Fig. 5.2(a) *Typical wood screws* SPINAWAY CABLES

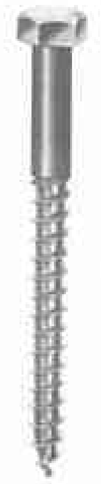


Fig. 5.2(b) *A coach screw* SPINAWAY CABLES

Fig. 5.2(c) *Some self-tapping screws* SPINAWAY CABLES

Fig. 5.2(d) *A 'self-drilling' self-tapping screw, commonly known as a 'TEK screw'* SPINAWAY CABLES

Bolts may be used to fix various electrical accessories to timber, provided that access is available to the bolt head and nut.

Fixing to concrete and masonry

The specialised range of fixing accessories suitable for concrete, brick, stone and other similar materials is impressive, some being patented or of registered design. The simplest and oldest type consists of a wooden plug, preferably cedar, driven into a neat hole in the material. A wood screw is then screwed into the plug, causing it to expand and grip firmly against the hole sides. The first improvement on this method was a cylindrical plug that was manufactured in standard sizes from highly compressed natural fibrous material and was more convenient and durable than the wooden version.

The fibre plug was eventually superseded by plastic or nylon plugs that utilise the same principle and are suitable for use in concrete, natural stone, solid masonry and brickwork. Plastic plugs are often colour coded to indicate length and size.

Figure 5.3 illustrates a plastic plug (made by Expandite Australia) in position and some other plugs (made by Hilti), including an impact anchor.

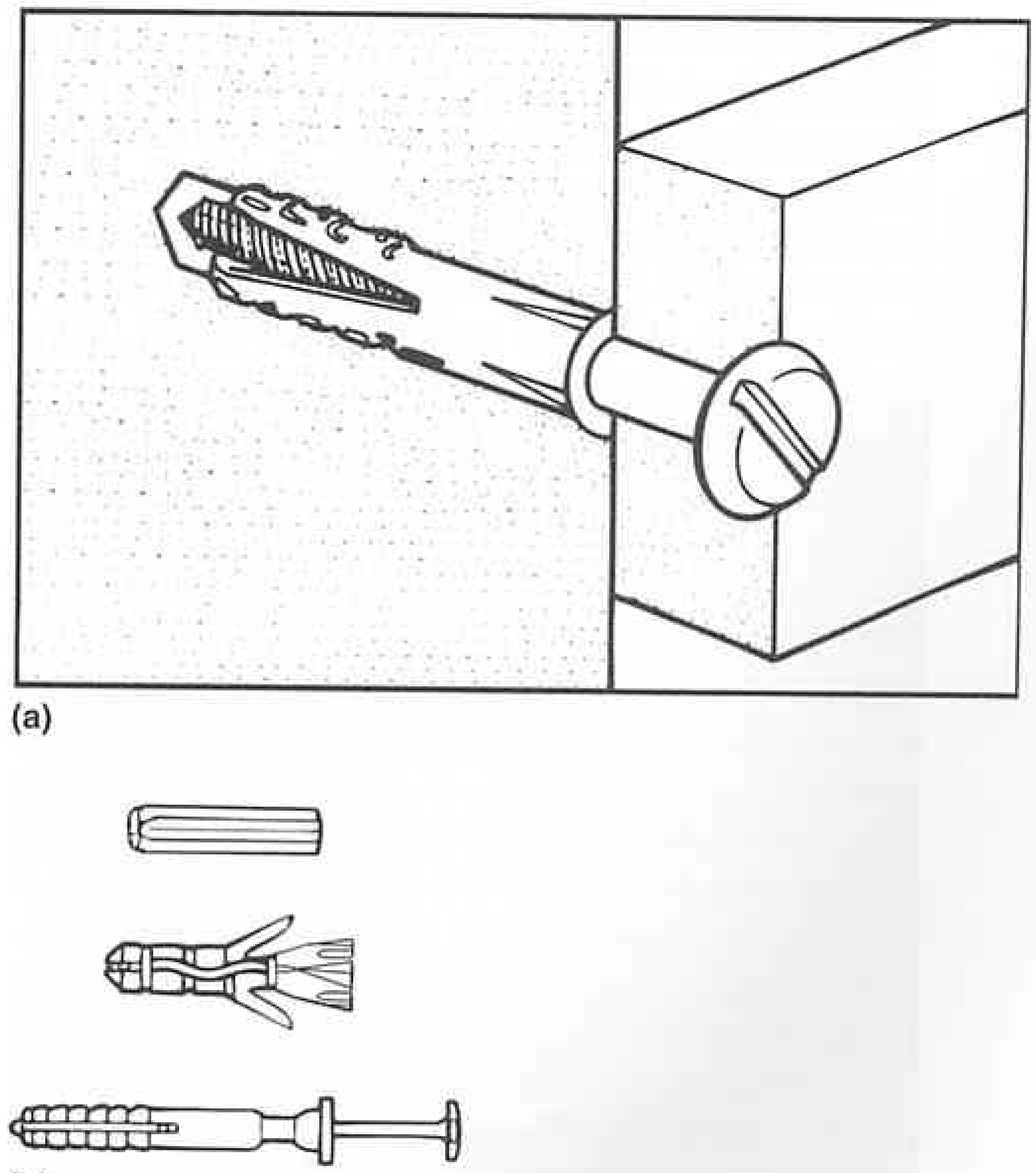


Fig. 5.3 *Plastic plugs* **(a)** in position; **(b)** some common types
HILTI (AUSTRALIA)

Fig. 5.9 *A deep-type round PVC junction box* GERARD INDUSTRIES

Figure 5.11(b) shows a steel mounting bracket, primarily intended for use in timber-framed construction, which is usually fixed to the studs and sometimes called a 'stud bracket'. It is manufactured in the form shown, where fixing is to the side of the stud, or as a flat plate, for fixing to the front of the stud. There are several sizes to suit different accessories.

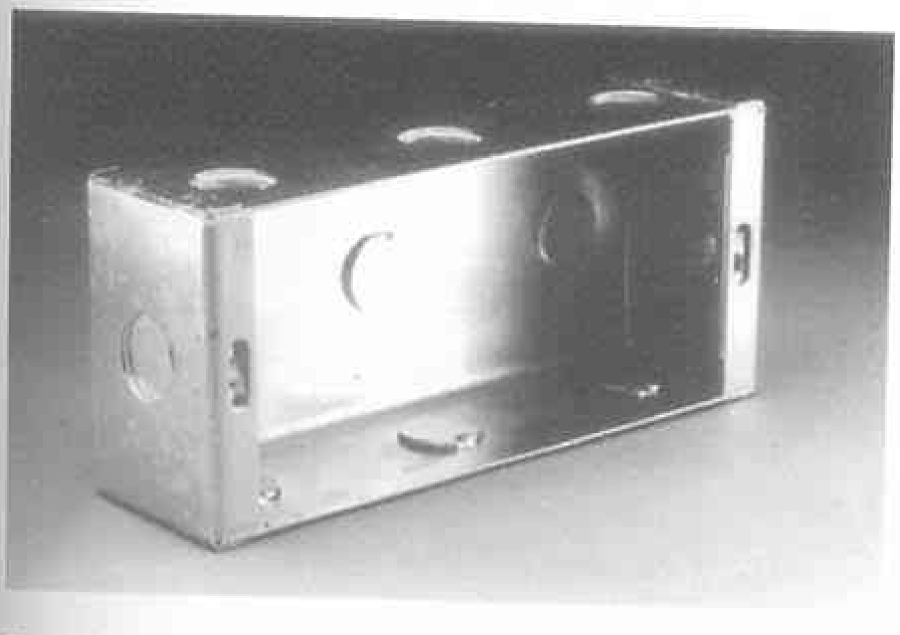


Fig. 5.10(a) *Wall box* HPM INDUSTRIES

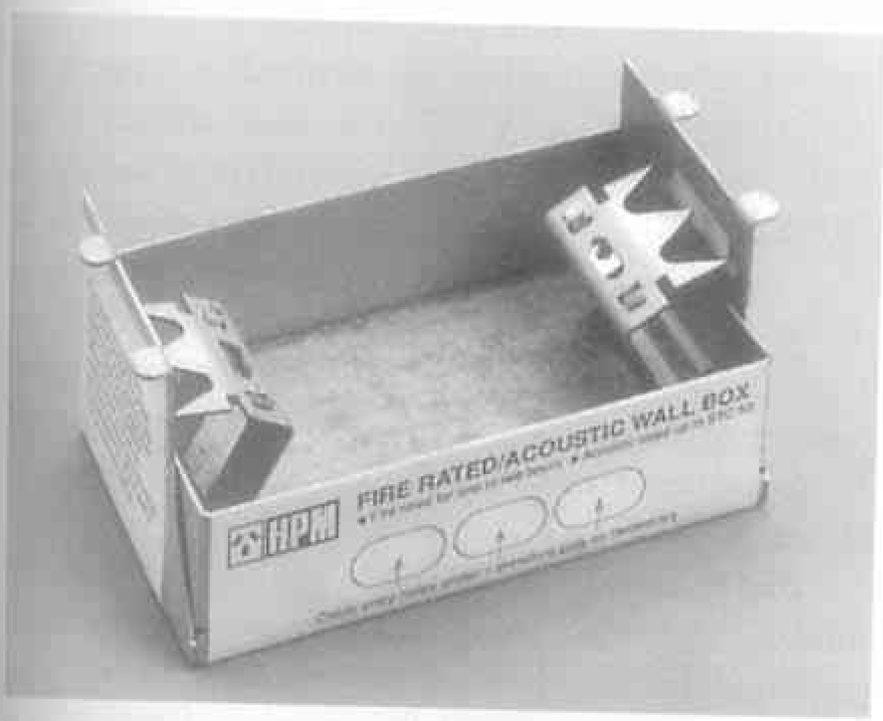


Fig. 5.10(b) *Fire-rated and acoustic wall box* HPM INDUSTRIES

Fig. 5.10(c) *PVC wall box* HPM INDUSTRIES

For additions to an existing wiring installation, a most convenient mounting bracket type is shown in Figure 5.12. It is designed for fixing to thin walls such as those composed of fibrous cement, plaster or hardboard sheets, where it minimises wall damage and saves labour. It is made in several sizes to fit different accessories and different wall thicknesses.

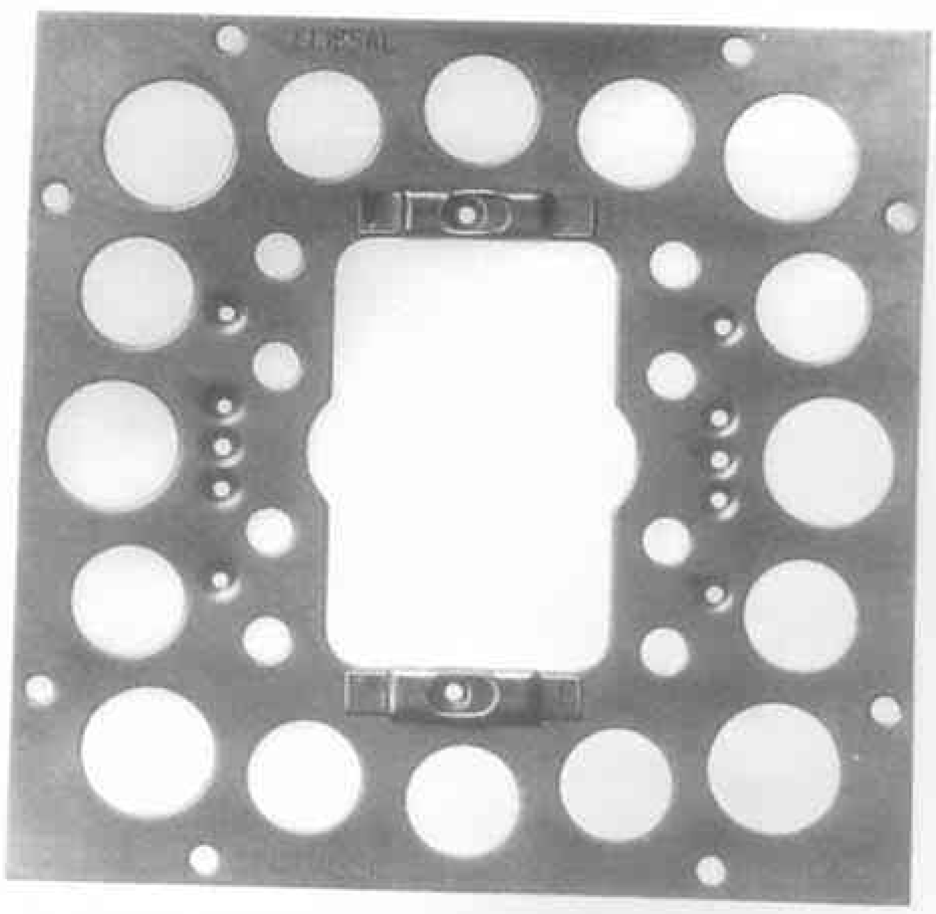


Fig. 5.11(a) *Plaster-mounting metal bracket* GERARD INDUSTRIES

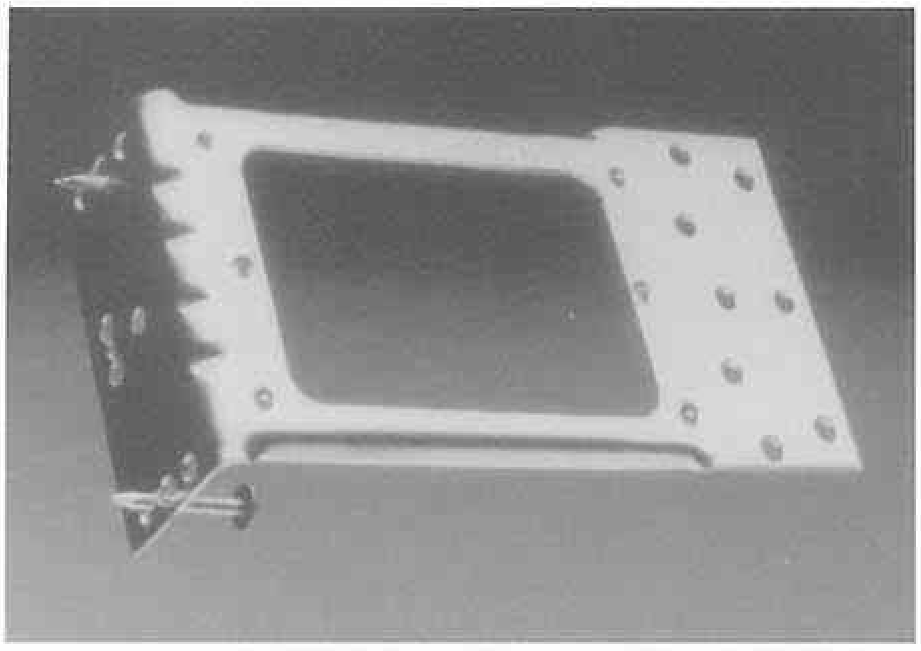


Fig. 5.11(b) *One-gang standard-pattern horizontal metal mounting bracket, also available in a vertical mounting pattern*
GERARD INDUSTRIES

Fig. 5.12 *Plaster or wallboard metal mounting bracket*
HPM INDUSTRIES

Accessories for surface mounting

For the surface mounting of accessories with exposed wiring, or where necessary with concealed wiring, plastic surface-mounting blocks such as that illustrated in Figure 5.13 may be used. Direct mounting of an accessory on a surface-type junction box is also possible. The mounting of accessories on wooden blocks as seen in old installations is generally redundant but is sometimes used in the restoration of older buildings and houses.

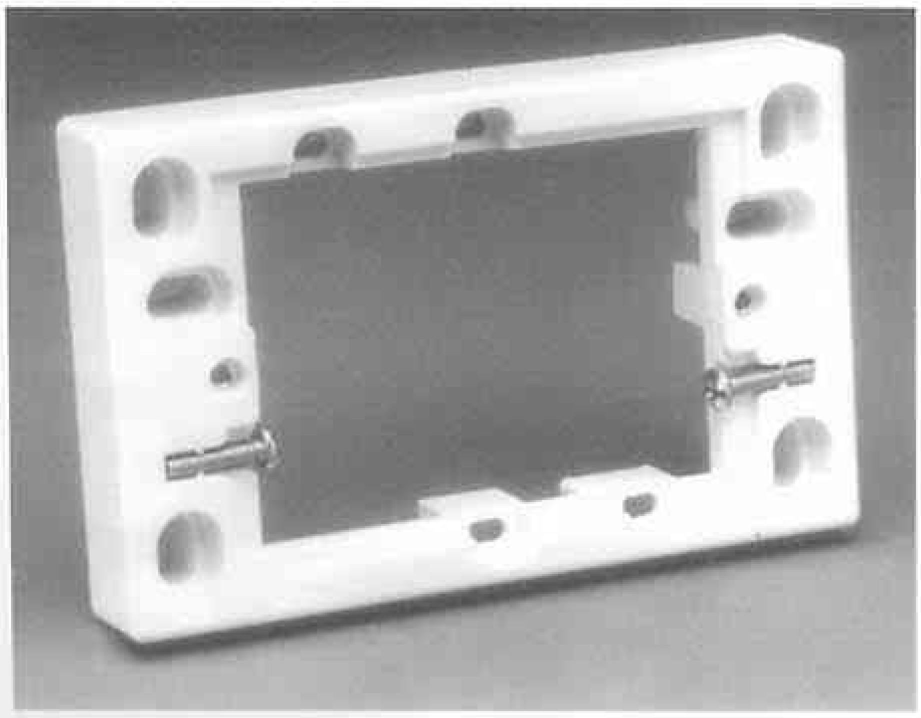


Fig. 5.13 *Single-gang plastic mounting block, available in depths of 13 mm, 18 mm and 37 mm* HPM INDUSTRIES

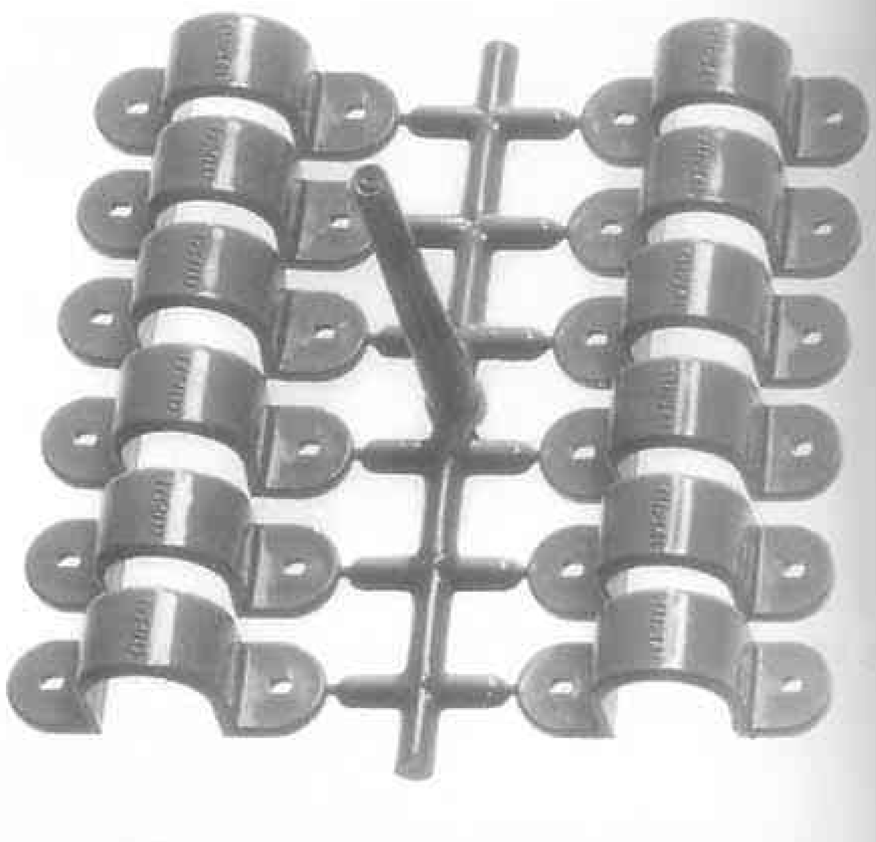


Fig. 5.14(a) *PVC saddles as they emerge from the mould*
GERARD INDUSTRIES

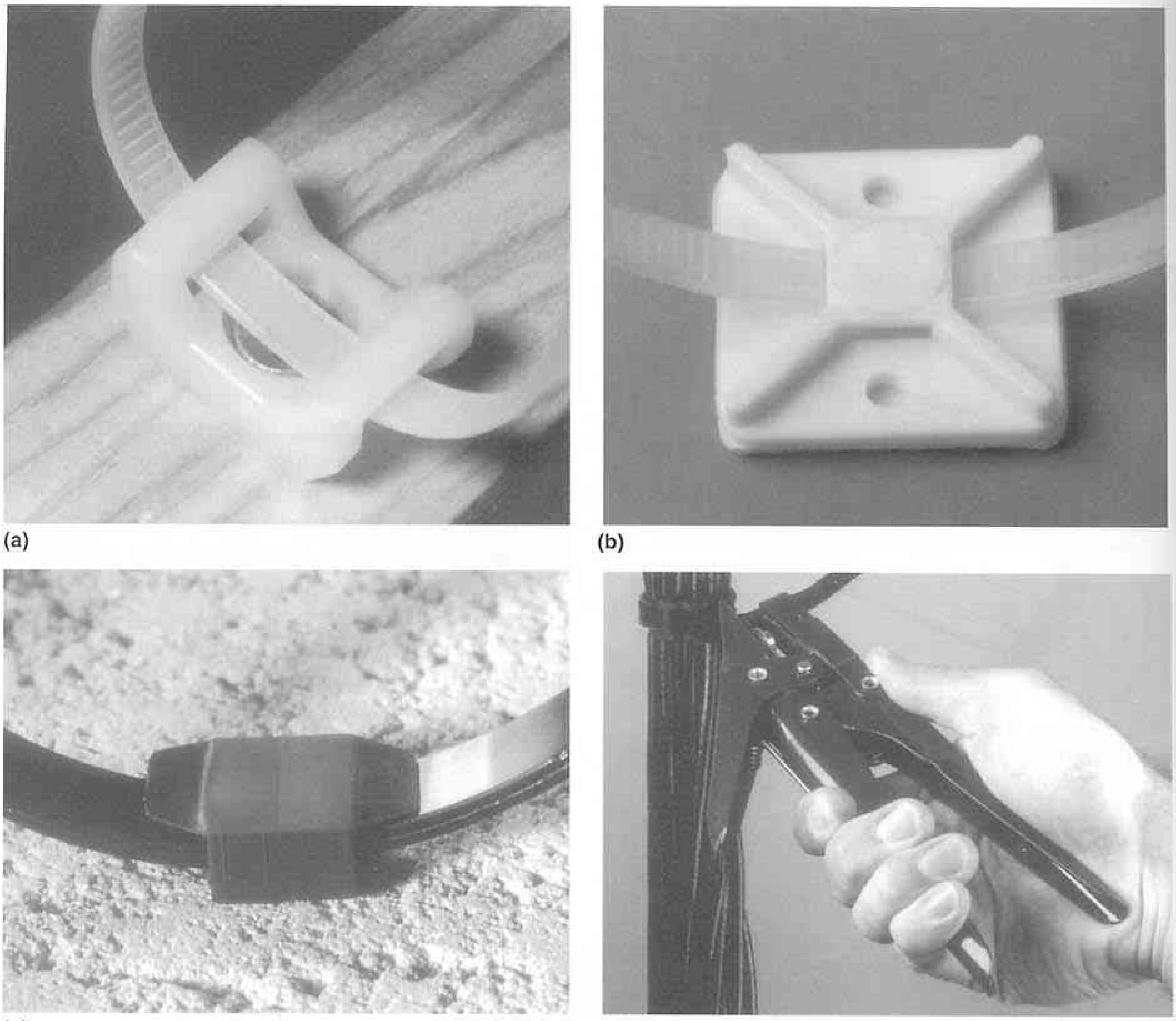
Fig. 5.14(b) *Steel conduit saddle and half-saddle* GERARD INDUSTRIES

Fig. 5.14(c) *A PVC saddle spacer* GERARD INDUSTRIES

Accessories used for the support of conduit, both steel and PVC, vary with the method of support, the most common being the conduit saddle and half-saddle or clip, which are shown in Figures 5.14(a) and (b).

Where specifications require the conduit to be spaced away from the supporting wall or structure, some type of saddle spacer is used (see Figs 5.14(c) and 5.16). There are several forms of saddle clip for attaching the conduit to structural steel beams, some being patented or of registered design, such as the one illustrated in Figure 5.15.

