse holder in a dry cloth** when replacing same. Should the fuse blow directly the fuse holder is placed in position on the board, **a fault behind the board or in the conduit is indicated.**

If the fuse holds, however, it is necessary to put the local switches in the "on" position, one at a time, when it will probably be found that the fuse will again blow when a certain switch is put "on." The fault will usually be found between the ceiling rose and the lamp of the point which is controlled by the last switch which was put on, and may be found by dismantling the holder and the flexible wire. The point of failure will be evident by signs of burning or fusion of the metal parts concerned.

If the fault is not located in the holder or on the cap of the lamp, or in the flexible, the ceiling rose should be inspected, and if the last named is found to be in good order the matter should be reported.

It will sometimes happen that **a short circuit will burn itself out** at the same time as the fuse is blown. In this case, everything will appear to be in order when the fuse holders are

replaced and the local switches put "on," but an early opportunity should be taken to examine thoroughly all the lamp holders, etc., on the faulty circuit until the cause of the failure is located.

If the fuse has only melted, either an **overload or a loose connection** at the fuse wire terminals (or the fuse clips), which has caused overheating, is indicated.

Provided there has been no alteration in the lamps on the circuit concerned, an **overload is usually due to leakage**, and the cause of this is frequently apparent by evidence of **dampness on the wall or ceiling**. If there is no evidence of dampness, it is necessary to trace the fault, and the following procedure should be adopted.

Remove both fuses which control the faulty circuit and connect one of the circuit terminals (or fuse clips) on the fuse board (the other connection of the fuse being termed the bus bar terminal or clip) to the "line" terminal on a Megger. The "earth" terminal is connected to the nearest water pipe. Then put all the local switches on the faulty circuit in the "off" position and remove all the lamps which they control. Then turn the handle of the Megger and note the reading, and if this is three megohms or over, the wire attached to the "line" terminal should be transferred to the other circuit terminal and a reading taken, and for the sake of example, a very low or zero reading is noted.

It is now necessary to determine whether the Megger is connected up to the ceiling rose wire or the switch wire, as there may have been a departure from the standard practice of connecting the ceiling rose wire to the upper side of the fuse board and the switch wire to the lower side. This point may be verified by means of a **bell and battery**, as follows:—

Disconnect the Megger and test for continuity between the circuit terminal and the nearest switch. Both terminals of the switch should be tested. If the bell rings, the leakage is on one of the switches, or on the wiring between the fuse board and one of the switches, but if the bell does not ring, the leakage is on the ceiling rose wiring. For example, the bell rings. The bell testing wires are removed and the Megger is again connected up to the terminal which was tested in the first instance (the opposite terminal to that on which the low reading on the Megger was obtained). Then insert a lamp in one of the lamp holders (making sure that the lamp is in good order), and note the reading on operating the Megger. If the reading obtained is 3 megohms or over, insert the lamp in a second lamp holder, then in a third, etc., making a test on the Megger between each and it will eventually be found that the insertion of the lamp in a certain lamp holder will give the very low reading on the Megger.

The fault will probably then be located on the switch which controls the point on which the lamp was last inserted, and this switch should be removed and examined. If no fault is found in the switch or in the box or block on which it is mounted, the trouble is in the wiring.

A fault at a ceiling rose may be traced in an exactly similar manner with the "line" terminal of the Megger connected to the other circuit terminal, and by putting the local switches "on" one at a time, all the lamps being removed, and noting the reading on the Megger after each switch is put "on."

In the event of **the preliminary Megger tests** to "earth" both **proving satisfactory**, the "line" connection to the Megger should be left on one circuit terminal, and the "earth" connection taken from the water pipe and connected to the opposite circuit terminal, and the Megger operated. The reading now obtained should be three megohms or over (the lamps being removed and the local switches in the "off" position), and the fault will probably be found at one of the ceiling roses or lamp holders, and the identity of the faulty rose or holder may be traced by putting on the switches one at a time, and making a test with the Megger after putting on each switch. The holder and the rose which are controlled by the switch which gives the low reading on the Megger should be dismantled and cleaned and carefully reconnected.

In all cases, the condition of the wires where they come out of the conduit at the ceiling rose, switch or fuse board should be carefully examined to see if the insulation is damaged.

Failure of one or both of a pair of fuses on a main distributing switch and fuse board.—This is probably caused by a fault on the fuse board which is connected to the fuses which have failed, and this may sometimes be seen and cleared on the later pattern boards if the fuse holders are removed. A fault of this nature usually requires expert attention. Similarly, **the failure of the main fuses in the iron-cased cut-outs** points to a failure on the relative main distributing switch and fuse board.