Support systems for PVC or steel conduits are similar, and the same support systems are often employed for sheathed cables, especially in the larger sizes. The support system illustrated in Figure 5.16 is suitable for mounting conduits that are to be run



(a) (b) (c) (d)

Fig. 5.17 *Cable ties and mounts* GERARD INDUSTRIES

TPS (and conduit) wiring may be supported by a catenary system either inside or outside buildings. Refer to Figure 7.9 in Chapter 7 and to *Clause 3.15*, and note here that all the associated hardware, such as turnbuckles and support clips, is classed as electrical accessories.

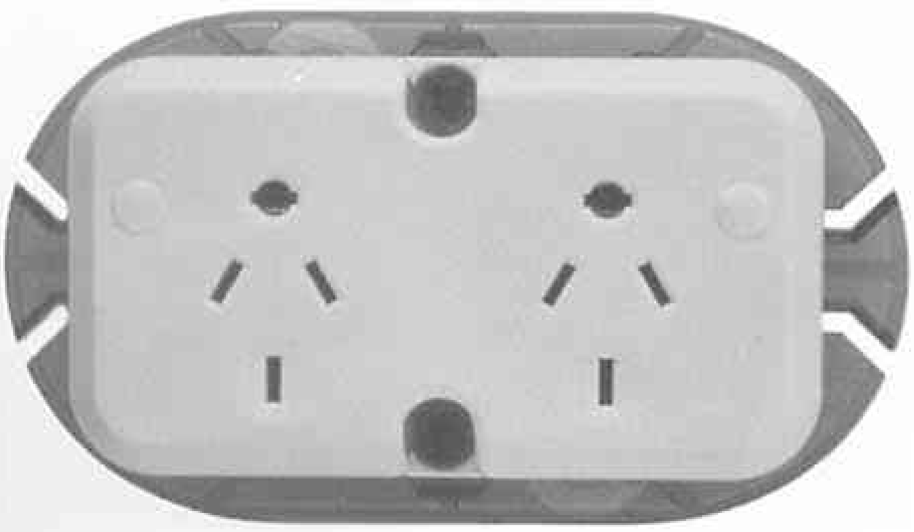


Fig. 5.18 *Twin 4-pin surface-mounted socket outlet with two actives 250/440 V 10 A—an accessory used in loom-wiring systems* GERARD INDUSTRIES

Aerial systems also have their own peculiar accessories for support and fixing, such as pin-, shackle- and string-type insulators, together with attendant hardware, and the same remarks apply to open wiring on cleats or insulators.

5.3 Accessories for conduit and TPS systems

This section describes some typical accessories used in the installation of conduit and TPS wiring systems.

Conduit accessories of similar form and appearance are made for both steel and PVC conduit systems. Included in the accessories are couplings, unions, reducers of many types, junction boxes, bends (see Fig. 5.19), elbows and tees (both solid and inspection types), accessories for termination at switchboards, and appliances or accessories used to effect a change in the wiring

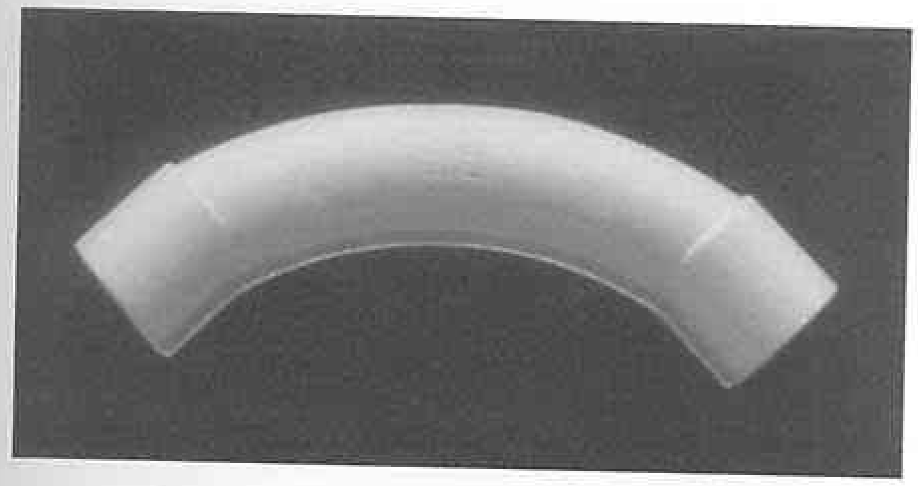


Fig. 5.19 *Typical solid PVC 90° bends* GERARD INDUSTRIES

Fig. 5.20 *PVC inspection-type elbow and tee* GERARD INDUSTRIES

system. Comprehensive listings of all types will be found in manufacturers' catalogues, but a few illustrations representative of the different groups follow.

Steel inspection elbows and tees of similar design to those shown in Figure 5.20 are also available for use with heavy-duty steel conduit.

Figure 5.21 illustrates some typical PVC conduit couplings readily available on the Australian and New Zealand market. It should be noted that the screwed couplings illustrated are intended for use with other moulded accessories. PVC conduit should never be threaded, but a 'screwed-to-plain conduit reducer' may be used.

Protection of conduit ends, and prevention of the entry of dirt, cement, plaster, water or other matter, are important where building operations are in progress. Figure 5.22(a) shows conduit end plugs for this purpose.

Figure 5.22(b) shows a conduit-locating flange, which serves the dual purpose of conduit location and

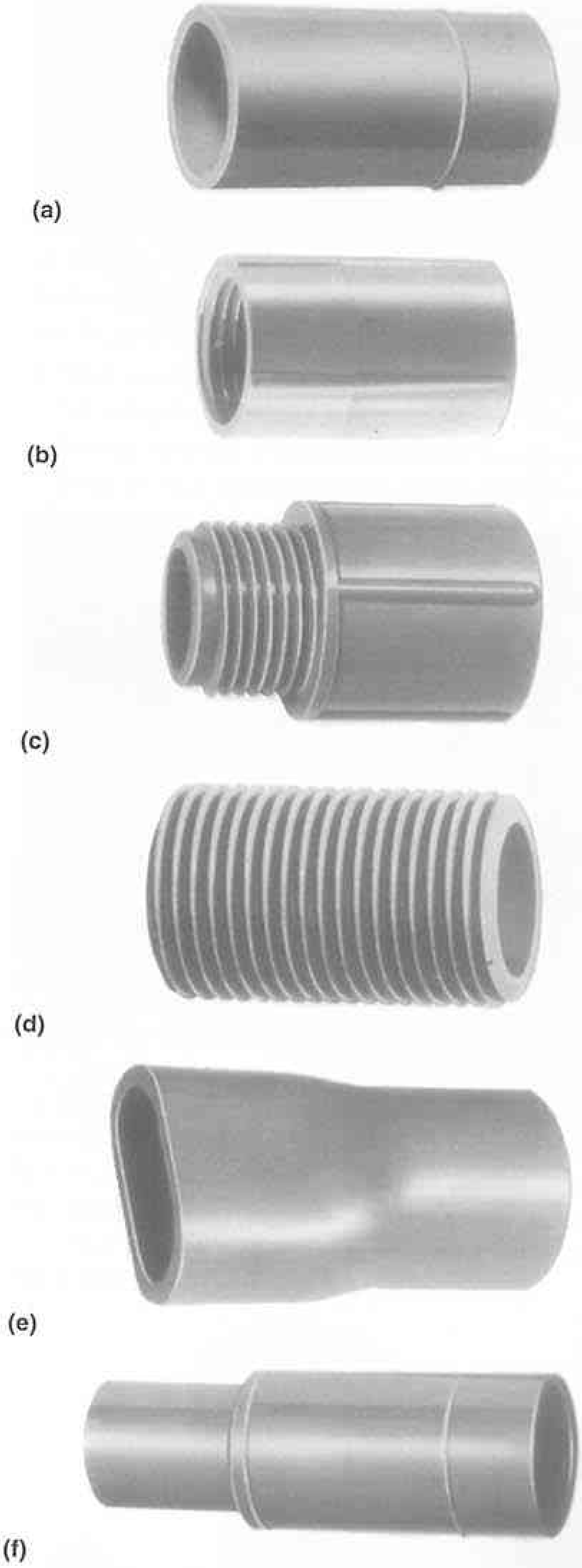


Fig. 5.21 *Typical conduit couplings:* **(a)** *plain coupling;* **(b)** *screwed coupling;* **(c)** *screwed-to-plain conduit adaptor;* **(d)** *screwed nipple;* **(e)** *round-to-flat conduit adaptor;* **(f)** *expansion coupling* GERARD INDUSTRIES

protection on concrete jobs where conduit is turned down for penetration of a floor slab, or where it is carried through a poured concrete wall and is to be extended on removal of the formwork. Figure 5.22(c) shows a disposable lid for the protection of round-junction-box outlets.

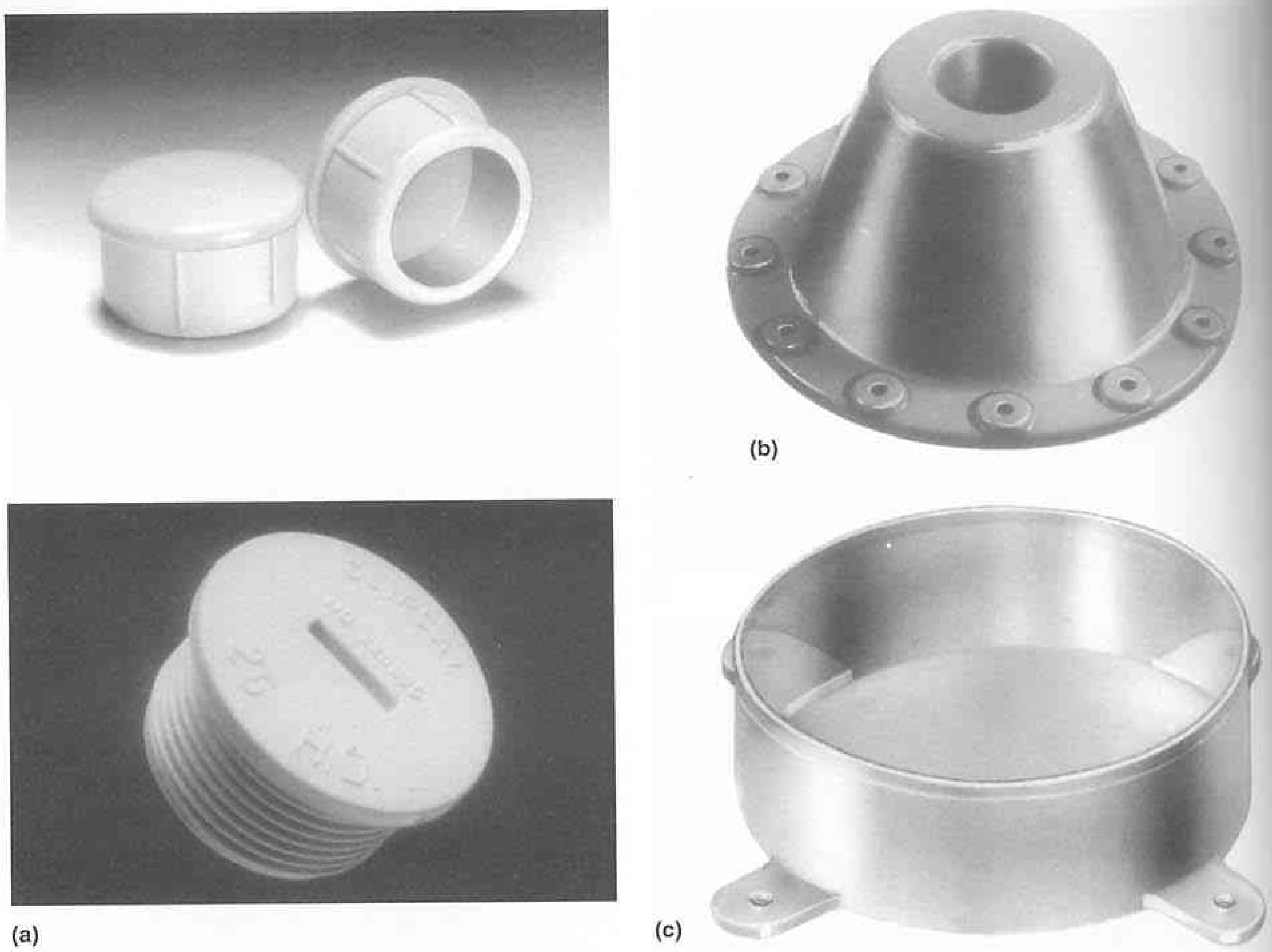


Fig. 5.22 **(a)** *Conduit plugs, screwed and plain;* **(b)** *Conduit-locating flange;* **(c)** *Disposable round junction-box lid* GERARD INDUSTRIES

The use of deep-type junction boxes in concrete jobs is mentioned in Chapter 9 and in section 5.2 of this chapter, but a variety of other junction boxes are available, some of which are shown in Figure 5.23.

The unique connection and junction-box system illustrated in Figure 5.24 does not require the use of adhesive or PVC solvents or threaded adaptors; conduits are simply pushed into position. The manufacturers

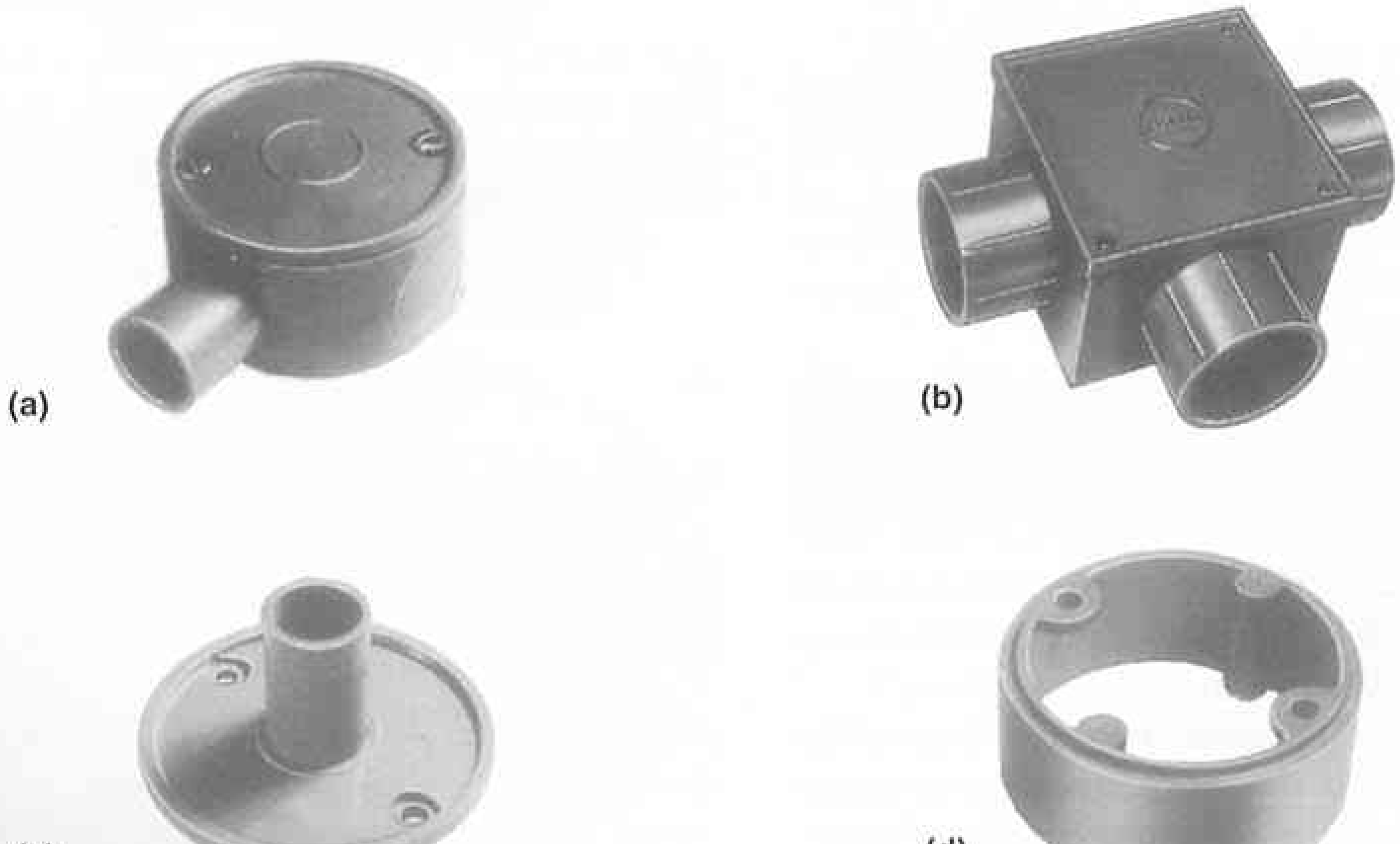


Fig. 5.23 **(a)** *One-way round PVC junction box;* **(b)** *Three-way square PVC junction box;* **(c)** *Round PVC junction-box take-off plate;* **(d)** *Round PVC junction-box extension ring* GERARD INDUSTRIES

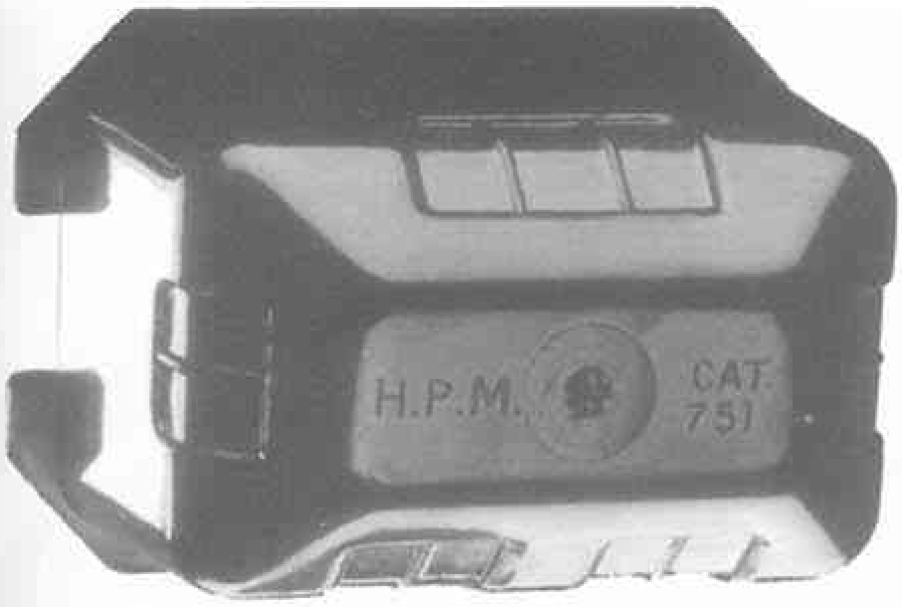


Fig. 5.31(c) *Safety shroud for socket outlet: fits standard switch or socket outlet to protect against inadvertent contact with live parts* HPM INDUSTRIES

separate accessories (socket outlet and control switch) or one accessory comprising the outlet and switch within the same assembly. This is termed a 'switch–socket combination', usually shortened to 'combination' and sometimes referred to as a 'power outlet'.

The term 'socket outlet' defined by *Clause 0.5.80* includes a socket outlet with or without a switch. Note that a 'general-purpose outlet' (GPO) (*Clause 0.5.66*) is a 10 A socket outlet designed to accommodate a 10 A three-pin flat-pin plug.

Accessories may be of the flush type or arranged for surface mounting, and the usual socket outlet is the three-pin flat-pin type (see Fig. 5.32); but socket outlets are available in a variety of two- and three-pin shapes and configurations also.

With respect to the current ratings of 240 V socket outlets, it is interesting to note that the design incorporates a safety provision, in that a 10 A plug may be inserted into a 15 A-rated socket, but it is not possible to insert a 15 A plug into a 10 A socket. This feature is repeated for higher ratings.

The same technique of not being interchangeable is the reason for using different pin configurations and shapes, for example with mixed light and power outlets, or where 32 V extra-low-voltage outlets are near 250 V low-voltage outlets. A further example in industry is the provision of socket outlets for tools on high-frequency supply located near standard 250 V 50 Hz outlets.

Much thought has been given to the development of the standard 250 V ac switch–socket combination for

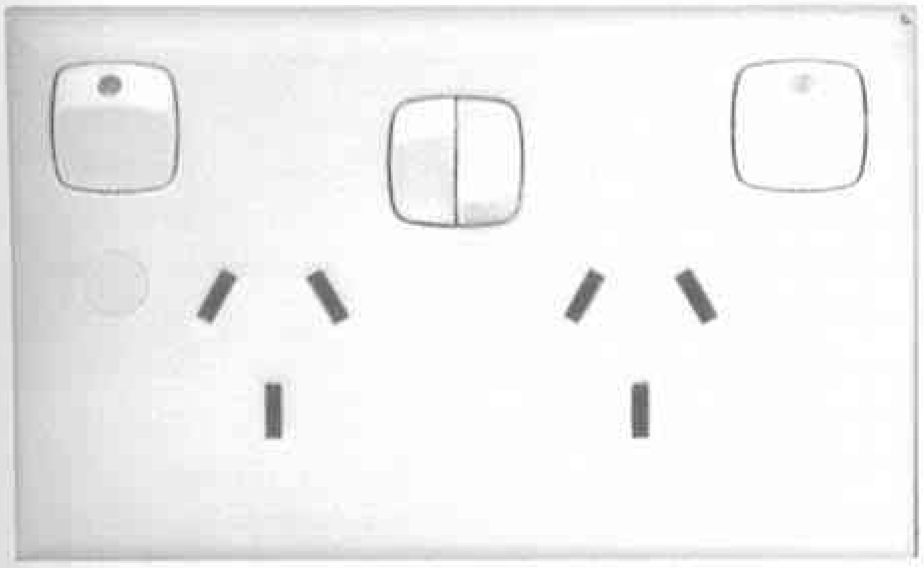


Fig. 5.32(a) *Socket outlet for flush mounting* HPM INDUSTRIES

Fig. 5.32(c) *Socket outlet with built-in RCD* HPM INDUSTRIES

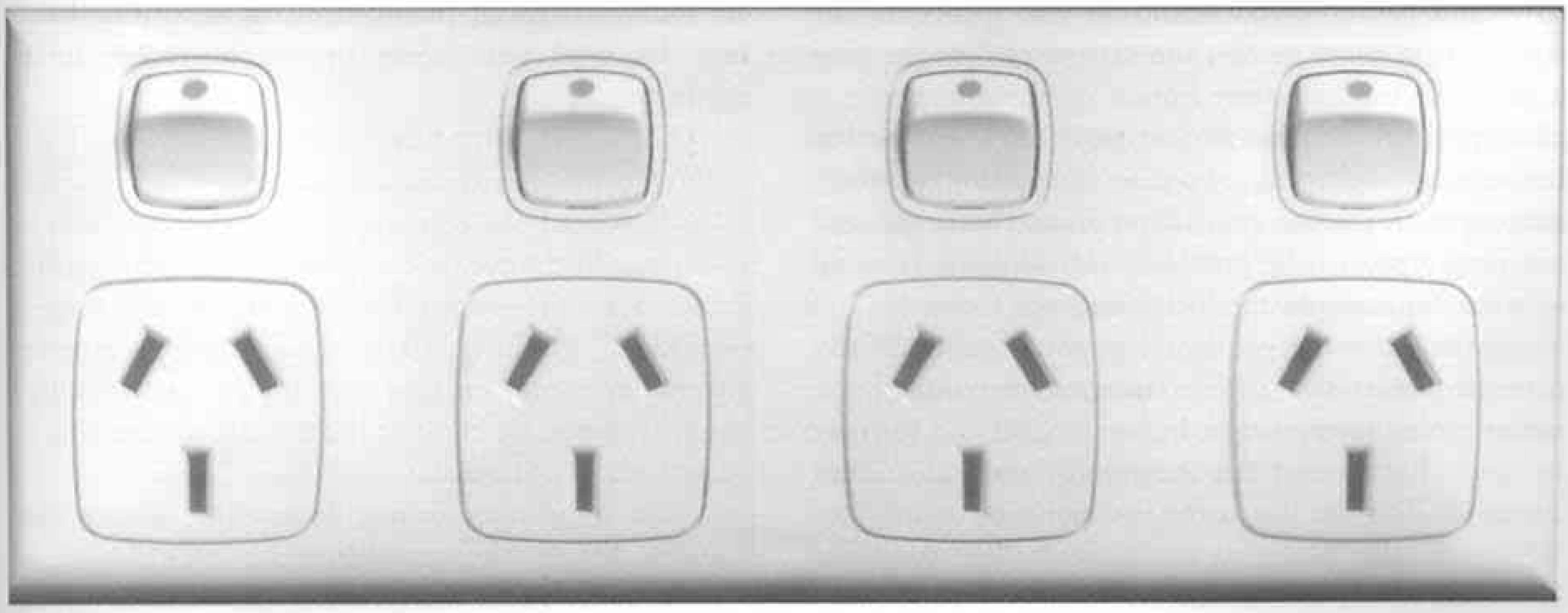


Fig. 5.32(b) *Four-in-one socket outlet: mounts directly to standard wall box or bracket* HPM INDUSTRIES

Fig. 5.37(a) *Three-pin PVC plug top. Visual check for correct connection is provided in the base of the plug* GERARD INDUSTRIES

Fig. 5.37(b) *Three-pin plug top with side entry* GERARD INDUSTRIES

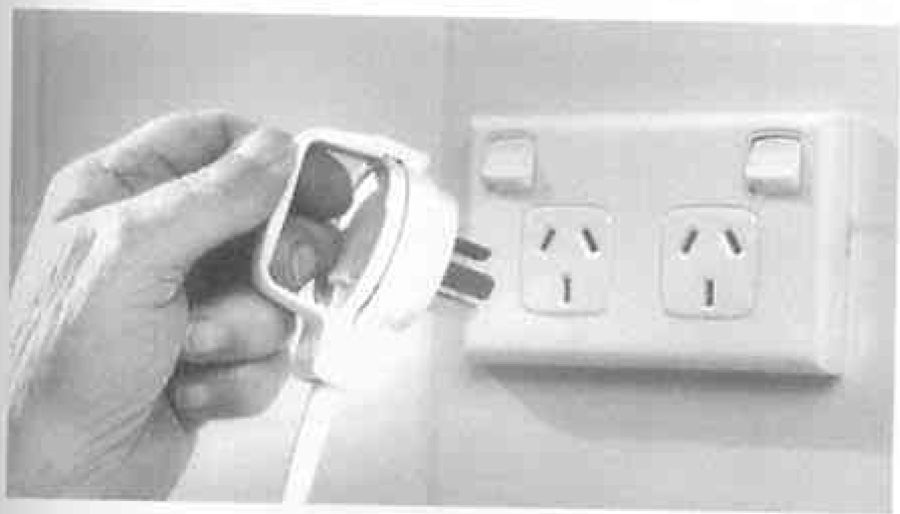


Fig. 5.37(c) *Three-pin plug top designed for people whose dexterity is impaired by arthritis or other disabilities affecting the ease with which they can insert or withdraw plugs* HPM INDUSTRIES

Fig. 5.37(d) *Three-pin suppressor plug designed to reduce mains-borne electromagnetic interference caused by the switching of thermostatically controlled appliances* GERARD INDUSTRIES

electrical butt contacts. The plug may now be removed by twisting anticlockwise and pulling outwards.

The use of butt contacts makes it much easier to insert or withdraw the plug from a deconnector than it is to insert or withdraw the plug from the traditional round-pin type of plug-socket fitted with a pin and socket-sleeve configuration.

A 'phasing disc' is fitted to the deconnector illustrated in Figure 5.35, and this isolates the live contacts when the plug is not inserted. It may also be adjusted to permit the connection of single-, two- or three-phase supply. A deconnector with dc switching capacities is also available from the manufacturer, and the phasing disc may be adjusted so that ac plugs cannot be inserted into the dc setting and vice versa.

Lampholders

Lampholders are primarily designed for easy lamp replacement. Neglecting special designs, the two main types for general lighting service are 'bayonet cap' (BC) and 'Edison screw' (ES). The illustrations of Figure 5.38 are typical examples. The maximum lamp loading for a **normal** bayonet lampholder is 200 W; **Goliath** Edison Screw holders must be used above this rating (see *Clause 4.13.2* and *Table 4.1* of AS 3000). Also note the range of lampholders listed in *Table 4.1*.

Joining dissimilar wiring systems

Conductor terminations and accessories are discussed in Chapter 4. In addition to accessories such as junction boxes in general use, there are those designed specifically for joining dissimilar wiring systems. To illustrate this principle, two typical examples are given in Figure 5.39.

Fig. 5.38(a) *Large-base bayonet cap batten holder*
GERARD INDUSTRIES

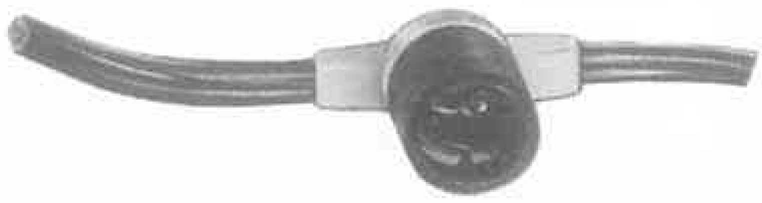


Fig. 5.38(b) *Festoon lampholder moulded on the cable festooning* GERARD INDUSTRIES

Fig. 5.38(c) *Adjustable Edison screw batten holder*
GERARD INDUSTRIES

You should endeavour to think of other possible situations, such as an underground wiring system being joined to another type of wiring system.

Note that the active terminals of the three-phase mains-connection box of Figure 5.39(a) are covered by insulating mouldings to prevent inadvertent personal contact.

Fig. 5.38(d) *Switched bayonet cap lampholder* GERARD INDUSTRIES

Fig. 5.38(e) *Safety BC lampholder. Also available as a batten holder. Terminals become live only after a light bulb or BC adaptor is fitted* HPM INDUSTRIES

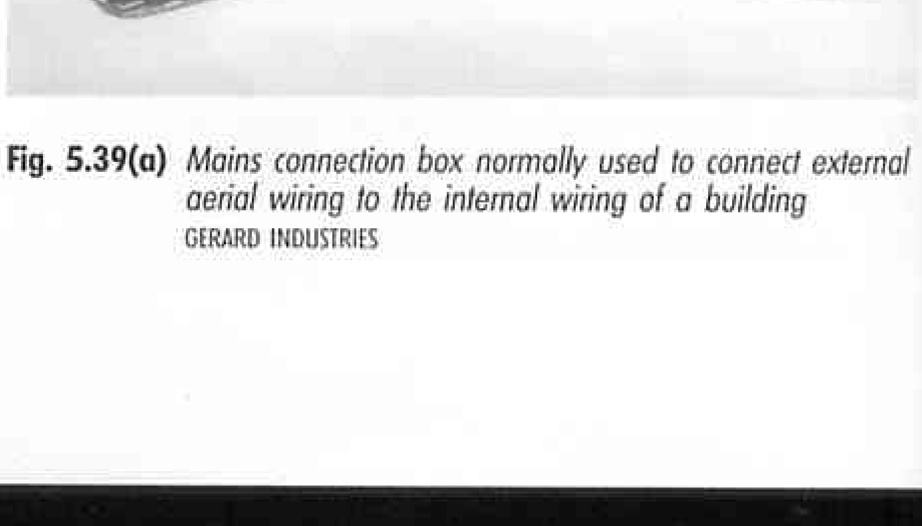


Fig. 5.39(a) *Mains connection box normally used to connect external aerial wiring to the internal wiring of a building*
GERARD INDUSTRIES

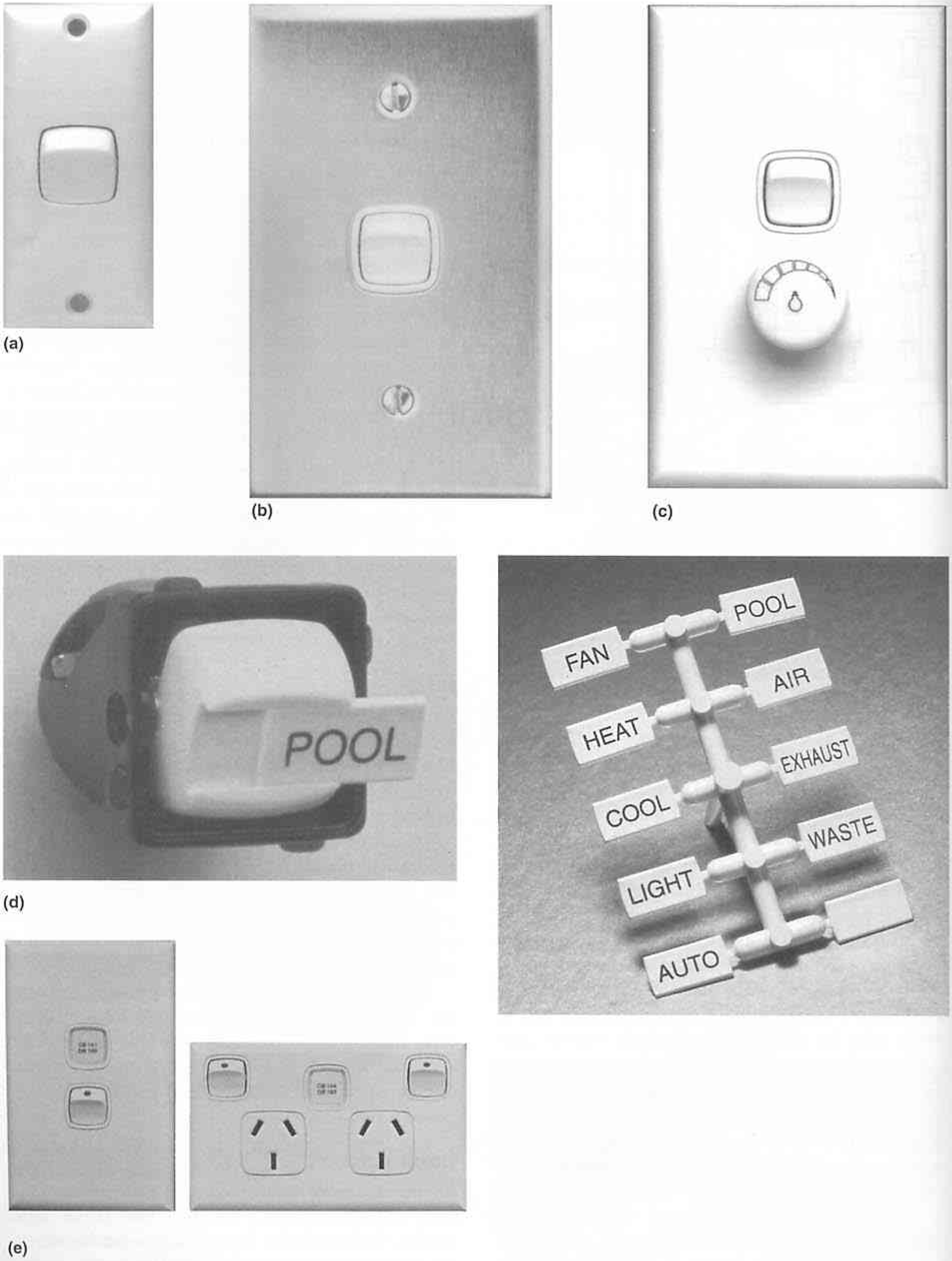


Fig. 5.40 **(a)** *One-gang flush switch;* **(b)** *'Architectural' metal one-gang switch;* **(c)** *Light-dimmer switch;* **(d)** *Switch mechanism with dovetail dolly and printed 'name tree';* **(e)** *Blanking piece inserts for identification of circuits; may also be used on socket outlets* HPM INDUSTRIES

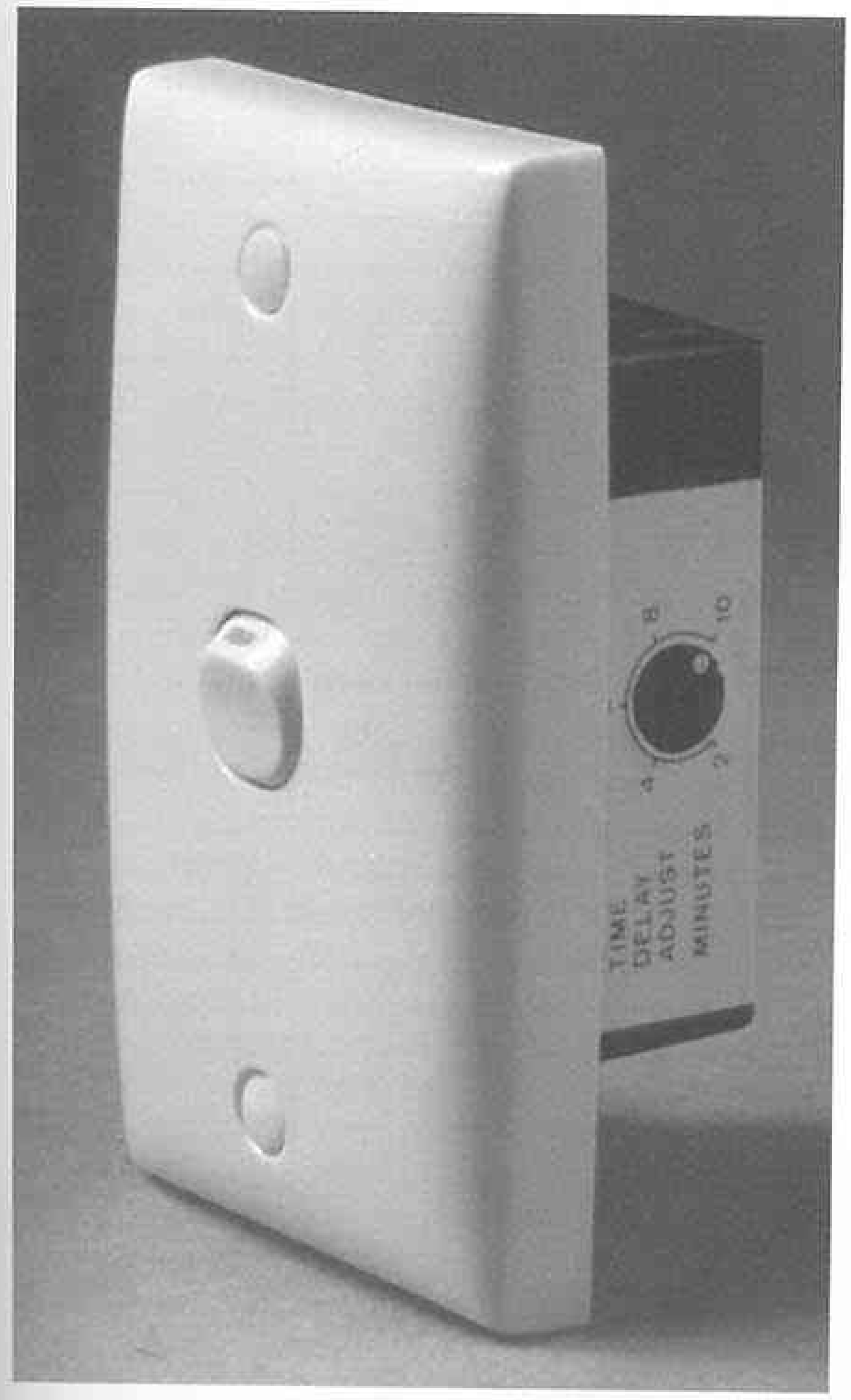


Fig. 5.41 *Electronic time-delay switch* GERARD INDUSTRIES

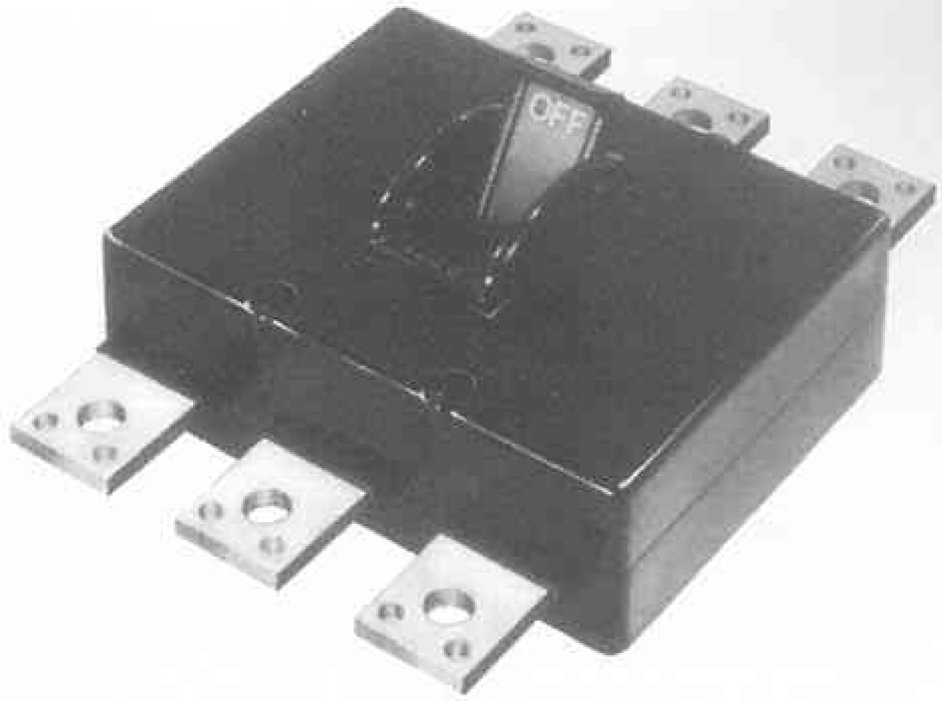
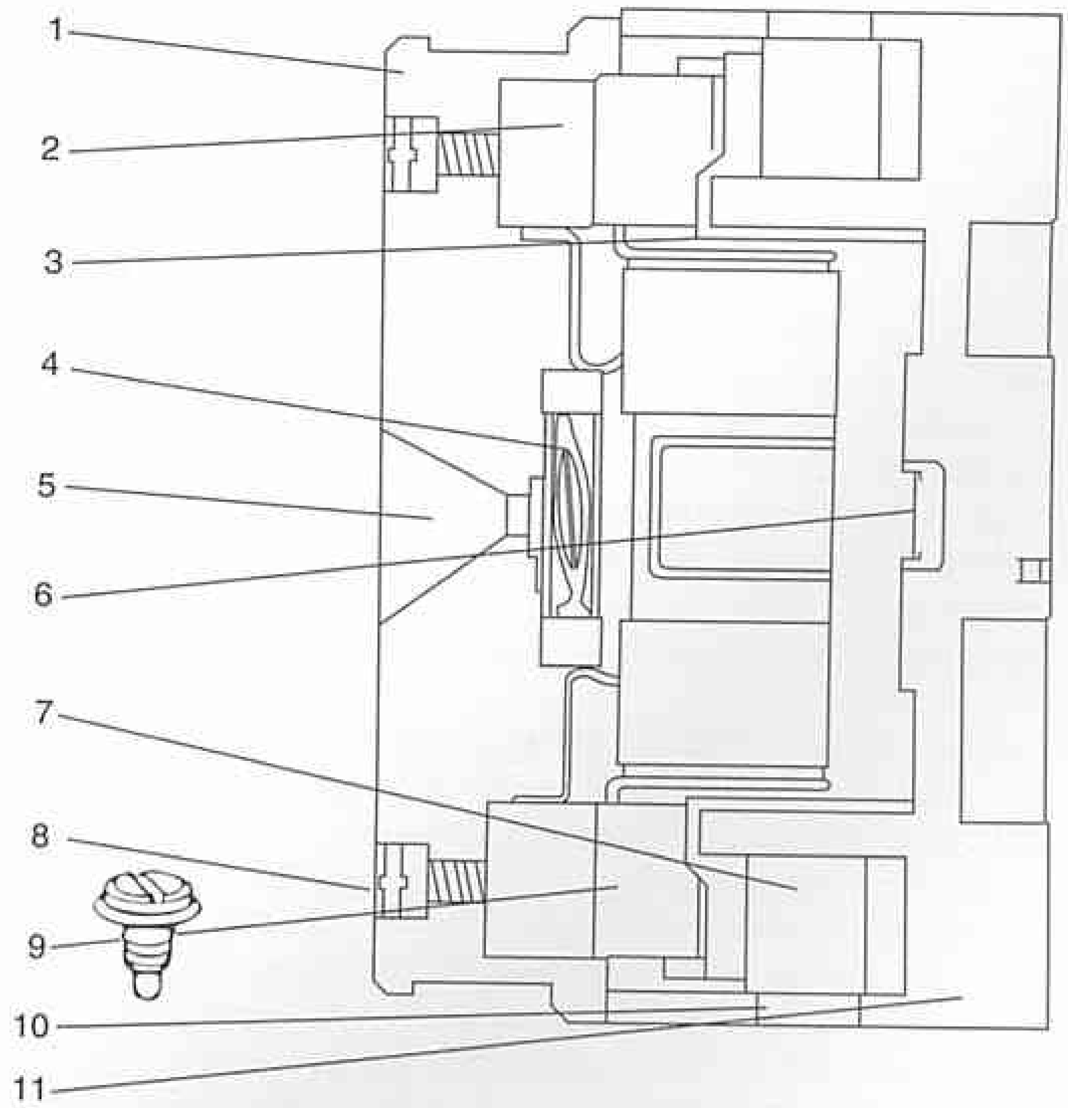


Fig. 5.42 *440 V 500 A triple-pole switch with front lug connection facilities* GERARD INDUSTRIES

Standards. They must be installed with the same care and attention to current and voltage rating, category of duty and operating characteristics as a fuse. The operating characteristics of the circuit breaker depend on design, and it is sometimes possible to adjust some of these in the field, whereas fuse characteristics are fixed.

For some protection applications the fuse and circuit breaker are complementary, one common application being where overload protection is provided by the circuit breaker and 'backup' protection against short circuit is given by the fuse. In other applications their



1. Fuse carrier
2. Extruded brass carrier contacts
3. Nylon shrouds to shield live terminals
4. Visual blown fuse indicator
5. Frontal aperture to permit visual inspection of HRC fuse link
6. Circuit-rating indication
7. Non-ferrous backing stirrups to provide positive pressure on carrier contacts
8. Test probe facilities
9. Cartridge fixing screws
10. Enlarged terminal holes fitted with full-diameter terminal screws
11. Non-hygroscopic phenolic moulding

Fig. 5.43 *Section through a typical 200 A high-rupturing-capacity (HRC) fuse* 'single-pole' switch with the voltage and current rating specified, for example, '250 V 10 A—single-pole'. Note that some switches are marked 'ac only' and are not suitable for dc operation; therefore be careful when specifying the type of switch required.

Figure 6.6(a) illustrates the control of a lamp by a single-pole switch. Note that the switch must be in the active conductor. In Figure 6.6(b) the same control is achieved but by the use of a double-pole switch operating in both conductors simultaneously. The rear view of, and connections to, a modern-type double-pole switch (which may also be used for a double-pole double-throw application) are shown in Figure 6.6(c). The double-pole switch is mandatory for some applications, for example in caravans (see AS 3001: *Electrical Installations in Caravans and Caravan Parks,* and *Clause 6.11* of AS 3000).

For general wiring circuits, the 'loop-in' system is the normal wiring method, and most modern wiring accessories such as switches, ceiling roses and batten holders are provided with a spare 'looping' terminal for this purpose. The loop-in system makes the joins of conductors accessible at common terminals in these accessories, maximising the use of multicore cable without the need for junction boxes (refer to Fig. 6.8).

Junction boxes are usually less accessible and take longer to install. They are still used, however, where convenient or expedient, but looping-in is the normal method and is preferred by most electricians and energy distributors.