Where the fuses in cut-outs in cast iron boxes are of the cartridge pattern, spare fuses should always be available and no other pattern or size is to be fitted. In cases where a porcelain fuse carrier is fitted, a supply of the correct size of fuse wire should be available.

To test the whole of the installation.—This can be done only when no lights are required in the building. Put all local switches, also the main switch in cast iron case, in the "off" position, the switches in the main distributing switch and fuse board being left "on." Open the main cut-outs and remove the cartridge fuses. The insulation resistance is tested by a Megger with the "earth" terminal connected to a water pipe

and the "line" terminal connected to that terminal of one of the main cut-outs to which the main distributing switch and fuse board is connected. **The reading obtained in megohms should not be less than 30 divided by the number of points.**

The minimum insulation resistance permissible is that giving a leakage current $\frac{1}{10,000}$ th part of the maximum circuit current,

i.e. minimum insulation resistance = $\left\{ \begin{array}{l} \text{Circuit voltage} \times 10,000 \\ \text{Maximum circuit current.} \end{array} \right.$

If the **insulation resistance** is found to be **lower than the figure stated in the preceding paragraph**, it will usually be found that **one circuit is faulty**. To trace this circuit the Megger is still connected up to the terminal of the main cut-out which gives the low reading, all the local switches on the circuits which are fed from the cut-out under test are put in the "off" position, and all the fuses on the relative main distributing switch and fuse board are removed, and a reading is then taken on the Megger. This should be fairly high, say, five megohms or over, and if so, the fuse holders will be put in, one at a time, and a reading taken on the Megger after each fuse holder is put in. It will be found that putting in a certain fuse holder in the lower half of the board if the cut-out under test is connected in a meter main, but in the upper half of the board if not, lowers the Megger reading to approximately the same figure as that originally obtained, and it is then necessary to locate the fuse board which is controlled by this fuse holder.

When this board has been located, by following the conduit or casing, the Megger will be disconnected from the main cut-out and the "earth," and connected up to the board now being dealt with, another suitable "earth" being found, and the "line" terminal being connected to one of the bus bars. Another reading will be taken on the Megger to determine on which side of the fuse board the fault is situated, and it may be found, for example, that the reading obtained on one bus bar is satisfactory, say, one megohm or over, but that the reading on the other bus bar is low.

Leave the Megger connected to the latter bus bar and remove all the fuse holders which are fitted on it, and take another reading on the Megger. This should be satisfactory, say 5 megohms or over, and if a reading of this order is obtained, it will indicate that **the board itself is satisfactory**. Then proceed to take a reading after placing a fuse holder into each circuit. One of these readings will be found to be much lower than the others. **The faulty circuit has now been located**, and it must then be determined whether the lamp wire or the switch wire is concerned by means of the bell and battery test already referred to.

For example, if this test shows that the lamp wire is faulty, the lamps should be removed and a further test taken on the Megger. If this brings the Megger reading up to a satisfactory value, say 3 megohms, it follows that the fault lies between one of the lamps and the switch which controls it. Transfer the "line" wire of the Megger to the other bus bar and make a test on the Megger after putting "on" each of the local switches on the relative sub-circuit. The reading will be found to fall to a low value after putting "on" one of these switches, and it is then known that **the fault lies between this switch and the ceiling rose which it controls** and the conduit or casing should be carefully examined between these points.

If no fault is apparent from an external examination, the switch and ceiling rose (or other fitting) should be removed and the condition of the wires behind them examined, and if this appears to be in good order, it will be necessary to renew the wire between the two points.

If the bell and battery test shows that the switch wire is affected, the conduit or casing should be followed to determine which local switches are connected to the circuit under test, and for the purpose of this example, the switch which appears to be nearest the fuse board shall be called No. 1, the next No. 2, and so on, the most remote switch being called No. 7. Remove local switch No. 4 or 5, and separate the wires from each other. (There will probably be three wires, two in one terminal of the switch and one in the other, and **it should be carefully noted how they are coupled together** so that no mistake is made when replacing the switch.) Take a reading on the Megger, and if the reading is still low, **the fault lies between the removed switch and the fuse board**, but if the reading is high **the fault lies between the removed switch and the end of the sub-circuit**. In this manner a faulty switch can be identified, and should be dealt with in the same manner as a fault on the lamp wire.