In Figure 6.7 the looping terminal in a ceiling rose or batten holder is used, while in Figure 6.8 the looping is done at the switch. Both systems are commonly used and are employed in thermoplastic-sheathed (TPS) cable wiring and with single-insulated polyvinyl chloride (PVC) cables in PVC or steel conduit, where a 'draw-in' job is required. Refer to Chapter 4, section 4.6, for

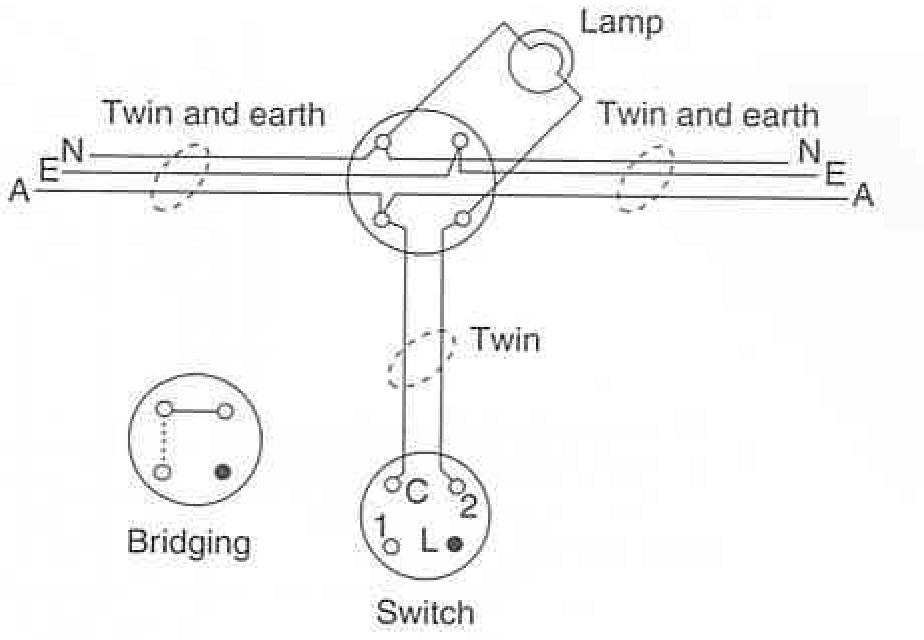


Fig. 6.7 *Looping-in at batten holder or ceiling rose—looping terminal not used*

a method of joining earth wires where they cannot be accommodated in the looping terminal of the switch.

Drawing-in of cables is required in concealed wiring or conduit buried in a concrete screed, where elbows and tees are not used (see Fig. 6.9).

Figure 6.10 shows a system of wiring in conduit that was commonly used before the introduction of tough rubber-sheathed (TRS) and TPS wiring in domestic installations and is still used in surface wiring for some industrial installations.

Note here that the basic circuit of Figure 6.6(a) applies to all these circuits; it is only the method of wiring that is different. For example, in Figures 6.7 and 6.8 the looping is done at **either** the light fitting **or** the switch, whereas in Figure 6.10 **both** the switch **and** the light fitting are used for looping.

In Figure 6.11, all the joins are made in a junction box.

The loop-in system is usually preferable, but sometimes it is expedient to use a junction box provided in

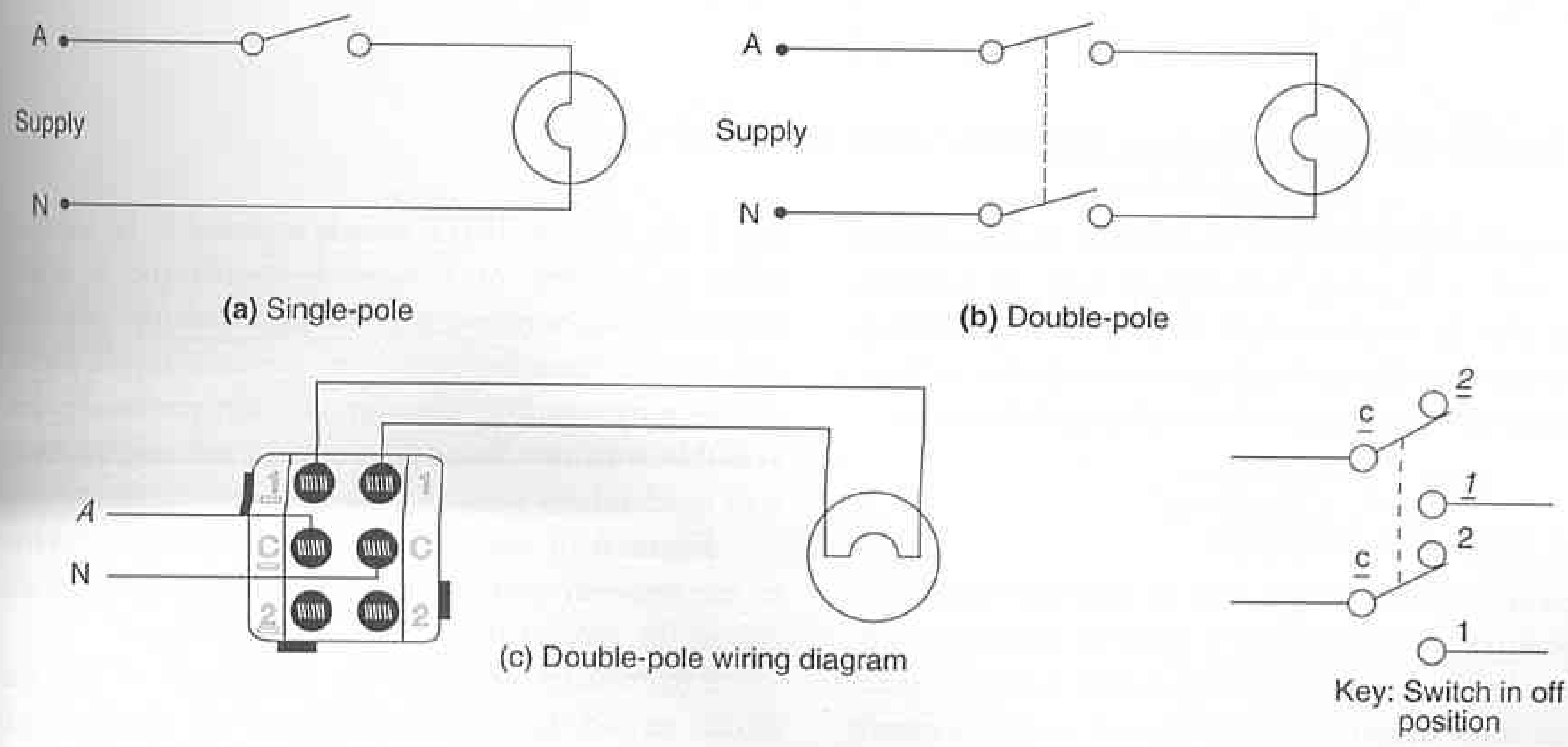


Fig. 6.6 *Single- and double-pole switching*

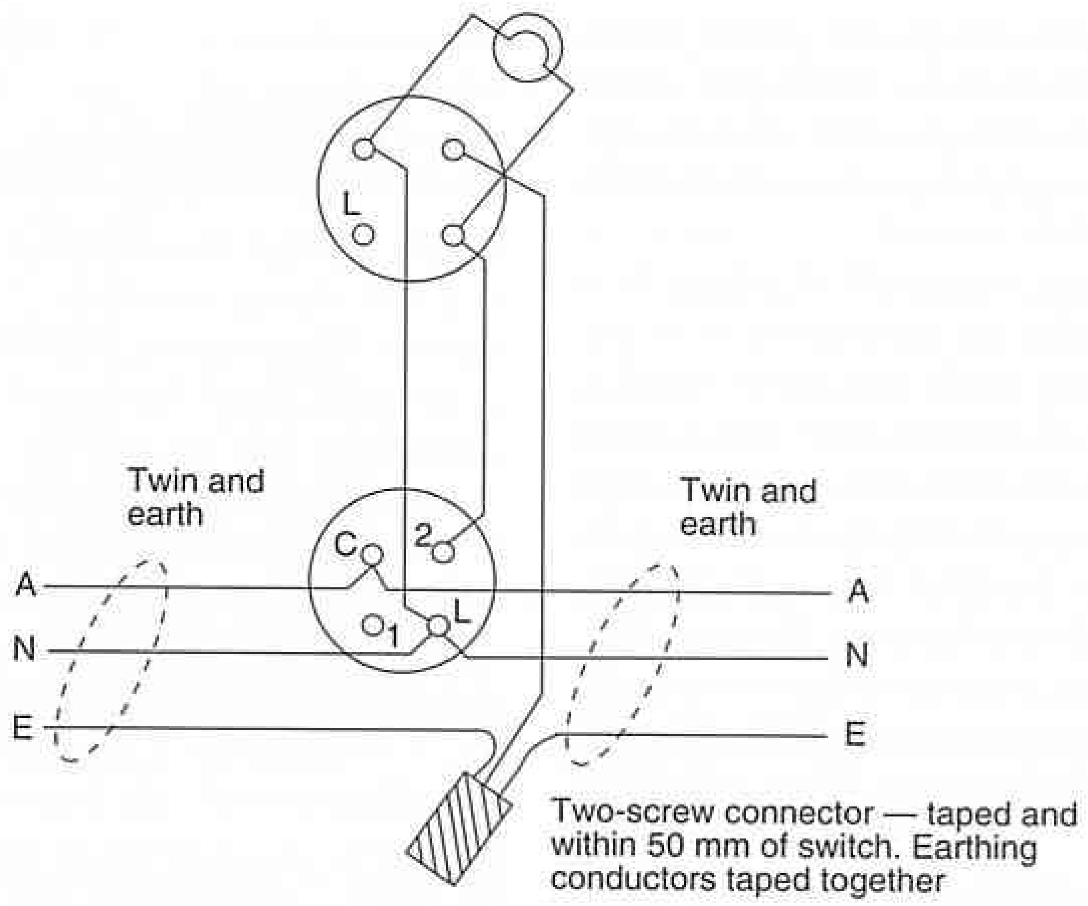


Fig. 6.8 *Looping at switch using twin and earth cable*

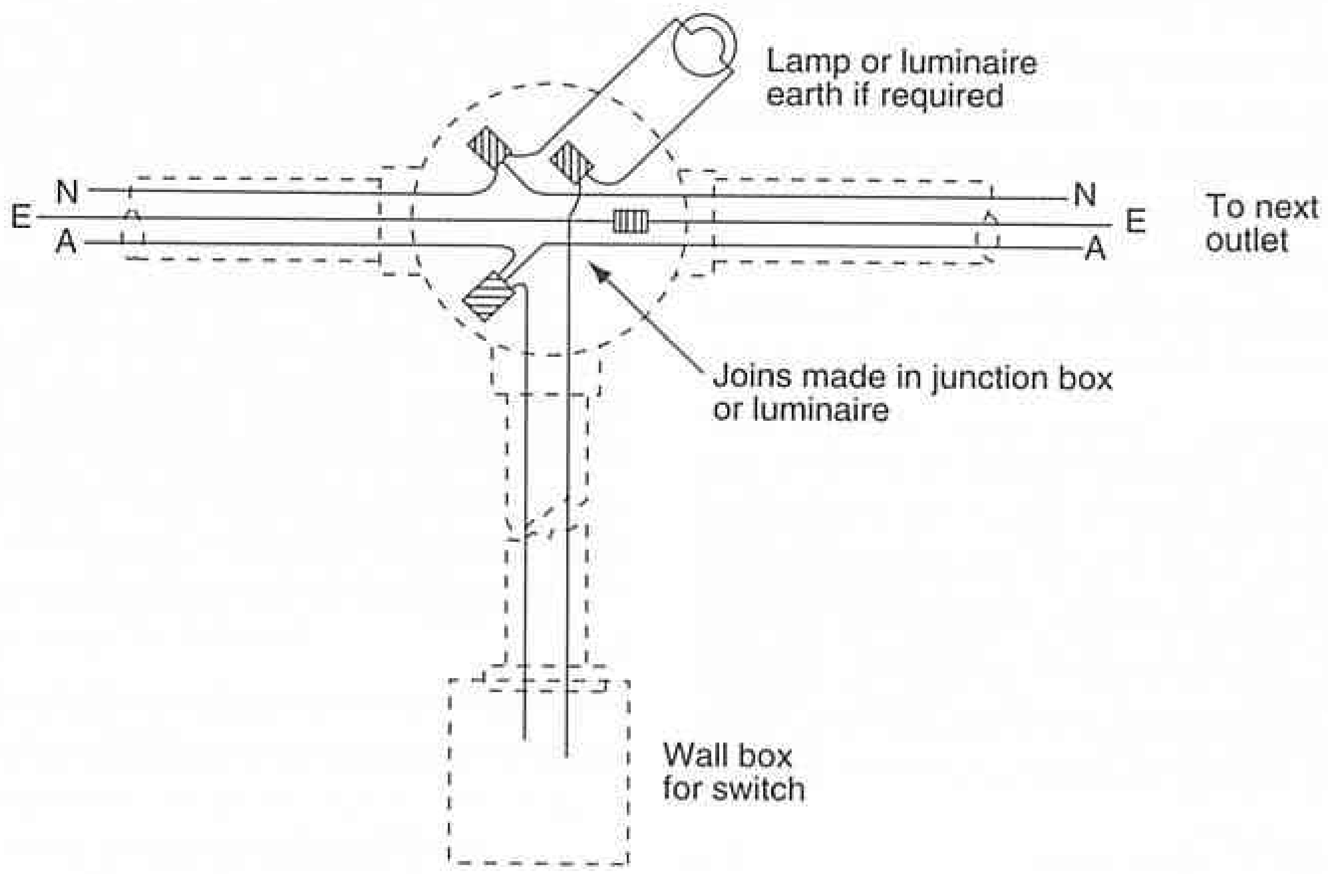


Fig. 6.9 *Looping-in at accessible junction box or luminaire in a conduit system buried in concrete*

an existing installation or for 'cutting-in' to the existing wiring, such as at point X in Figure 6.11. A junction box may also be used to avoid looping at a light fitting that does not provide for looping connections in its base, for example in some types of outside porch lanterns.

Control from two positions

Whereas the modern single-pole or one-way switch has two operative terminals, plus a spare or looping terminal, the two-way switch used for control from two positions has three operative terminals, and usually a fourth looping terminal. The terminal connections for one type of modern two-way switch are shown in Figures 6.12 and 6.13. It is an SPDT switch intended to be used as either a one-way or a two-way switch and is often termed a 'one-way/two-way switch'. Both the one-way and one-way/two-way switch are normally supplied with one looping terminal; however, one-way mechanisms are available with two looping terminals, and one-way/two-way mechanisms with three looping terminals.

Figure 6.14 illustrates (a) the basic switching action of the two-way switch and (b) the basic and most used circuit for control from alternative positions.

Figure 6.15 illustrates an adaptation of the basic circuit to add the two-way facility to an existing circuit in circumstances where either it is not desirable or it is impracticable to disturb the existing wiring.

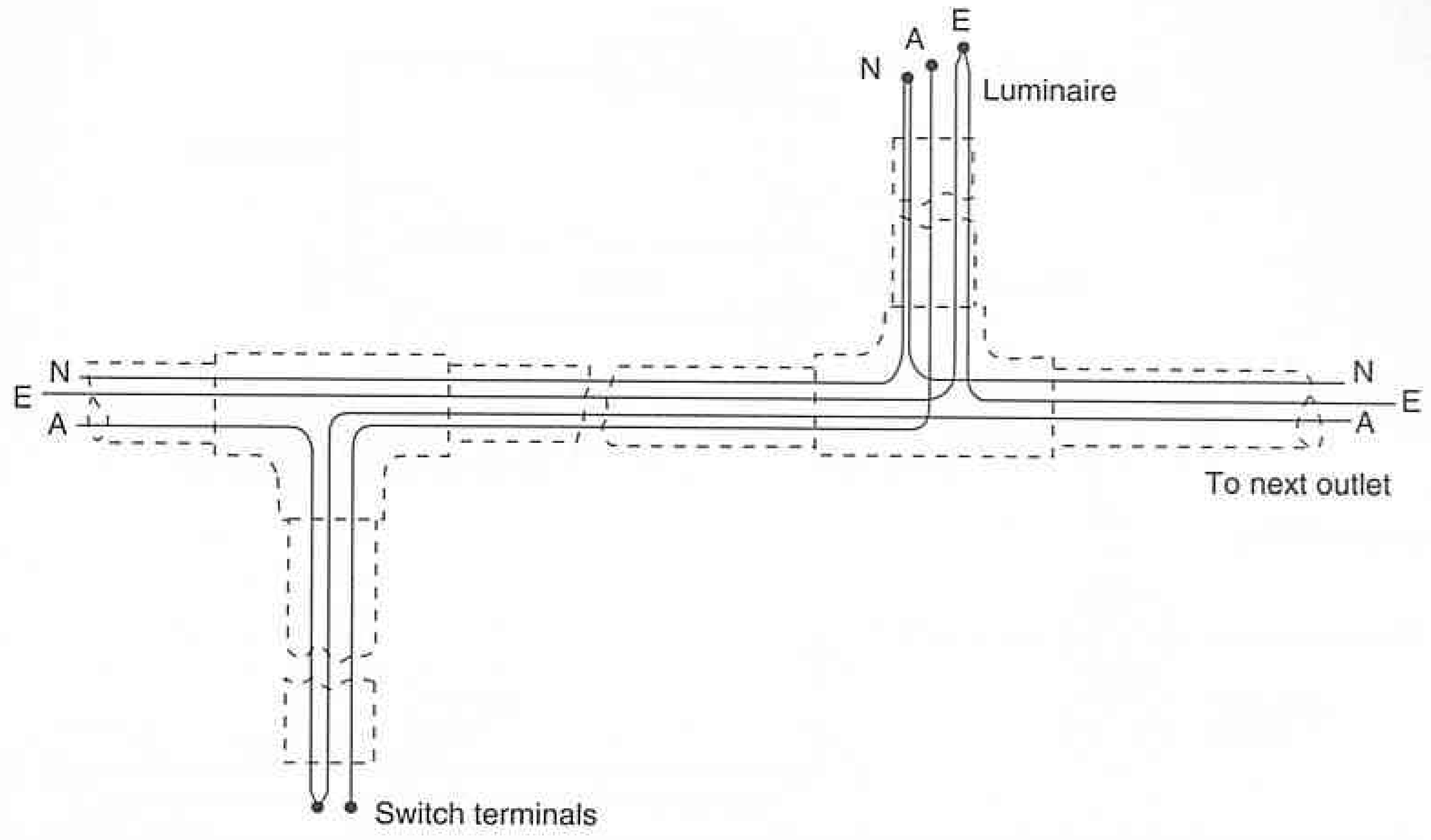


Fig. 6.10 *In this surface conduit system, actives are looped at the switch and neutrals or earths at the outlet or luminaire*

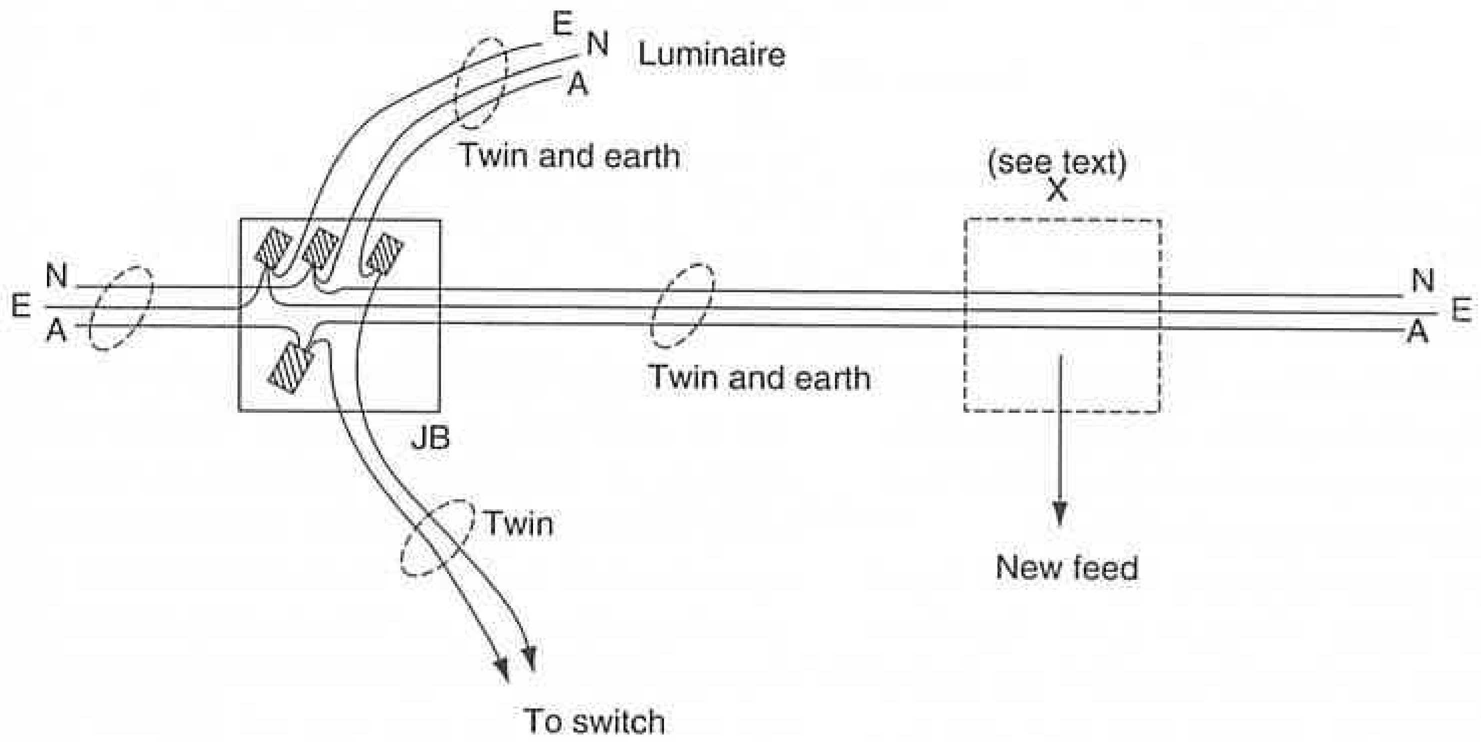


Fig. 6.11 *Use of a junction box as an alternative to 'looping-in'*

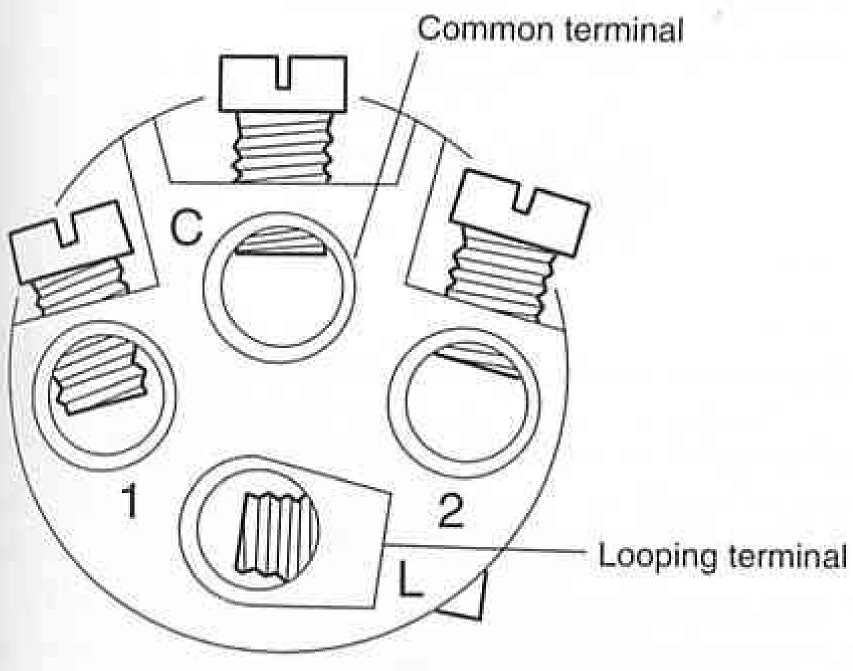


Fig. 6.12 *Terminal arrangement of a typical one-way/two-way switch*

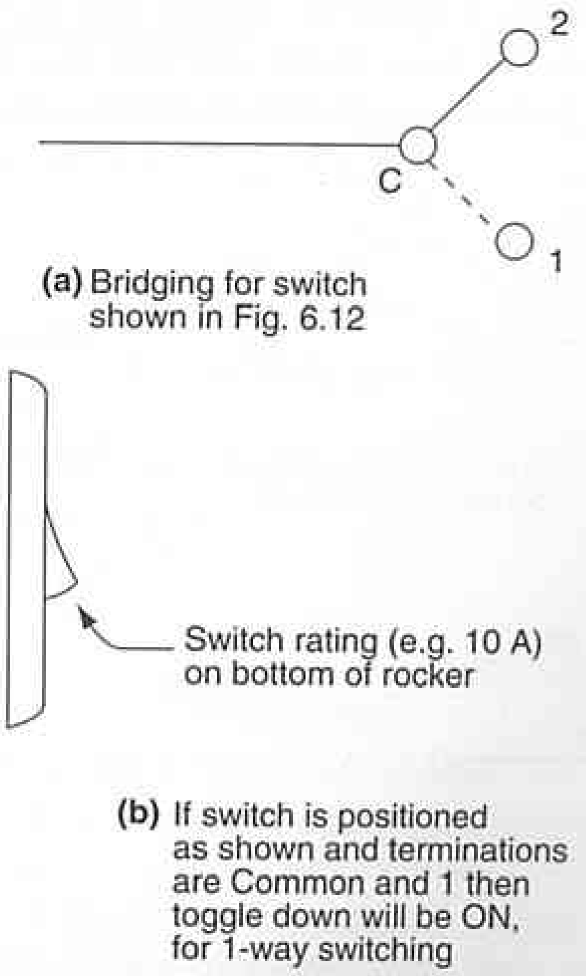


Fig. 6.13 *Switch operation and positioning*

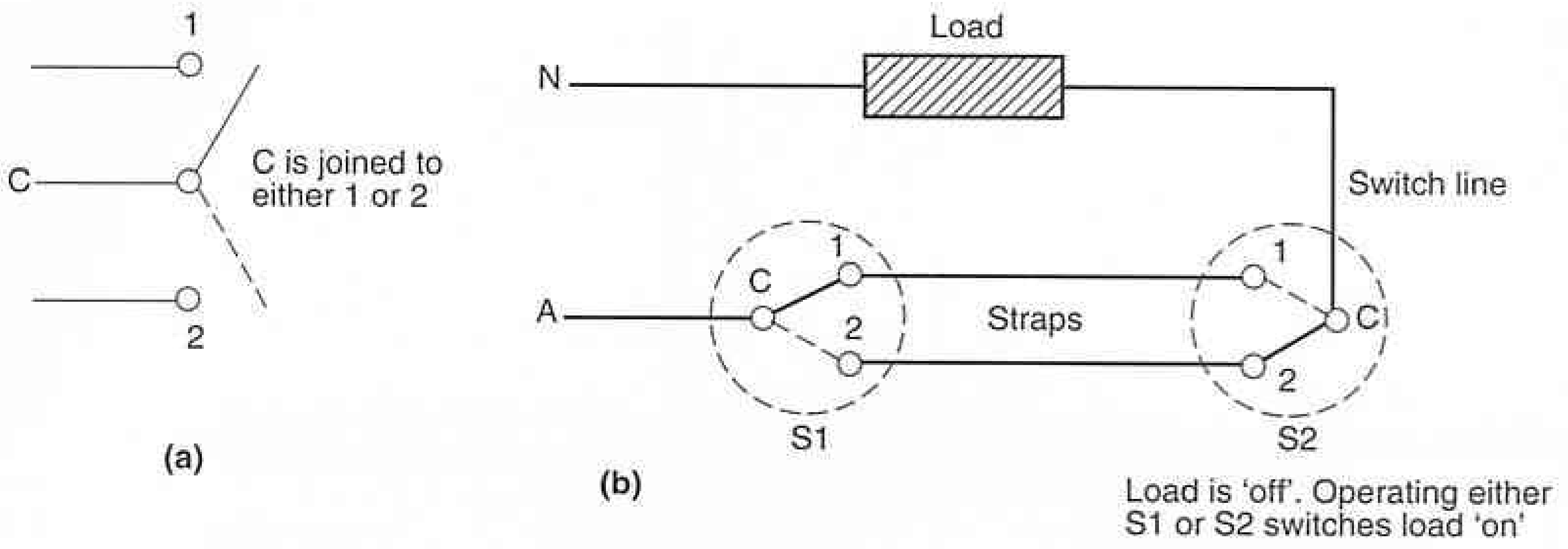


Fig. 6.14 *Two-way switching*

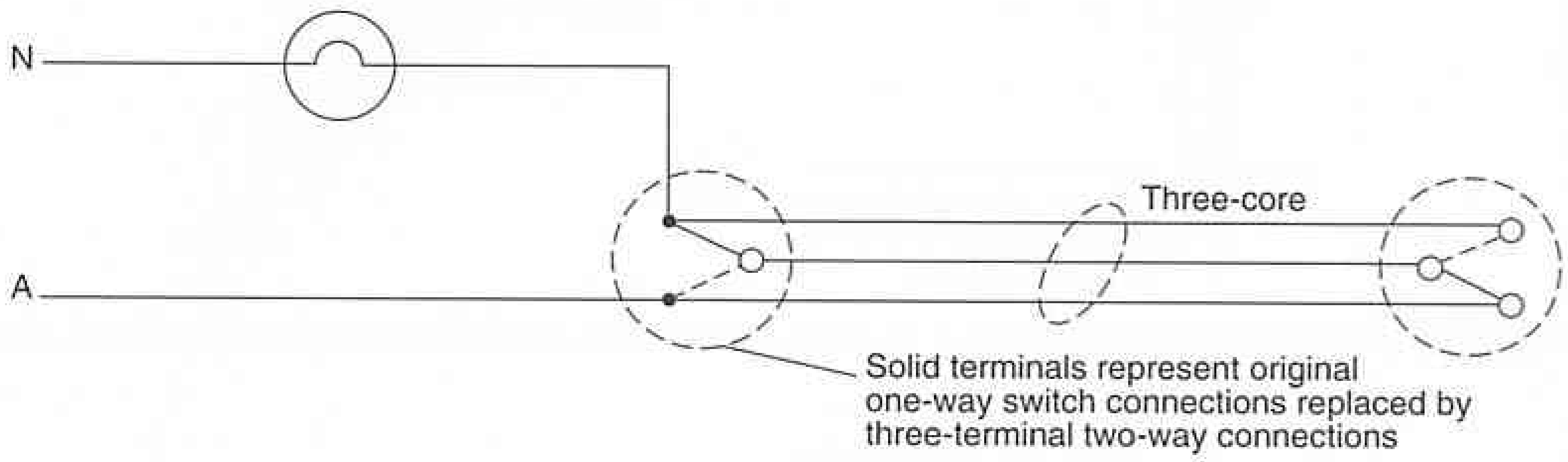


Fig. 6.15 *Changing from one-way to two-way control*

For any of these electrical controls, once the basic switch action is known its circuit application is limited only by the ingenuity of the person employing it. Some applications for the two-way switch are shown in Figure 6.16, and further illustrative examples follow.

There are many practical wiring layouts, all based on the fundamental circuit of Figure 6.14. The three illustrations of Figures 6.17, 6.18 and 6.19 are typical of these. Again it must be stressed that each job is a variation on the basic theme and that the manner in which the basics are applied is an 'on-the-job' decision.

Control from more than two positions

This control is achieved by the use of two-way switches, one at each end of the control circuit, and as many switches at intermediate positions as required, there being no limit to the number of control positions. The type of switch necessary at the intermediate positions is quite logically called an 'intermediate switch', and it has four connections or operative terminals; the rear terminal connections for one type of modern intermediate switch (HPM 770/1M) are shown in Figure 6.20(a). The bridging arrangements shown correspond to those

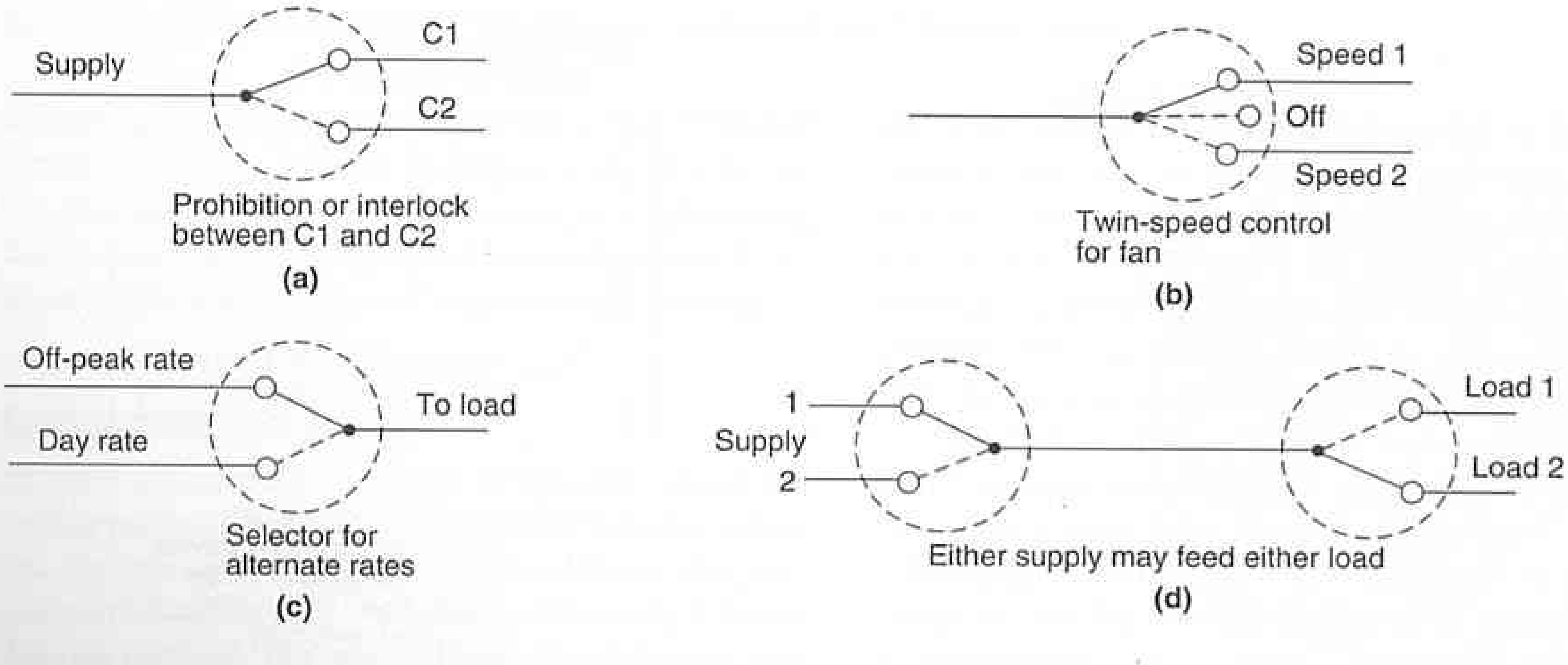


Fig. 6.16 *Some other applications of two-way switches*

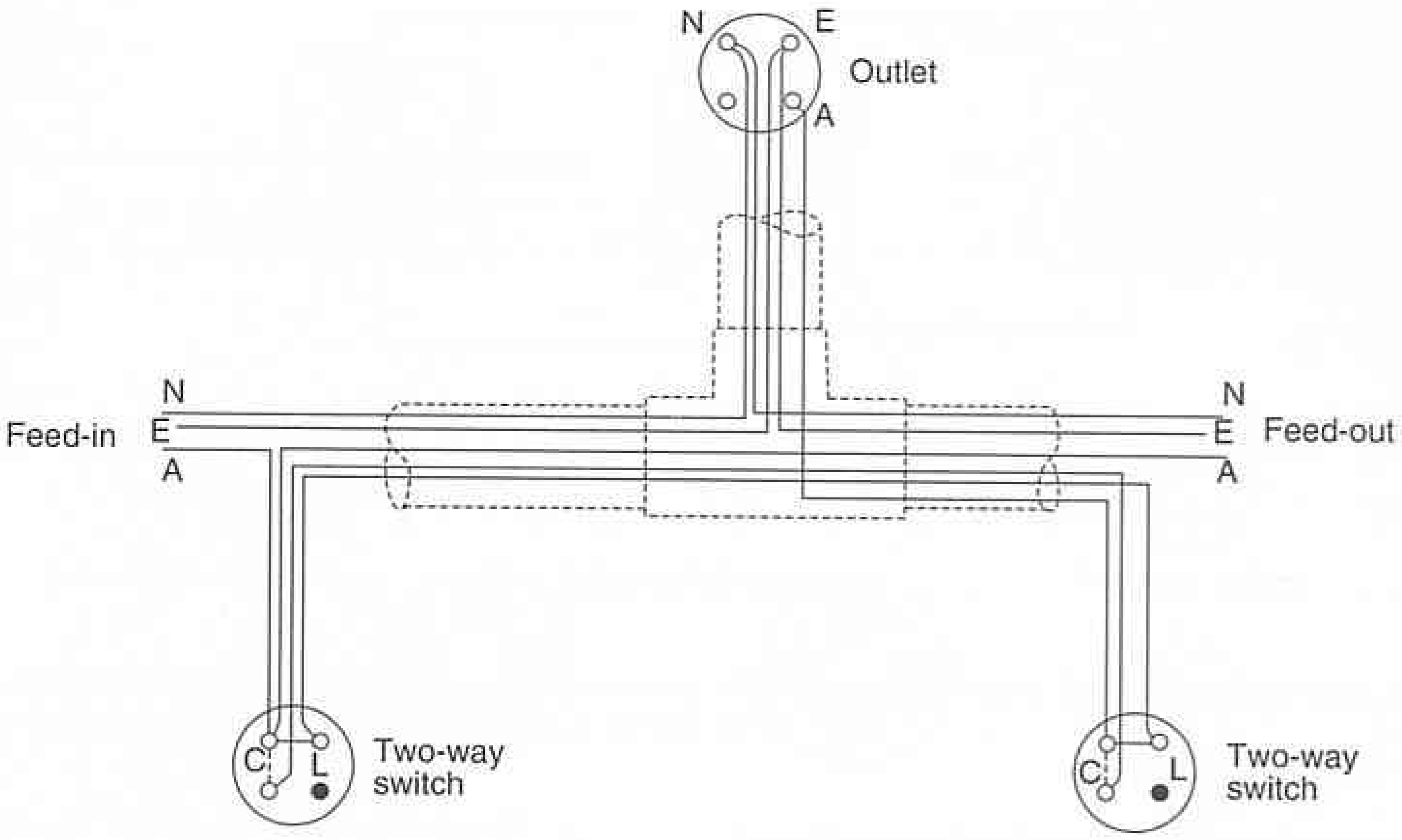


Fig. 6.17 *Connections for two-way switching using the 'looping-in' system with surface wiring in conduit*

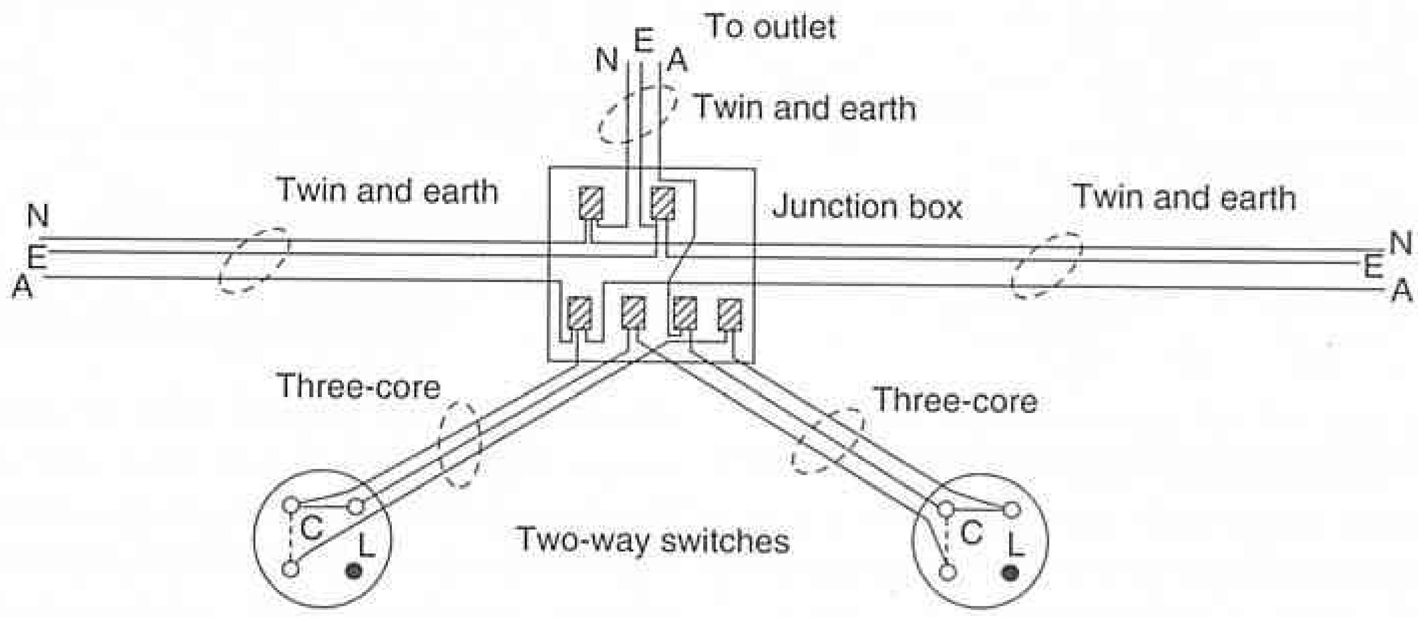


Fig. 6.18 *Two-way switching using twin and earth, and three-core cable and junction box. A two-core and single-core cable may be used instead of the three-core*

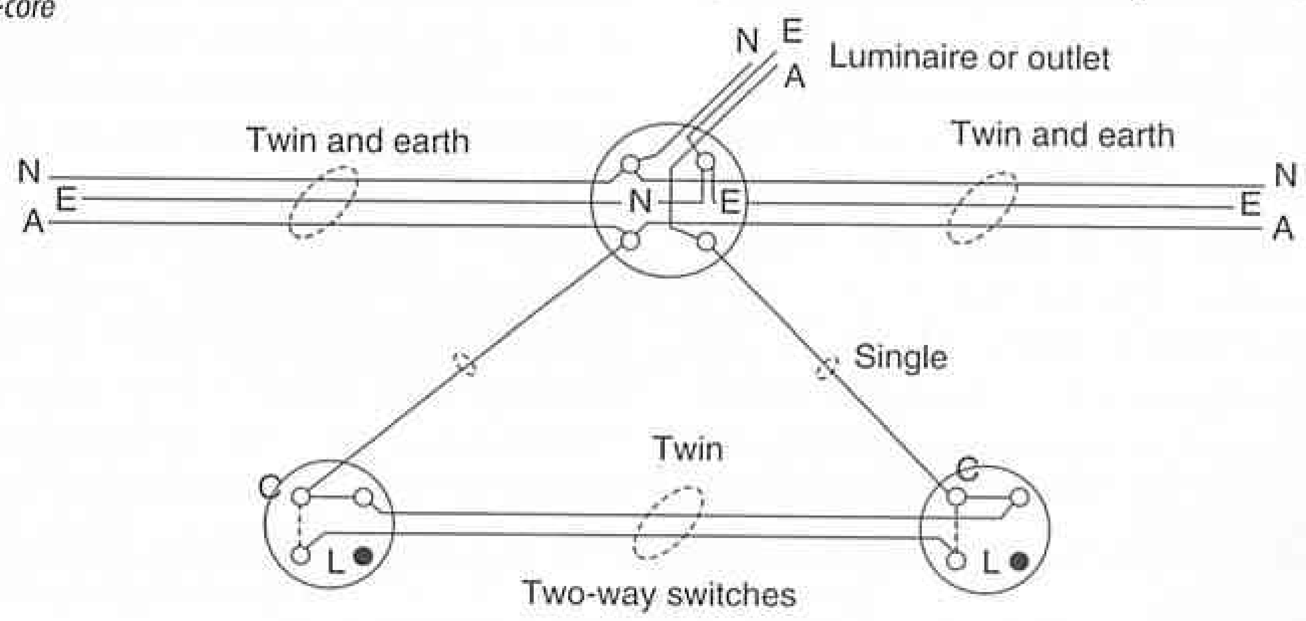


Fig. 6.19 *A method for two-way switching single-core, two-core, and twin and earth cables*

in Figure 6.20(b)(i). The two methods of bridging for two different switch types are shown in Figure 6.21(a) and (b).

The wiring is the same for all types, irrespective of the internal bridging arrangements for the switches. It is only when connecting the conductors interconnecting the two-way switches ('straps') to the switches that care must be taken to connect up correctly. Figure 6.21 illustrates this.

Figure 6.22 illustrares a typical circuit, showing multiposition control of a lamp using twin and single TPS.