Whether the circuits are found to be satisfactory or not, a final test should be made on the Main Switch in Cast Iron Case, as these switches are frequently fitted in damp situations. To make this test, **be quite sure that the Main Switch is in the "off" position**, then connect the "line" terminal of the Megger to the other terminal or clip of each main cut-out, the "earth" terminal of the Megger being connected to the original water pipe, and take a reading in each case. This reading should be at least 5 megohms.

The foregoing particulars are intended to facilitate the tracing of a fault of which there is no external indication, but **it will most frequently be found that there will be evidence of damp wherever a low installation test is obtained**, and thus no tracing of the fault is required. External circuits, also

circuits in damp situations, are likely to cause low insulation tests, and these causes should always be investigated before the methods previously described are adopted.

Joints should seldom be necessary, but where they are unavoidable they will be thoroughly cleaned and soldered, resin only being used as a flux, and after soldering they will be made smooth and free from points. Each joint will be thoroughly rubbed over with india rubber solution, after which four layers of rubber strip will be tightly wrapped round it in alternate directions. India rubber solution will again be rubbed over, and then two layers of waterproof tape will be wrapped round, the finished joint being finally covered with waterproof varnish. It is important that the layers of rubber strip and waterproof tape are wrapped round the ends of the original insulation for at least half an inch back from the point at which it is cut away. Where conduit is used, **joints must be made at a joint box, and must not, under any circumstances, be drawn into the conduit.**

9.—GENERAL NOTES.

The lamps originally fitted are normally of the correct candle power, and **substitution of, or renewal by, a lamp of a different candle-power is not permitted.**

Lamps for renewals must be of the wattage shown on the Lamp Schedules which are supplied to the Postmaster or other Officer in charge of the building in accordance with Eng. Regulation A3/85.

Where the lighting is on the individual lighting system, **a light** which is not in the most convenient position for the officer who uses it **should not be pulled to one side by a piece of string**, but a ceiling hook should be fixed in the ceiling directly above the position in which the lamp is required, and the flexible wire passed over the insulator. If this alteration brings the light too high, a new flexible wire will be fitted.

No **alteration in the position**, either horizontally or vertically, **of any fitting in a general lighting system is permitted.**

The metal of all counter standards or other fittings in public offices which is within reach of members of the public should be efficiently "earthed."

Do not remove a lamp from, or place a lamp in, a lamp holder without previously putting the local switch in the "off" position.

After connecting a flexible wire to a ceiling rose, a **knot** should be tied **in the flexible wire** as close to the ceiling rose as possible. This knot will come inside the cover of the rose when

it is screwed on, and thus the weight of the shade, etc., will be taken by the cover instead of by the small screws in the plates of the rose.

When fitting a shade on to a lamp holder, do not screw up the shade ring too tightly. Some lamps give off a fair amount of heat, and if the shade is firmly clamped between the shade ring and the assembling ring there will be no allowance for the unequal expansion of the brass and the glass. The shade ring should be screwed up until it holds the shade firmly, and then unscrewed about half a turn.

The meter and the main cut-outs provided by the supply authority **must not be interfered with under any circumstances, nor must the seals or sealing wires be disturbed in any way.**

The **shades** of all electric lighting fittings **will be washed periodically.** When they are washed, the lamp and shade will be removed from the lamp holder, but the shade may be dusted while in position.

Electric light fittings for use in Public Offices are usually of Rate Book patterns subject to the approval of H.M. Office of Works where concerned.

===== LIST OF =====
Technical Pamphlets for Workmen

(Continued)

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19. Cord Repairs.
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21. Call Offices.
22. Units, Amplifying. (*Not on Sale.*)

GROUP E.

1. Automatic Telephony: Step by Step Systems.
2. Automatic Telephony: Coded Call Indicator (C.C.I.) Working.
3. Automatic Telephony: Keysending "B" positions.

GROUP F.

1. Subscribers' Apparatus. Common Battery System.
2. Subscribers' Apparatus, C.B.S. Part I—C.B.S. No. 1 System.
3. Subscribers' Apparatus. Magneto.
4. Private Branch Exchanges—Common Battery System.
5. Private Branch Exchange—C.B. Multiple No. 9.
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7. House Telephone Systems.
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GROUP G.

1. Maintenance of Secondary Cells.
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3. Maintenance of Power Plant for Telegraph and Telephone Purposes.
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GROUP H.

1. Open Line Construction, Part I.
2. Open Line Construction, Part II.
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GROUP I.

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GROUP K.

1. Electric Lighting.
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