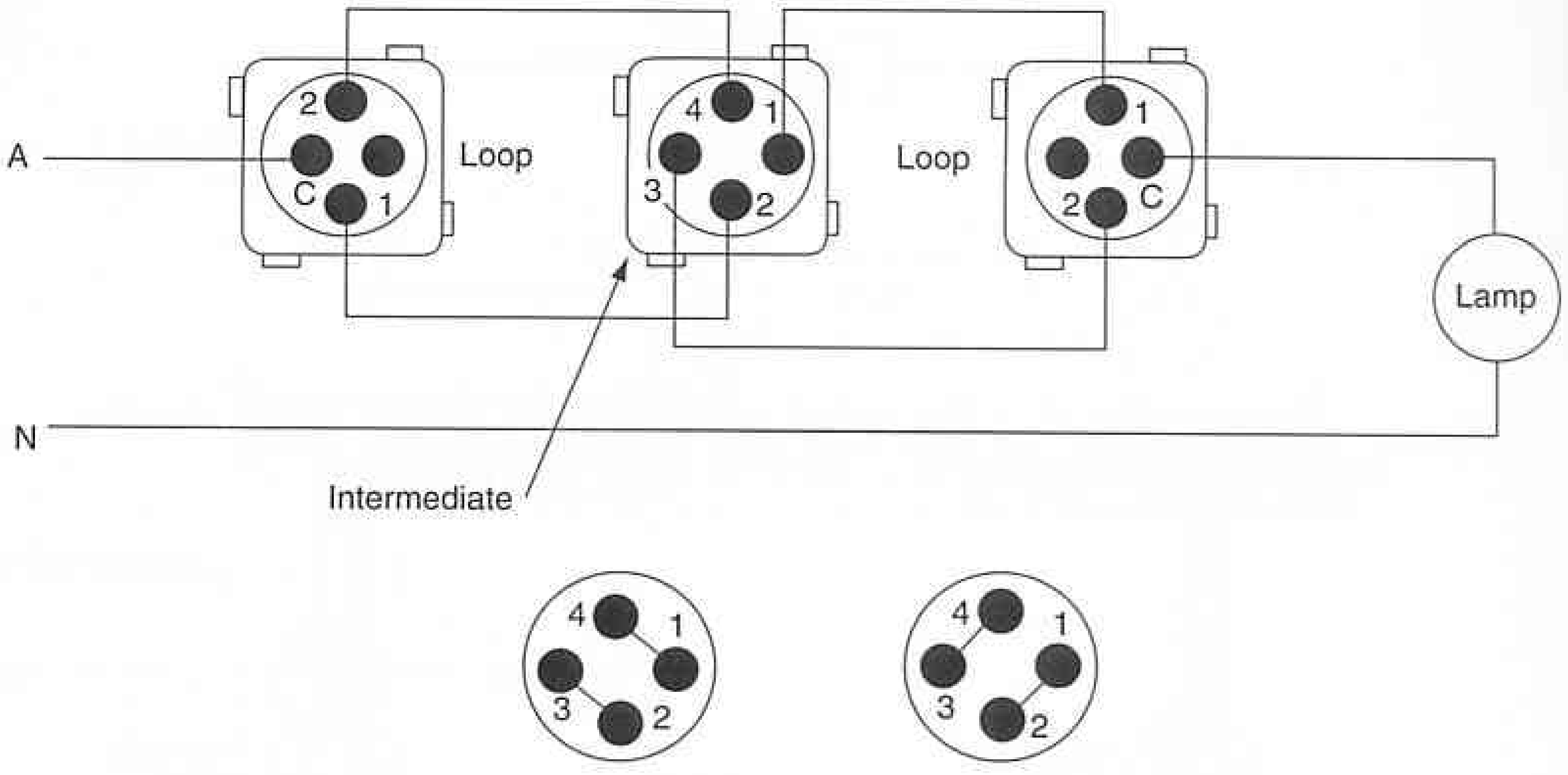


Fig. 6.20(a) *Rear terminal connections of a typical intermediate switch*

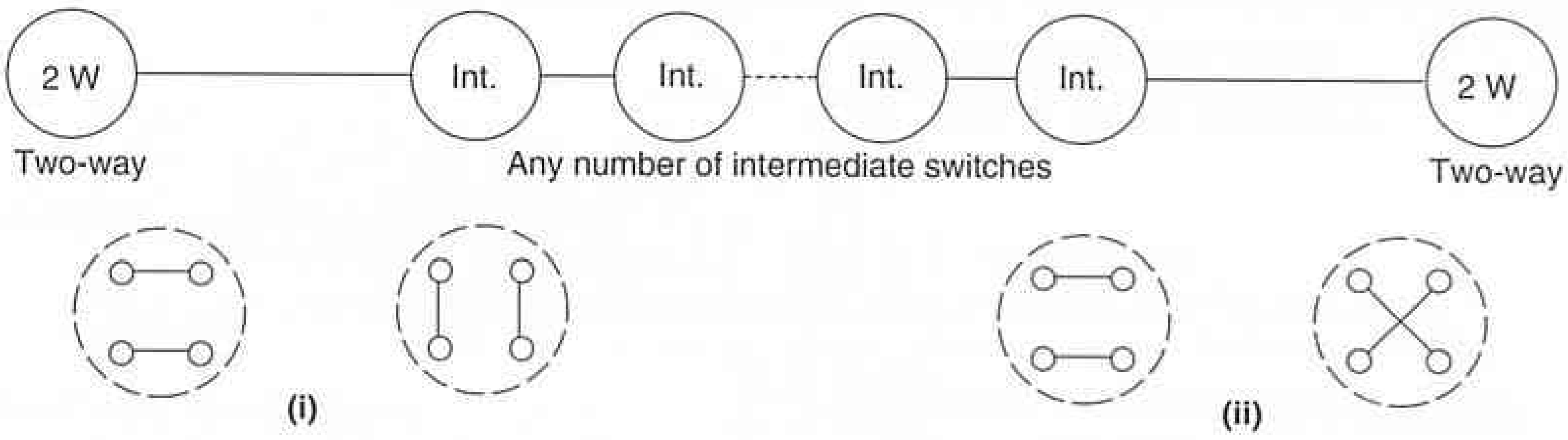


Fig. 6.20(b) *Two common methods of bridging for intermediate switches*

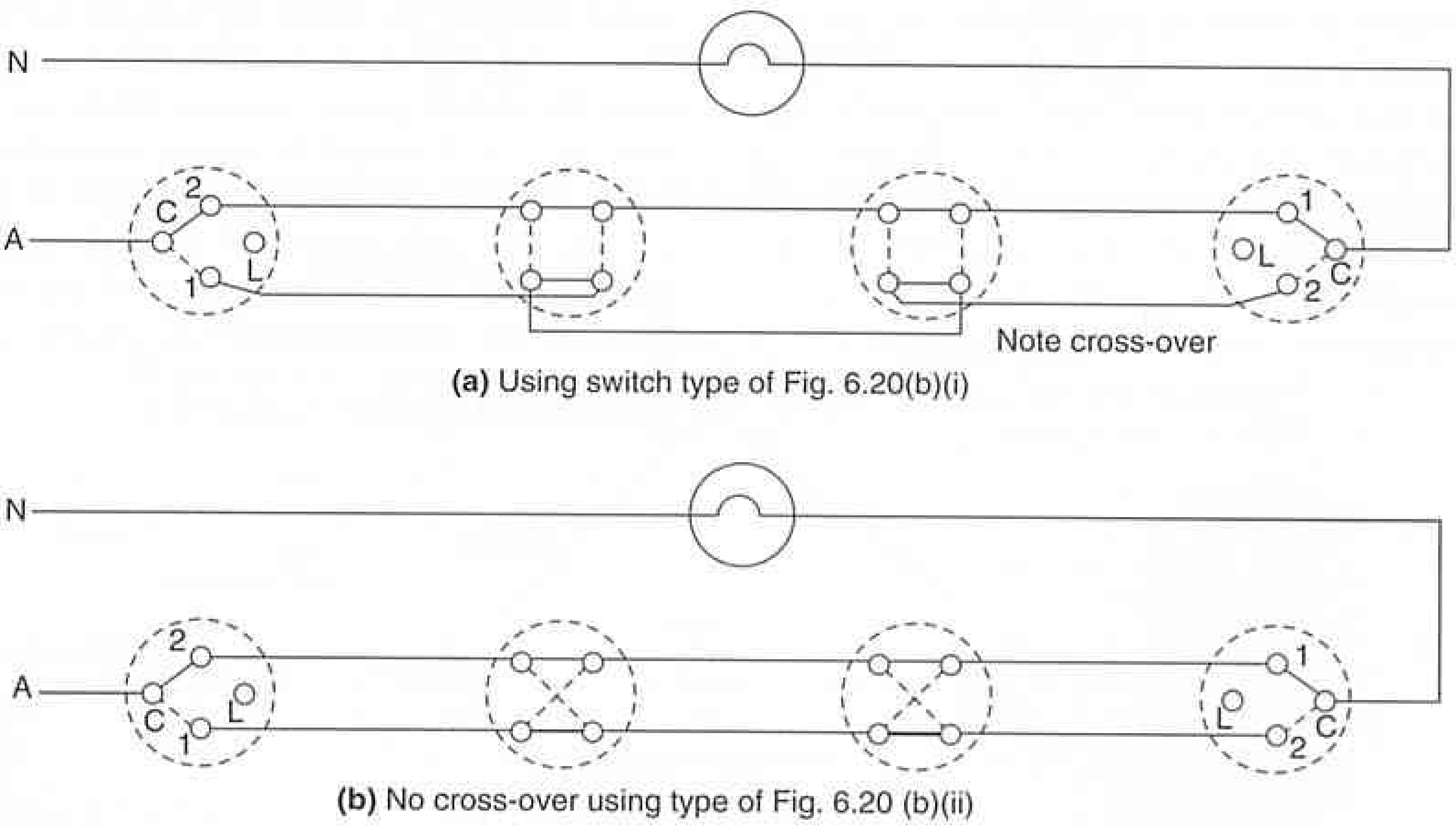


Fig. 6.21 *Connection of 'strap wires' between two-way switches and the intermediate switch depends on the internal bridging of the intermediate switch*

As with other switch types, the extent of the applications for the intermediate switch is dependent on the ingenuity of the electrician; an illustration is given in Figure 6.23.

Many other applications exist where two-way or intermediate switches could be used to advantage. Some are included in Chapter 24 (Volume 2).

Tracing out a circuit using the many combinations

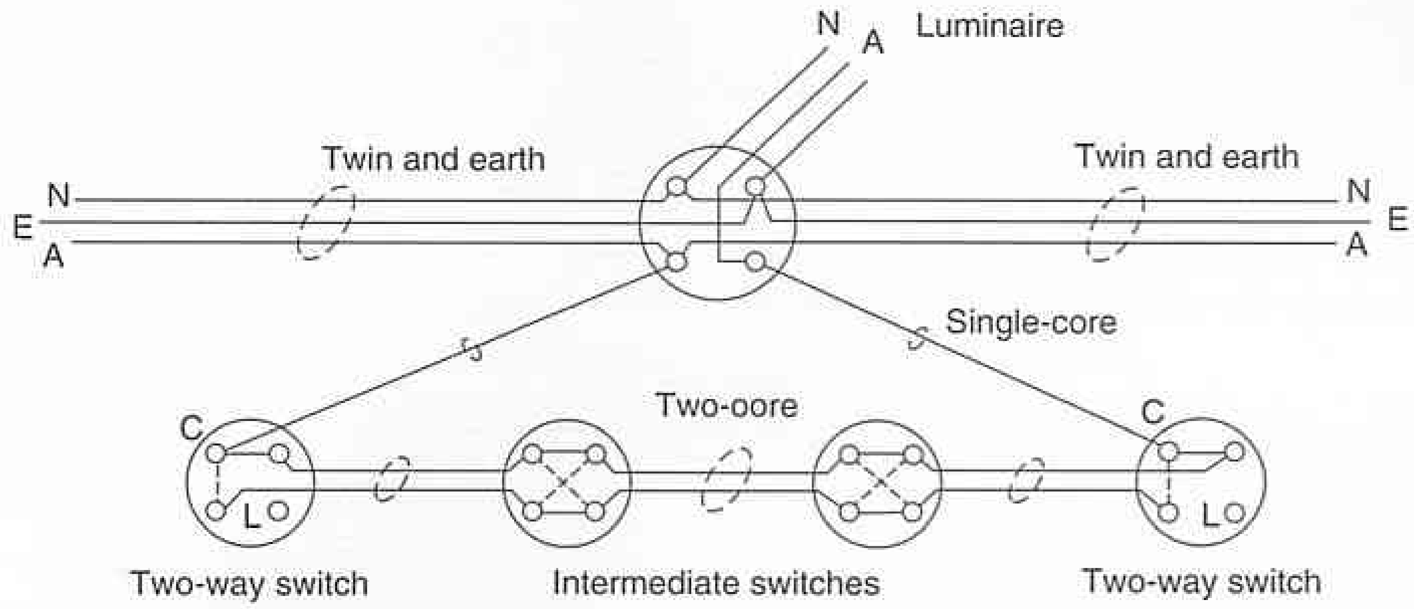
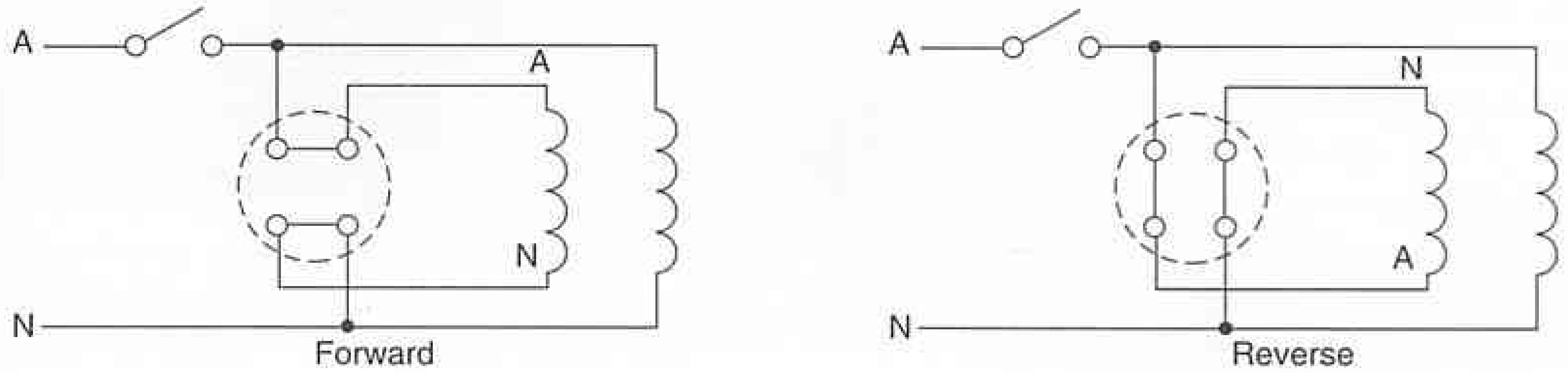


Fig. 6.22 *Multiposition control of a luminaire, using single-core, two-core, and twin and earth cable. Connection of 'strap wires' to intermediate switches depends on the internal bridging positions of switches used*



Intermediate switch reverses supply to starting winding to reverse direction of motor

Fig. 6.23 *An application for intermediate switches*

of switch positions to check whether operating a certain switch will put the load 'on' or 'off' would require multiple and confusing diagrams. A practical method is to draw the circuit plainly and large enough so that portions of matchsticks (say, half a match) may be used to simulate the bridges in the switches. To check, it is necessary only to shift the matches to the alternate switch bridging and trace the circuit through for 'on' or 'off' operation. Try this! Each switch may be 'operated' in turn to ascertain whether it has correctly performed its circuit function.

At this point you are strongly advised to consult manufacturers' catalogues and wiring diagrams for familiarisation with the many switch types available, for example a four-position switch having three separately switched 'on' positions and an 'off'. One manufacturer's catalogue illustrates, with circuits, over twenty different types; hence it should be possible to choose a suitable switch for most circuit applications.

Switch multipliers

A switch multiplier is a device that will convert one existing switch circuit into two separate and independently operating switch circuits without the need for additional switch wires.

A common application is where a lighting point and an exhaust fan in a bathroom or toilet are connected in parallel and controlled by the one switch, and it is desired to control them independently. This would normally involve running extra switch wires, which is often a problem in an existing installation, particularly on an inside wall. Alternatively, it might involve fitting a ceiling switch to control the exhaust fan, which is not always well accepted in modern installations.

The device used to avoid employing the above (sometimes inconvenient) methods of providing the extra control is illustrated in Figure 6.24(a), and the way the device is connected in the circuit is shown in Figure 6.24(b). Each switch of the 'switch multiplier', as it is termed by its manufacturer, utilises opposite halves of the ac cycle to operate a relay through a 'decoder' to switch each load—a surprisingly simple concept. Note the diodes incorporated in the switch mechanisms of Figure 6.24(b). Diodes are also incorporated in the decoder to 'gate' the switched half-cycle to the appropriate relay.

The 'new load' in the diagram could be an exhaust fan or an additional light. Another application would be where it is desired to split a large bank of lighting into two for energy-saving purposes.

Total maximum load for the device is 16 A with a maximum of 10 A on one load: for example,

load no. 1: maximum current 10 A
load no. 2: maximum current 6 A.

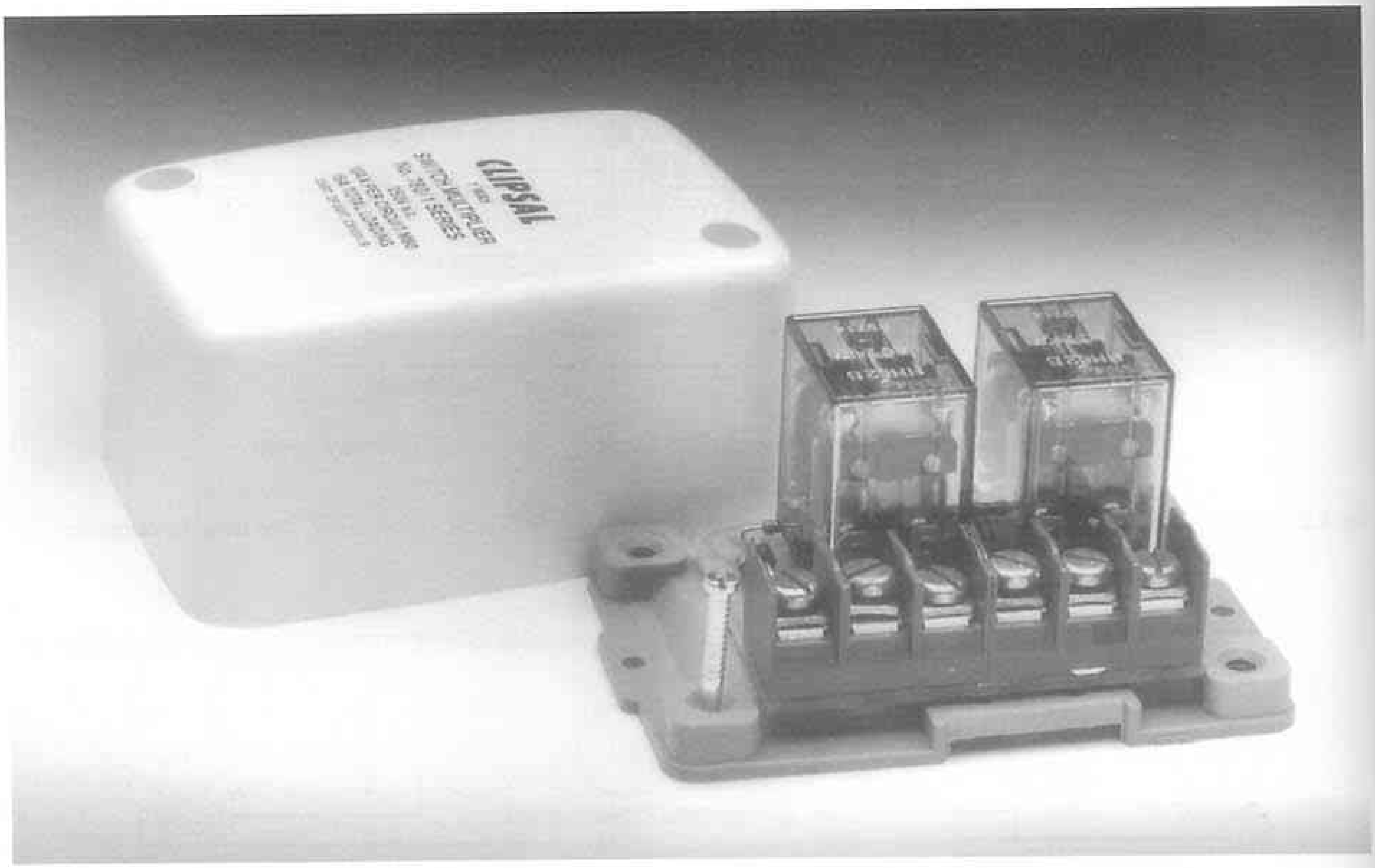
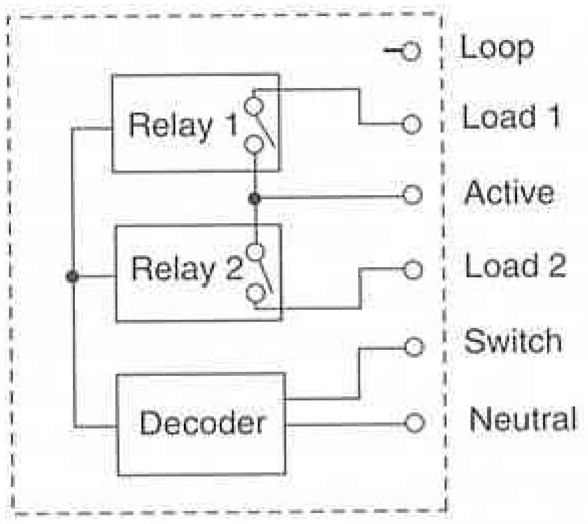


Fig. 6.24(a) *Switch multiplier* GERARD INDUSTRIES



Another type of switch multiplier is available that will enable:

1. conversion of an existing one-way switch into an intermediate switch;
2. control of multiple loads from two positions, one position with single pair of switch wires;
3. conversion of an existing one-way switch to two-way application.

Circuits for these applications are supplied with the product by the manufacturer; the circuit for 3 above is reproduced in Figure 6.25.

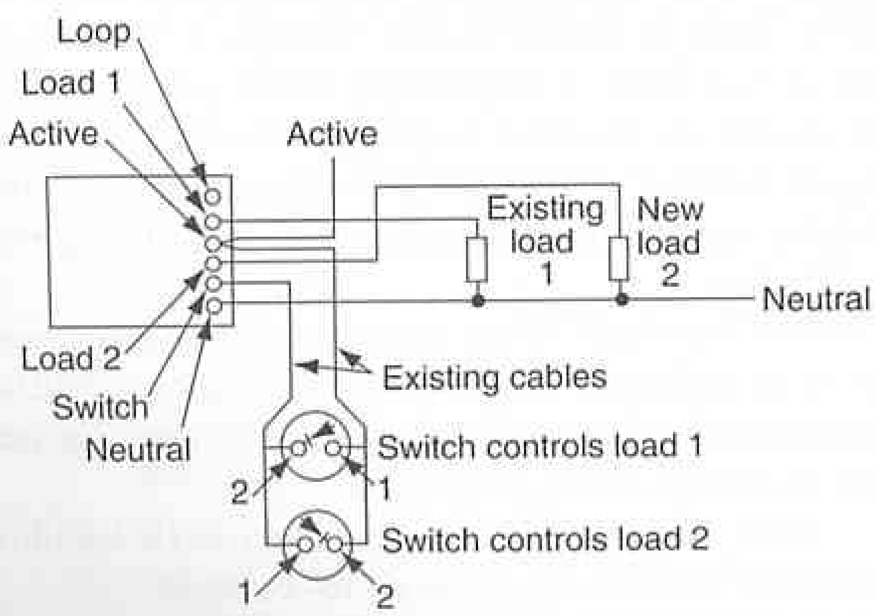


Fig. 6.24(b) *Connections and wiring diagram for switch multiplier* GERARD INDUSTRIES

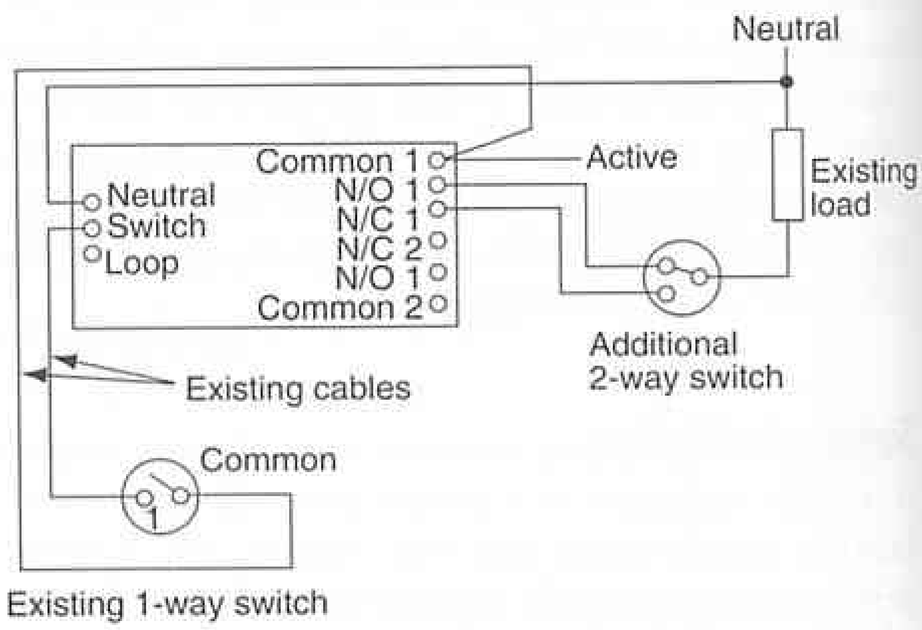


Fig. 6.25 *Conversion of existing one-way switch to two-way application using switch multiplier* GERARD INDUSTRIES

6.5 Power wiring and motor circuits

Power outlets

Power outlets are perhaps the easiest parallel circuits with regard to the wiring, as usually they are looped from point to point as shown in Figure 6.3(b). Twin TPS cable with enclosed earthing conductor is the most popular cable type used for the wiring. Figure 6.26 illustrates the same circuit but using single-insulated cables in surface conduit wiring.

It is appropriate here to emphasise that, for the safety of persons using socket outlets, correct polarisation of the outlets is essential when connecting them to the circuit wiring (see Chapter 11, section 11.8, and *Clause 4.16.8*).

Clause 4.14.5.4 permits the control of a socket outlet in general by a switch up to 1.5 m distant from the outlet, provided that the outlet is visible from the switch. A remote switch at a greater distance than 1.5 m is permissible if the conditions of *Clause 4.14.5.4* are fulfilled. The wiring to one such outlet, using a 'loop-in' method and a junction box, respectively, is illustrated by Figures 6.27(a) and (b). Note that the circuit is essentially the same as that used for the control of a light outlet or appliance from one position.

This chapter is necessarily limited in scope, being simply an introduction to wiring circuits, but the same principles are employed in all the diverse applications met in practice. If you absorb these principles, they may be applied to any of the thousands of applications that occur in an electrician's experience. The principles are universal.

As an illustration of the above statement, a power circuit protected by a 20 A circuit breaker and consisting of ten general-purpose outlets (GPOs) on the end of a long run (say 20 m) of 2.5 mm² cable comprises the maximum number of outlets permitted for this size cable in a factory installation.

Suppose that the factory owner requires one more outlet for convenience and, when told that this would require an extra circuit at considerable cost, expresses the view that 'the Rules' are illogical, as the load would remain the same; the extra outlet is wanted to prevent tripping over long flexible leads. The electrician gets the assurance that, when outlet C is required, outlet D would not be used. The electrician wires the addition as seen in Figure 6.28, leaving the **effective** number of GPOs at ten, as originally (see *Clause 2.9.6* 'Interlocked equipment'). The earthing conductor has been omitted from the illustration for simplicity.

An interesting arrangement for a circuit of GPOs, permissible only as a final subcircuit protected by a circuit breaker in a domestic installation, is the closed-loop or ring circuit. The arrangement involves connecting the GPOs in parallel on a circuit which starts and finishes at the switchboard or distribution board. That is, the circuit closes on itself to form a closed loop (see Fig. 6.29). The ring circuit is used primarily to avoid derating of cables totally enclosed in thermal insulation. It may be also be used to supply a circuit other than GPOs, such as a lighting circuit.

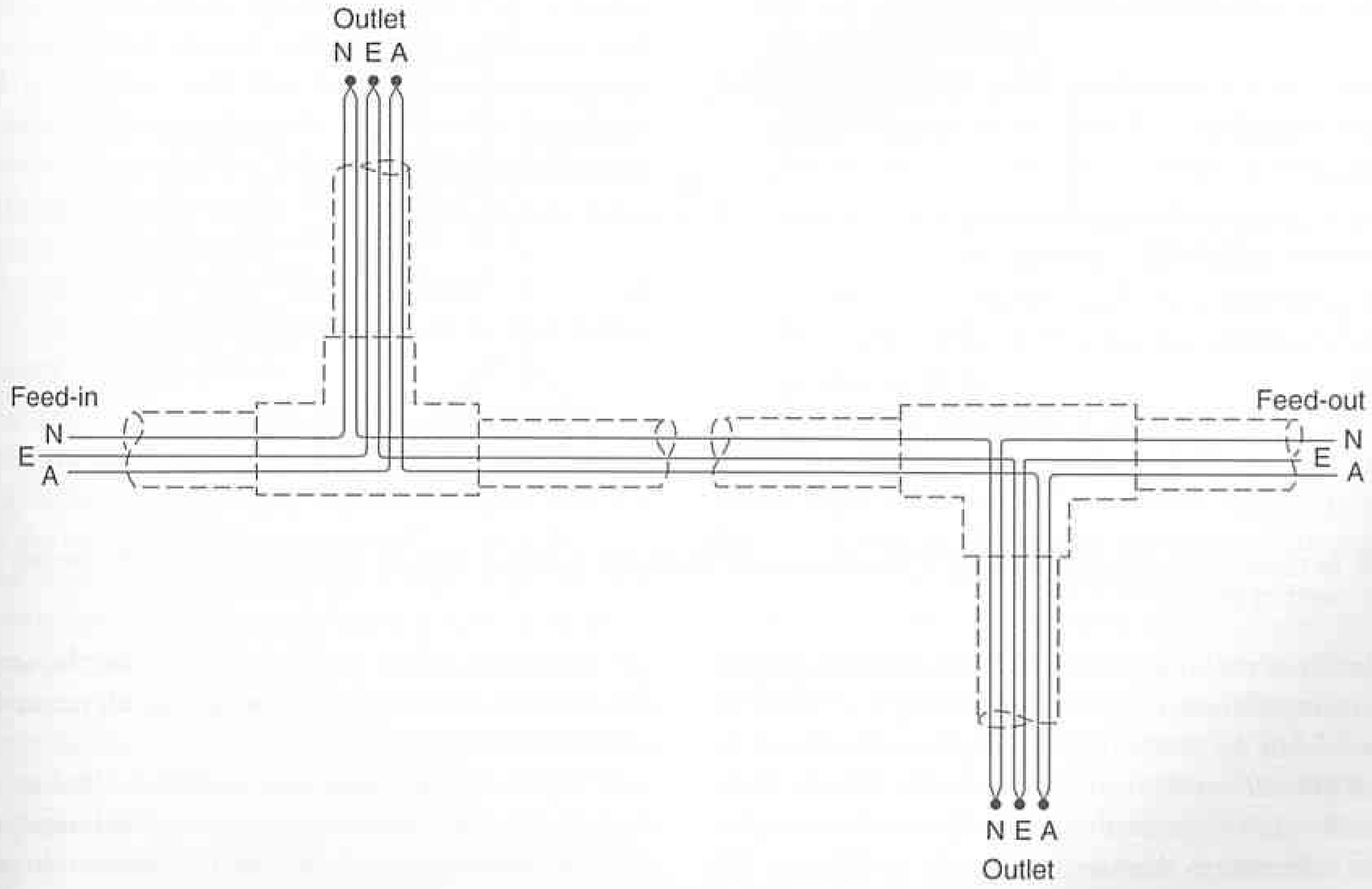


Fig. 6.26 *Wiring power outlets in a surface conduit system*

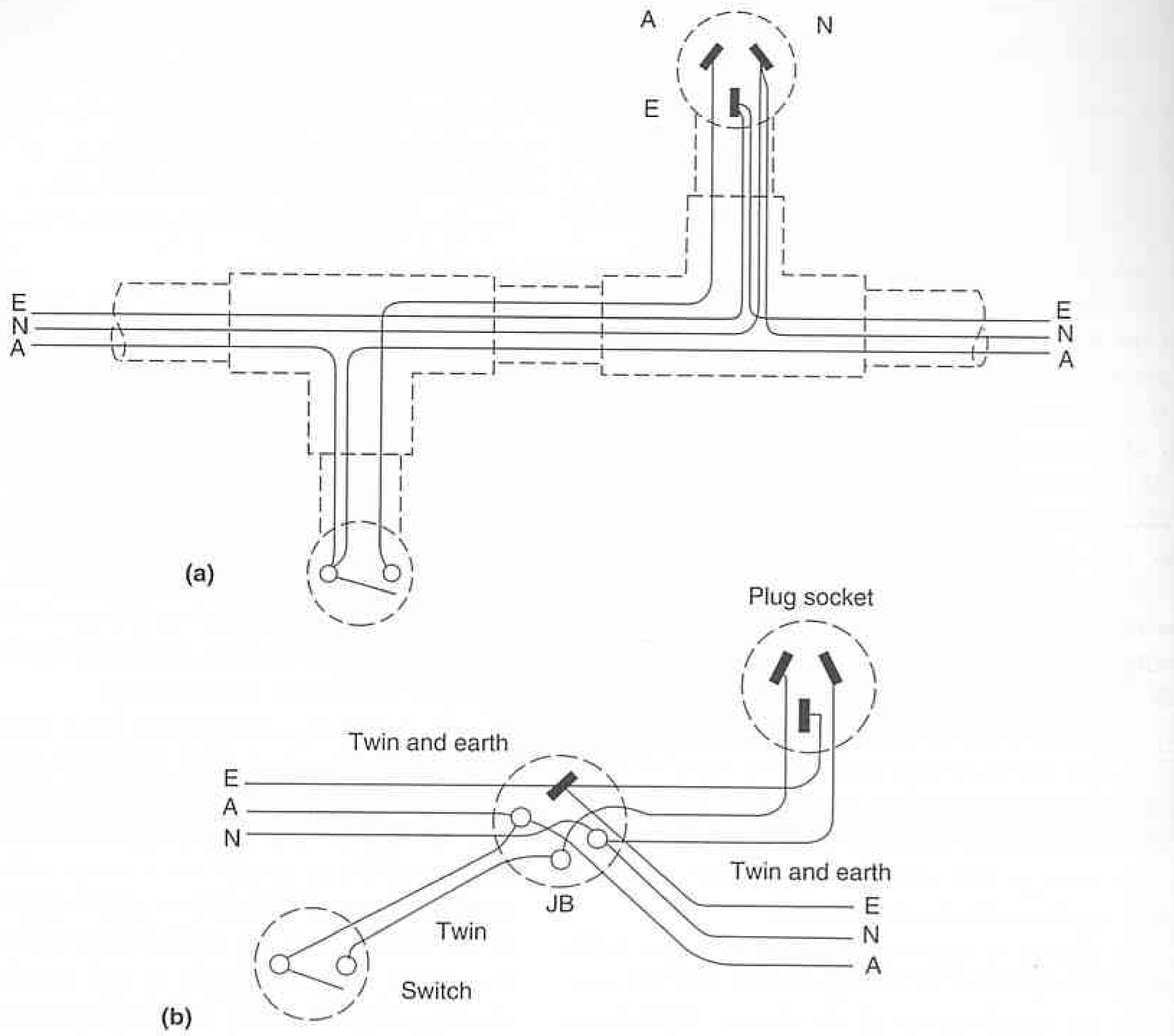


Fig. 6.27 *A power outlet may be controlled by a switch up to 1.5 m distant from the outlet, provided that the outlet is visible from the switch*

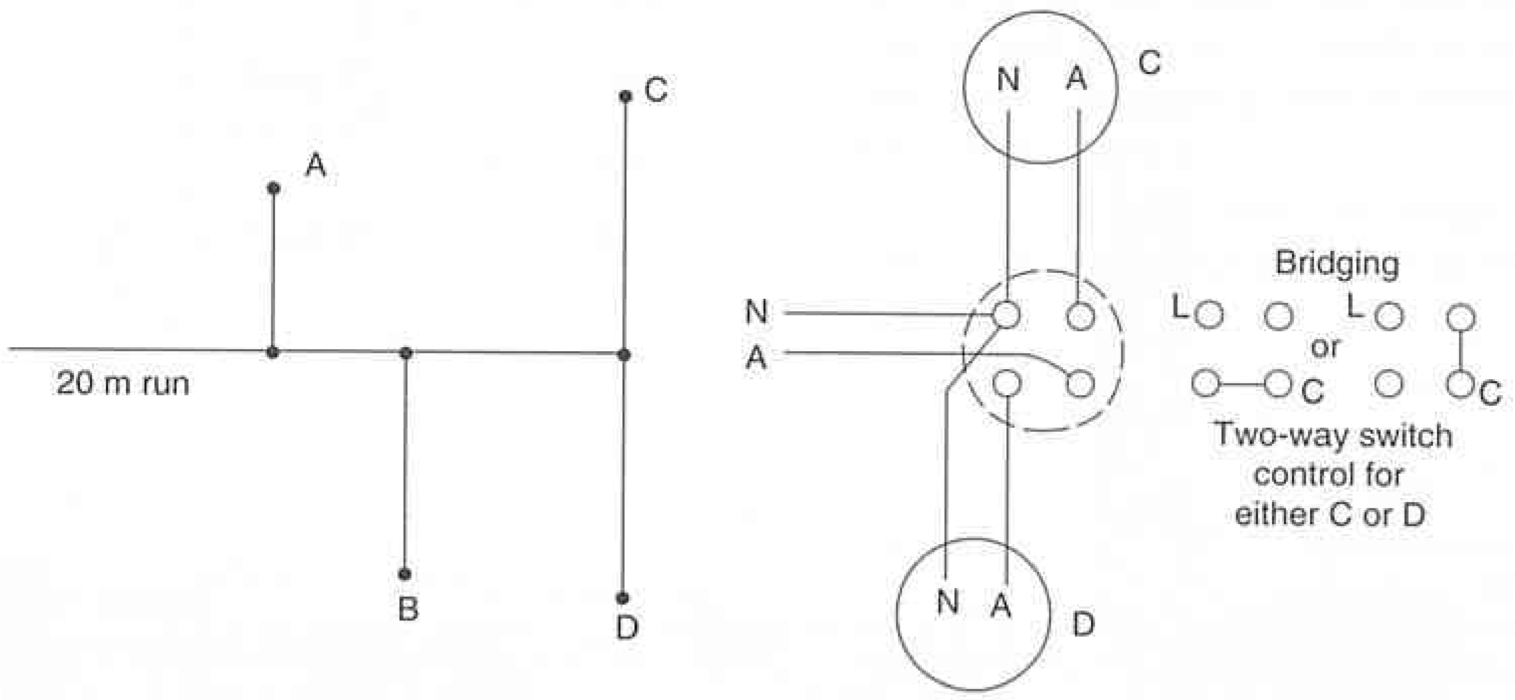


Fig. 6.28 *An additional power outlet installed at D has not increased the effective number of points on this circuit by virtue of the two-way switching provided*

Details of the ring circuit and the conditions applying to its installation are set out in Ruling C.714/91 to *Clause 2.14* of AS 3000. This Ruling may be found in *Doc. 3000 R/1—1991, Rulings to SAA Wiring Rules* (AS 3000—1991) obtainable from Standards Australia. Further reference to this circuit is made in Chapter 16, Volume 2.

Although motor circuits are outside the scope of this chapter, some insight into the wiring requirements of motors is appropriate here.

While circuits supplying socket outlets are often used to connect small single-phase motors incorporated in appliances such as washing machines, refrigerators and portable tools, larger motors are usually supplied by

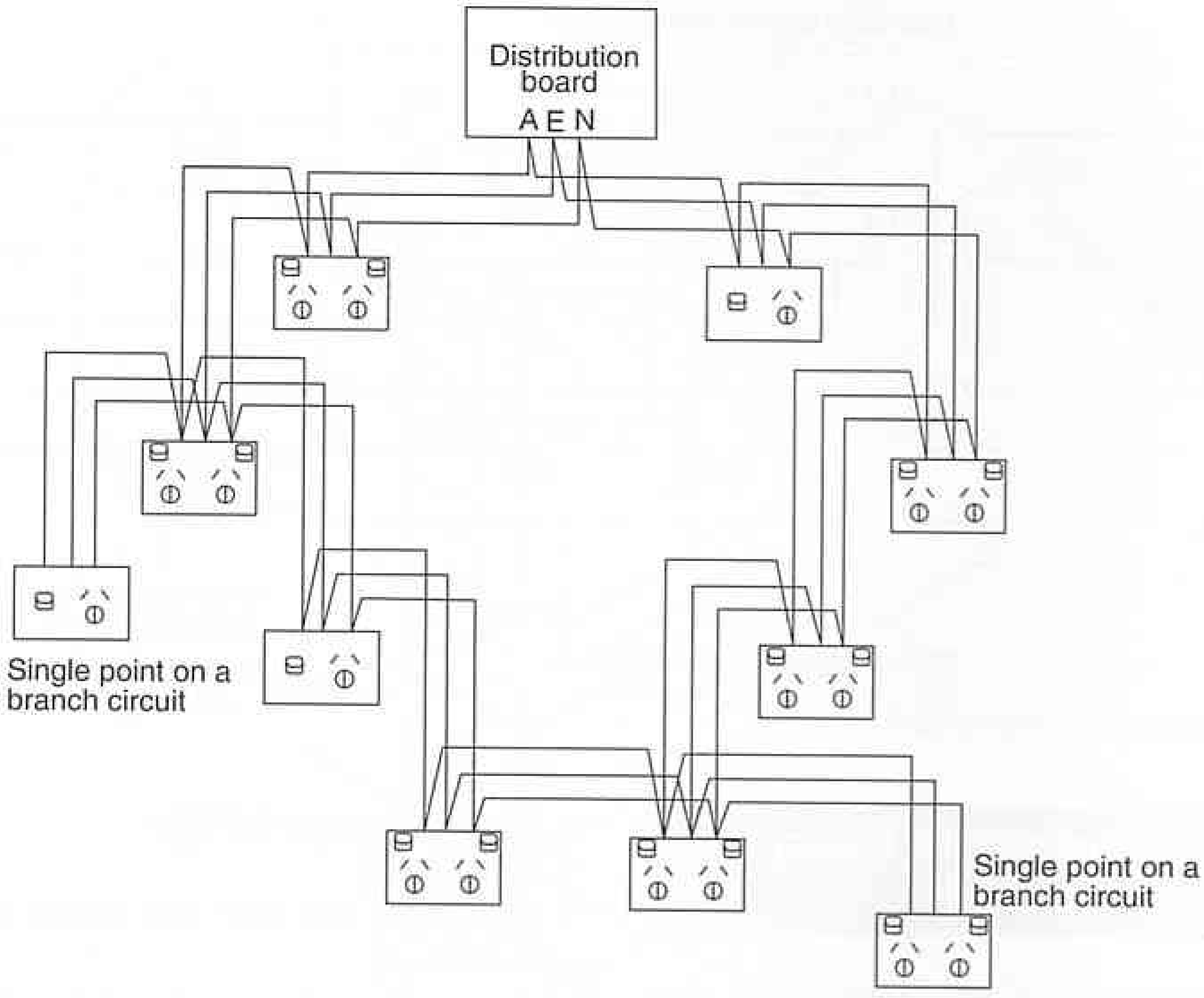


Fig. 6.29 *Ring circuit—a closed loop arrangement*

a separate circuit. Installation of the wiring for motors follows the same sequence as for other circuits, commencing at the switchboard and passing through a protection and control device to the motor terminals.

A wiring circuit for a motor is simpler than that for some other circuits. The installation usually entails a single run of wiring in its enclosure from the supply source, either to an isolating switch adjacent to or on the motor, or to a starter or control panel. The enclosure for a single-phase motor will contain an active and neutral conductor, and that for a three-phase motor three actives. A neutral is not required for the three-phase motor because it is a 'balanced load'. In both cases an earthing conductor may be installed in the same enclosure or run separately.

The number of wires from the starter or control panel to the motor will depend on the motor and starter type. Some examples follow:

Example 1: A motor switched direct on line could have a push-button starter similar to Figure 6.1(d), requiring three lines into L_1, L_2 and L_3 and three lines out to the motor from the terminals U, V and W.

Example 2: A slip-ring induction motor might have a control similar to that of Figure 6.1(a), with three supply lines to L_1, L_2 and L_3 and six motor feeds: three to the stator winding at U, V and W and three to the rotor circuit slip-rings at terminals K, L and M. Although the stator supply is at line voltage, this does not apply to the rotor circuit, and the three rotor cables may be of different current rating, depending on rotor voltage.

Example 3: The star–delta starting method of Figure 6.30 would require six conductors between motor and starter, as the starter's function is to connect the stator windings in star at starting and in delta for running. Because each conductor is carrying phase current of the delta-connected winding in the run position, current-carrying capacity of the cable from the starter to the motor may be reduced to 58 per cent of the rated motor current, as indicated by *Clause 2.14.4(b).*

Example 4: Both the auto-transformer and line resistance types of starter require three line conductors and three motor feeds, all of the same current-carrying capacity.

It can be seen that, for the types of three-phase ac starters discussed here, the general requirement is three lines in and three or six motor feeds out, depending on the type of starter being used, plus any additional control or protective devices.

During an electrician's training topics of motor control and protection, including dc motors, special motor types and control, are usually included in both the electrical-trade theory and the electrical drawing segments of the off-the-job training syllabus.

Other topics not dealt with in this chapter are basic heating-control circuits and basic circuits relevant to community lighting control and light dimming. These are dealt with in Volume 2, Chapters 21 and 24 respectively. Some metering and switchboard wiring circuits are included in Chapter 18, and some circuits used in the installation of residual current devices (RCDs) are included in Chapter 14 (Volume 2).

11

Testing and checking

In this chapter you will learn about testing electrical circuits and systems, including:

- reasons for testing
- testing principles and the difference between dead and live testing
- devices and accessories used in testing
- testing safely
- general requirements for testing an installation
- testing techniques
- appliance testing.

11.1 Introduction

During the installation of wiring and equipment, tests are carried out from time to time to check the circuitry and the condition of the installation, thus avoiding costly repairs or adjustments later. Once the installation is complete, and prior to its connection to the supply, final testing and checking is a requirement of regulations and the assurance of quality of an electrician's work.

An existing installation needs similar testing periodically, or whenever routine maintenance checks are made.

If a section of wiring or equipment develops a fault while in service, it becomes necessary to commence test procedure for the isolation of the fault immediately. Tests are required again after repairs or after additions to an installation. Whatever the situation, the final outcome of testing and checking an installation is to ensure that the following apply:

- that the earthing system is complete and continuous, and its resistance is sufficiently low to meet requirements of the regulations. This is to ensure that the circuit-protection devices such as circuit breakers and fuses operate to cut off the supply in the event of a short circuit between active conductors and earth.
- that the installation resistance between all live parts and earth is adequate and sufficiently high to meet the requirements of the regulations. This is to ensure that people using the electrical installation cannot come in contact with live parts and receive an electric shock. Also, it helps protect against damage and fire due to leakage or short-circuit currents.
- that the active, neutral and earthing conductors are connected to the correct terminals throughout the installation. Incorrect connections can result in the earthing system becoming 'live' or the terminals of appliances, lampholders and the receptacles of socket outlets remaining 'live' when they are switched 'off'.
- that all circuits are connected correctly to ensure that there are no interconnections of live conductors between different circuits or short circuits between conductors. An installation where there is an interconnection of live conductors between different circuits may appear to operate correctly. However, an electrician working on the installation at some future time may be exposed to an electric shock, for instance when the neutral conductor of an interconnected circuit is open-circuited, such as at the terminals of a batten holder. This situation might arise even though isolation procedures appeared to prove that the circuit was 'dead' and safe to work on.
- that switchboard equipment is marked correctly, in particular that active conductors and their corresponding neutral conductors are identified. This is to help ensure the safety of personnel carrying out work in the future on the installation or maintenance on equipment by identifying circuits and their protective devices for the purpose of isolating them from the supply.
- that the installation operates as intended. This is to ensure that all switches operate correctly; the rating of circuit protection devices, switches and control equipment is adequate; the current-carrying capacity of the circuit cables is sufficient; the voltage drop in the installation is not excessive; residual current devices operate under fault conditions; metering arrangements and connections are correct; and wiring and equipment are not damaged and are adequately protected against risk of damage.
- that the completed installation complies with the *SAA Wiring Rules*, local regulations, any relevant code, such as AS 1735: *SAA Lift Code* for example, and customer specifications.

This chapter is an introduction to simple methods used for testing and checking low-voltage installations.

11.2 Testing principles

Underlying the ability to test electrical circuits and find faults is a sound knowledge of Ohm's Law and the characteristics of series and parallel circuits, as well as a general understanding of how the wiring for the various types of circuits is arranged. All electrical testing methods employ the same basic principle of connecting an electrical energy source to a circuit to be tested and using electrical indicators or meters to observe how the circuit behaves. From these observations deductions are made as to whether a circuit is faulty, and if so the nature of the fault; or whether the circuit is sound, functions as intended and is safe to use.

For example, a battery and an audible device connected in series can be used to test that the conductors of a circuit are electrically continuous and have no open circuits. In this case the battery is used as the electrical energy source, with the audible device indicating whether a current is flowing in the circuit. If the device sounds, current must be flowing in the circuit and therefore the circuit must be continuous, and there is no open circuit in the conductor (see Fig. 11.1).

Many testing devices are designed with an inbuilt energy source and indicator or meter. For instance, an ohmmeter, used to measure resistance, has a battery as an energy source which is connected in series with the meter movement within the meter. An ohmmeter could have been used instead of the battery and audible device in the previous example. A zero reading on the ohmmeter indicates that the conductor is continuous.

Testing with audible devices or an ohmmeter to indicate whether a conductor or circuit is electrically

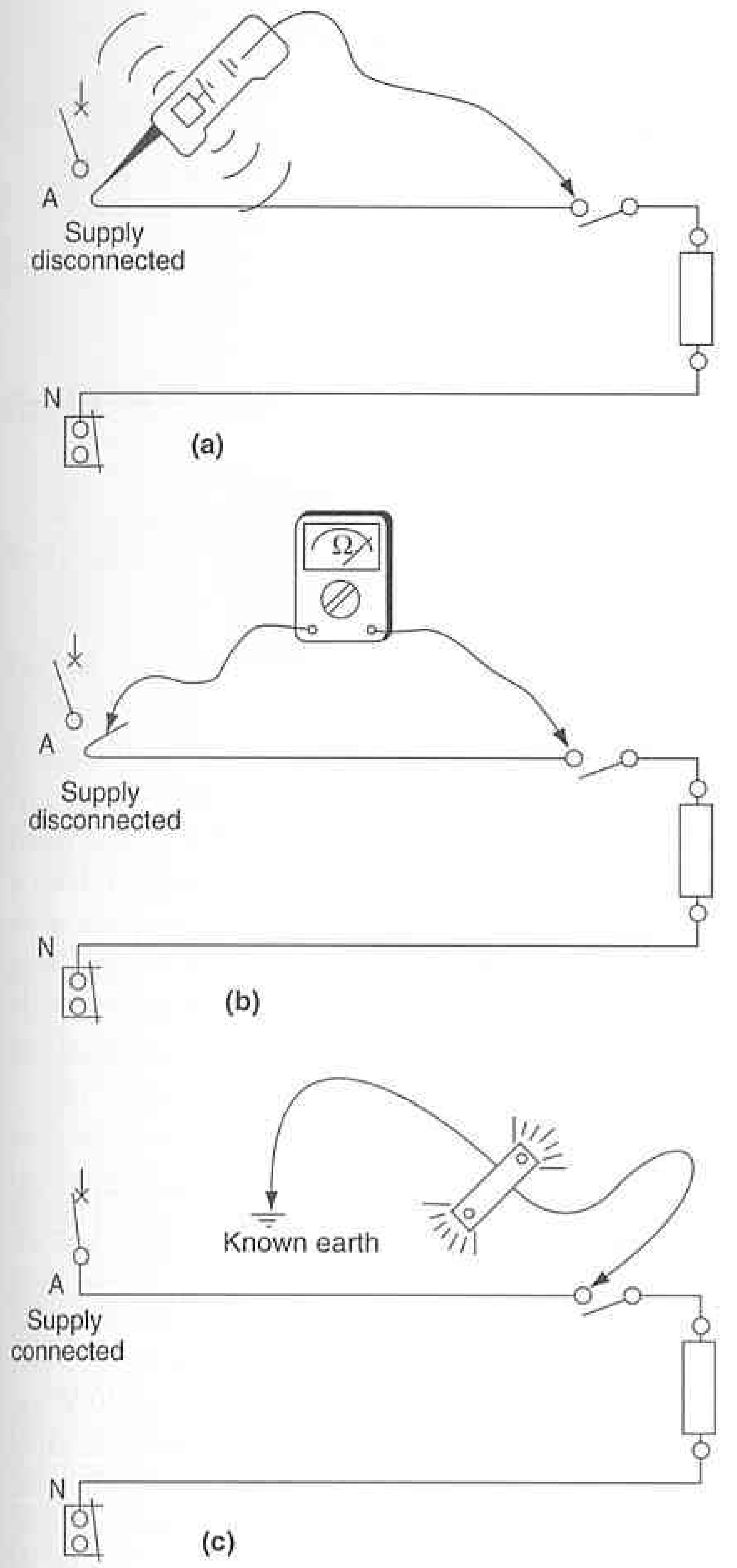


Fig. 11.1 *Testing the continuity of a circuit conductor:* **(a)** *using a popular tester with inbuilt audible device and battery;* **(b)** *using an ohmmeter;* **(c)** *using an approved test lamp*

continuous is referred to as **continuity testing**, and is used:

- to check that the earthing system is electrically continuous and of low resistance
- to identify active, control and neutral conducts prior to connecting them to an accessory or appliance
- to check that the wiring of a circuit is connected to the correct terminals at an accessory or appliance
- to check that there are no short circuits in a new installation or for locating a short circuit that may have developed in an existing circuit or equipment
- to check that there are no interconnections between circuits
- to identify a circuit by measuring its resistance
- to locate high-resistance connections that may have developed in a circuit while in service.

An important test carried out during the termination of some cable types and on completion of an installation or in fault-finding is to check that the insulation between active conductors and earth has not broken down or will not break down under the stress of the normal operating voltage. This is done with a special ohmmeter known as an 'insulation-resistance tester', which has an inbuilt energy source that produces test voltages of 500 V dc or 1000 V dc. Testing devices with an inbuilt energy source are used with the supply disconnected from the circuit under test, and this method of testing is generally referred to as **dead testing**. Dead-testing methods are preferred by many authorities for testing new work prior to connecting to the supply.

Another energy source that is used in testing is the normal electricity supply itself. In this method of testing, the supply is connected to a circuit to be tested and voltage indicators, voltmeters or ammeters are used to observe how the circuit behaves. Once again, this time with the supply connected, a voltage indicator such as a test lamp can be used to test that the conductor is continuous. Testing undertaken with the supply connected to the circuit is referred to as **live testing**.

It is important to apply a sound knowledge of circuit theory and an understanding of wiring arrangements to the testing process so that the test applied to a circuit and the interpretation of the test results leads to the correct diagnosis of any fault. For example, a defect may occur in a circuit with no apparent effect on the operation of the circuit.

In Figure 11.2, the neutral conductor has developed a short circuit to earth at B and an open circuit at A. The circuit appears to operate in a normal fashion, but the condition is dangerous. Testing devices such as test lamps or measuring instruments must be employed before the faulty condition can be detected.

11.3 Testing devices

Visual indicators

The largest group of testing devices used by electricians comprises those that give a visual indication of the effect being tested. Perhaps the simplest and most useful for the practising electrician is the test lamp device of Figure 11.3, which usually consists of two 240 V lamps connected in series. It may be used:

- to detect the presence of a potential (i.e. whether the point being tested is live);
- to test polarity (i.e. the location of actives, neutral and earth terminals or supply points);
- to locate blown fuses;

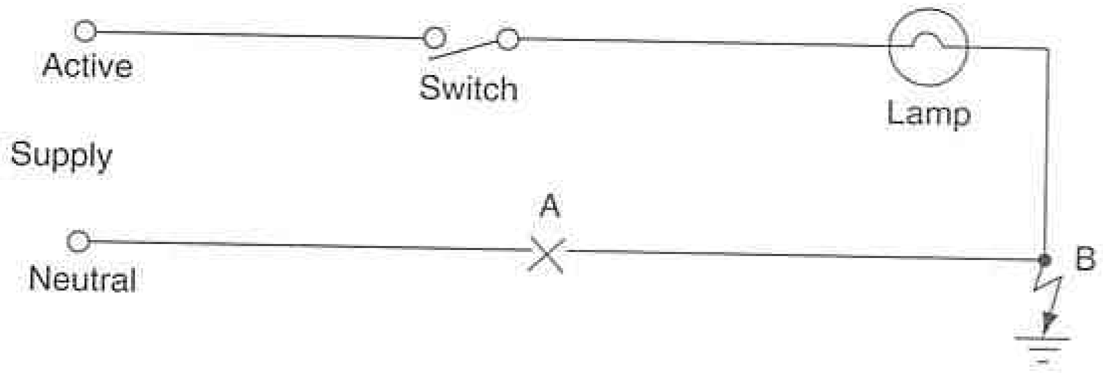


Fig. 11.2 *Dangerous condition in a faulty circuit that appears to function normally*

Fig. 11.3(a) *480 V test lamp* QUEENSLAND ELECTRICITY COMMISSION

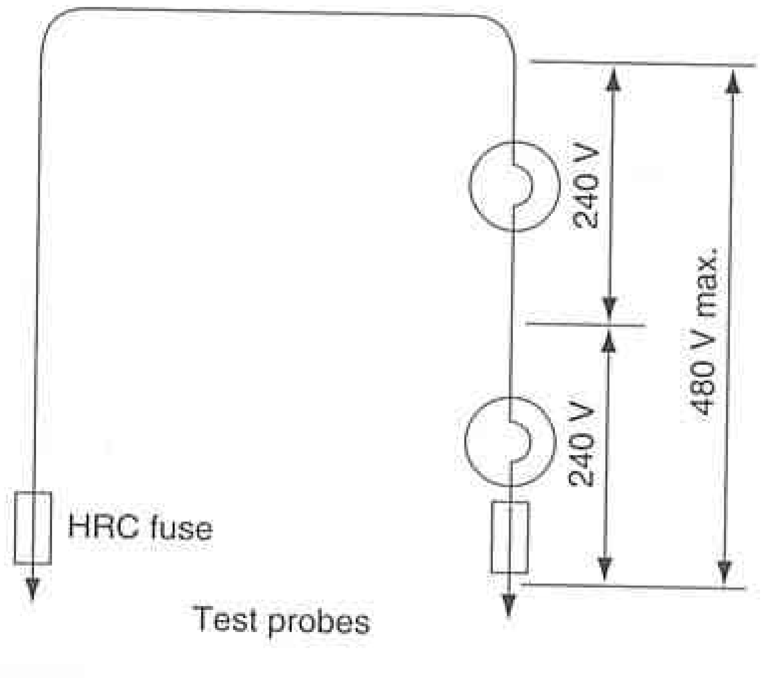


Fig. 11.3(b) *The two 240 V lamps housed in the plastic moulding are connected in series*

- for checking like or similar phases when 'phasing out' preparatory to paralleling two supplies;
- for other tests, dependent on the background knowledge and ingenuity of the electrician.

The lamp testing set illustrated comprises low-wattage lamps of equal power rating, not greater than 25 W per lamp, and fused probes. Because this set is designed for insertion into the socket terminals of a socket outlet, the metal exposed at the tips of the probes is greater than the 2 mm recommended and may need to be used with caution in some circumstances.

A single lamp type may be used when testing on ELV circuits such as 12 V or 32 V systems. A single 240 V lamp type should never be used, as it is dangerous to the user and may also give an incorrect interpretation of a fault condition, such as that shown in Figure 11.4. In this case a test of voltage to earth using a 240 V test lamp would indicate apparently normal conditions existing at the three load terminals. If the lamp leads were placed across the blown fuse in L_1, the lamp would burn out violently, as a potential of 415 V would be impressed across the fuse terminals.

Approved test lamps, correctly handled, are a safe live testing device as their impedance and rating are such that a user cannot mistakenly cause a short circuit. One drawback is that when testing circuits with residual current protection they draw sufficient current to trip the device when testing between active and earth.

A device used for the detection of electrical potential or for polarity testing is the 'neon test pencil'. A simple form of this is shown in Figure 11.5, but it is manufactured in a variety of types and designs. Provision is usually made for a test lead to be attached to the cap of the neon test pencil, but this is rarely used because the neon tube will glow on contact with an active without the lead. The intensity of glow will increase if a finger is placed on the cap or if the cap is earthed.

Care should be taken to see that the tube is never used without the correct current-limiting resistor shown.

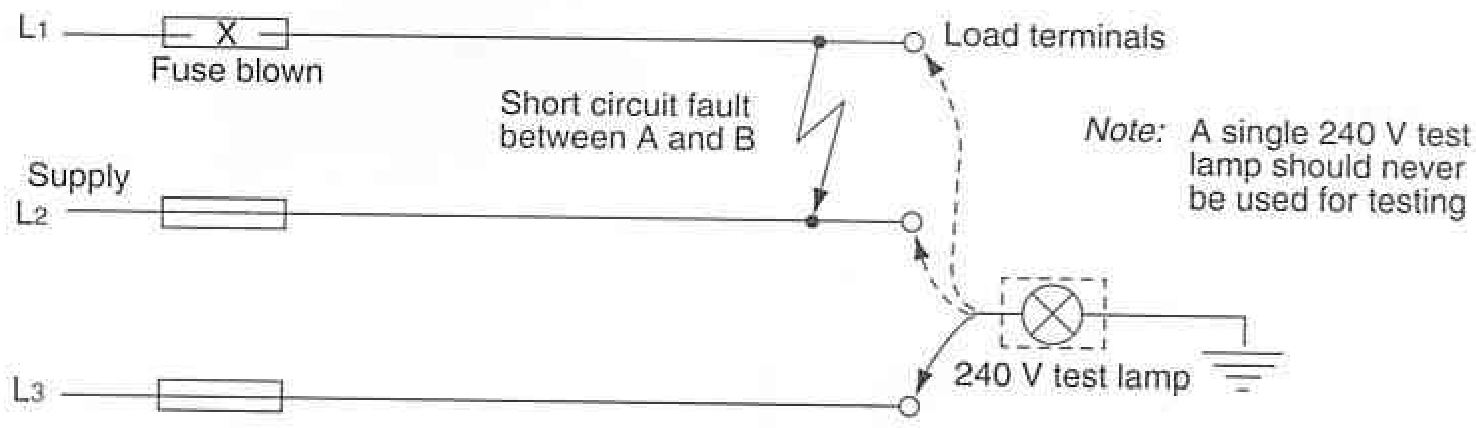


Fig. 11.4 *The short circuit in this diagram causes misleading test results for the type of test shown*

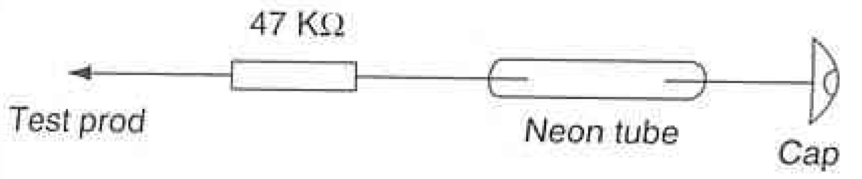


Fig. 11.5 *Neon test pencil (diagrammatic representation)*

It should also be noted that with this type of tester a faint glow is evident even on very low voltages, which could lead to misinterpretation—especially if the tester is used in a dark place. The authors do not consider the neon test pencil to be a particularly safe testing device, preferring the voltage indicator of Figure 11.6. However, a survey of some states indicated an extremely low incidence of accidents using a neon test pencil.

In common with most other testing devices, the neon tester may be damaged if it is dropped, and should be checked on a known live source before and after use to test for the presence or absence of voltage.

The high-impedance tester in Figure 11.6 gives an audible signal and a visual indication of the presence of voltage.

Note: Some light switches and power outlets incorporate a neon indicator, which is a visual indication of the presence of supply at the terminals of the switch or outlet. However, if the neon indicator does not glow, it cannot be assumed that there is no supply at the outlet; the neon indicator could be inoperative.

Fig. 11.6 *High-impedance tester* QUEENSLAND ELECTRICITY COMMISSION

Meters

It is appropriate at this point to make a brief comparison between analogue and digital instruments. Because an analogue meter operates by moving a pointer across a calibrated scale, the reading is subject to parallax error. The measured quantity on a digital meter is displayed as numbers and therefore not subject to this problem.

An inherent property of the analogue meter is that it provides an immediate visual indication through the movement of the pointer. This can be an advantage where an indication above or below a particular value is required and not a precise measurement. For example, full-scale deflection of the needle of an ohmmeter set to measure low resistance would show that the circuit or conductor under test is electrically continuous without the need to take an exact resistance reading. This can improve the efficiency of the testing process, and analogue meters are thus preferred by many electricians for testing new installations. However, when testing to determine a specific resistance, such as in fault-finding, the digital readout may be more suitable.

Voltmeters and ammeters

The voltmeter is another testing device that detects the presence of an emf, but it also indicates the magnitude or value of the emf in volts and for this reason is termed a 'measuring instrument'. Being connected between the points across which the voltage is to be measured, it is said to be shunt or parallel connected and indicates the voltage between the points.

The instrument must be suitable for the supply (ac or dc) and be set on the correct range or voltage rating. For example, an attempt to measure 240 V with a 10 V instrument will probably destroy the movement of the meter, which is expensive to replace and, more importantly, may produce a safety hazard.

The ammeter is an instrument for measuring the rate of charge movement or current flow in a circuit. When connected in series with the load, it indicates the value of the load current. Ammeters, in common with other measuring instruments, are made in a wide selection of ranges and designs. On ac circuits, both ammeters and voltmeters may have their range extended by the use of suitable current and voltage transformers respectively.

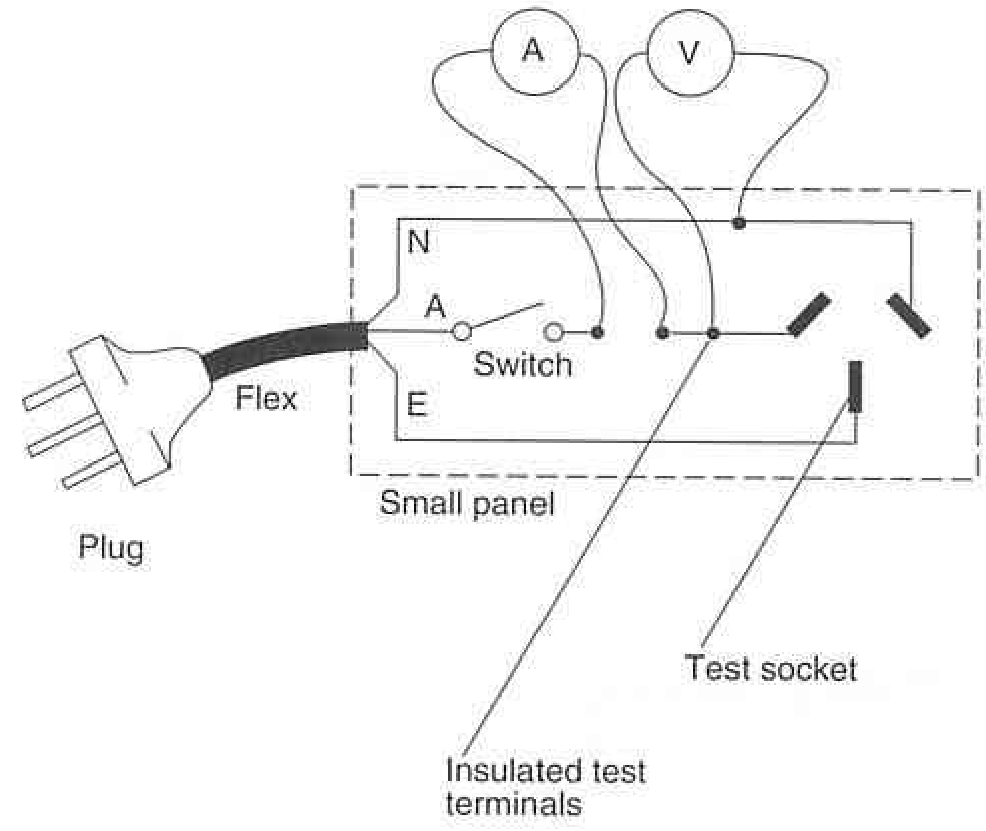


Fig. 11.7 *Simple test panel for metering current and voltage on an appliance*

Fig. 11.8 *Digital-type clip-on ac meter* NILSEN INSTRUMENTS

Figure 11.7 shows the connection of an ammeter and voltmeter through a simple test panel. The appliance being tested plugs into the test socket, and the panel is in turn plugged into the supply outlet.

Provided that a portion of the circuit wiring is accessible, values of voltage, current and power in a single-phase or balanced three-phase circuit may be measured without disconnecting the circuit or disturbing the wiring, by the use of a clip-on type of instrument, such as that illustrated in Figure 11.8. This digital-type meter is provided with analogue output terminals as a standard feature, and in this versatile measurement and testing device the instrument transformer and the meter are combined in the one hand-held instrument. The clip-on meter is the most commonly used type of meter in field testing the load conditions of circuits and appliances.

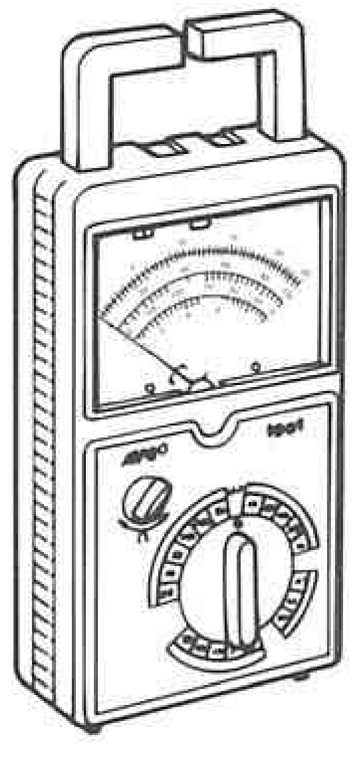


Fig. 11.9 *Typical multimeter* NILSEN INSTRUMENTS

Multimeters and ohmmeters

For convenience, the functions of several measuring instruments are sometimes combined and incorporated in the one instrument. This instrument has many trade names but is most widely known as a multimeter. A typical analogue multimeter, described by its manufacturer as a 'robust toolbag instrument', is shown in Figure 11.9. A wide range of voltage, current and resistance measurements is possible with the instrument shown.

Figure 11.10 illustrates a more expensive but very versatile type of testing instrument, termed an Insulation Polytester by its makers; it is included to illustrate the type of testing possible. The clip-on current transformer shown in Figure 11.11 is used in conjunction with the meter movement of the Polytester to measure ac. This is in effect a current transformer, which utilises the circuit conductor as the primary and has an ammeter connected across the secondary. Note the possible ranges of measurement shown below the appropriate diagrams included in Figure 11.11.

The measurement of resistance values in the field may be broadly divided into:

- measurements of relatively low resistance, such as earth-continuity resistance or the resistance of a heating element or motor winding;
- measurements of high resistance, typified by tests of insulation resistance.

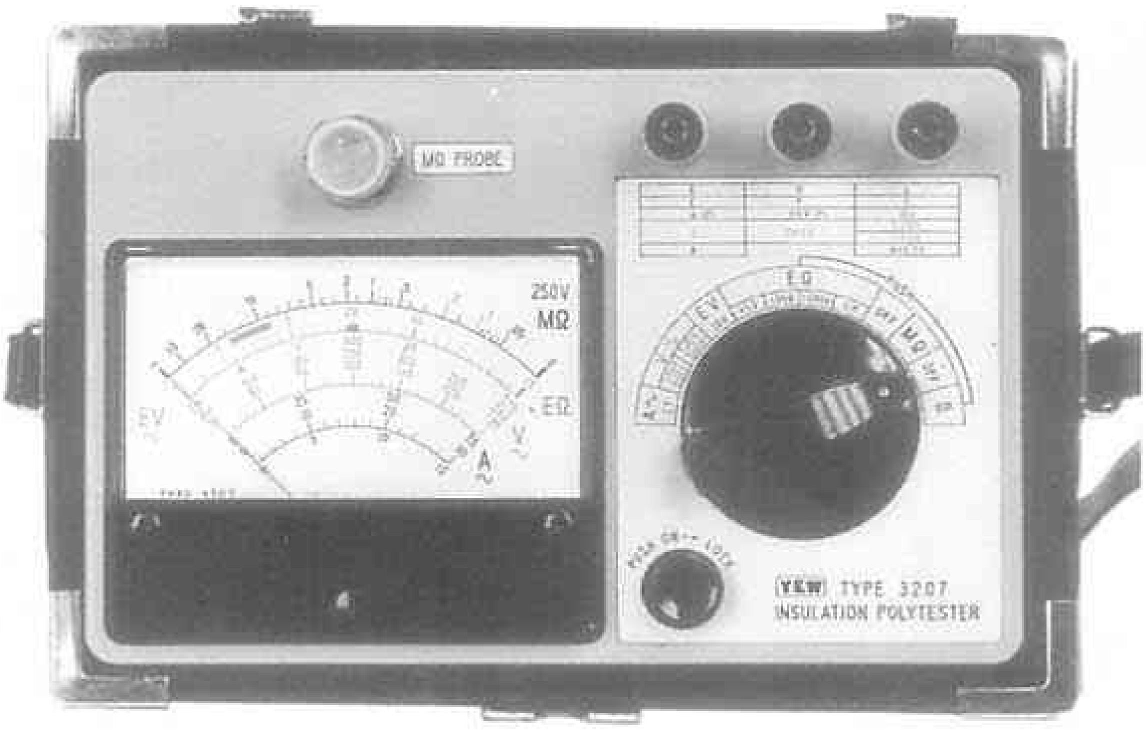


Fig. 11.10 *Electronic multifunctional field tester capable of use for the five steps of measurement illustrated in Fig. 11.11* NILSEN INSTRUMENTS

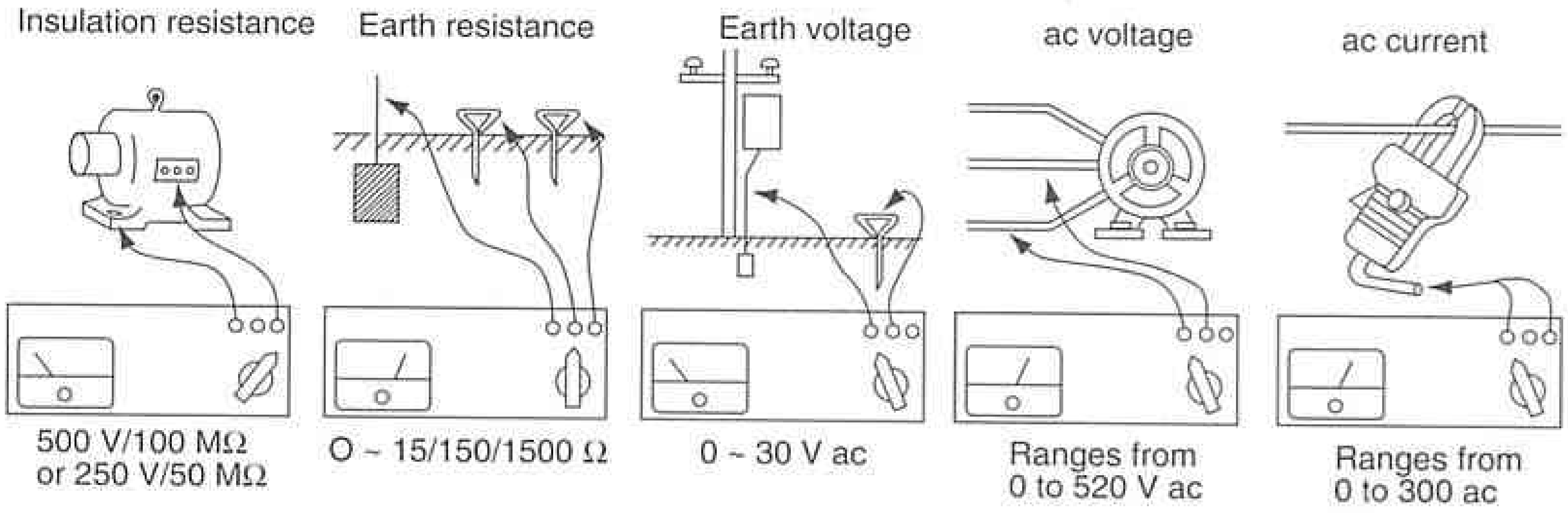


Fig. 11.11 *Multifunctional field tester applications* NILSEN INSTRUMENTS

A wide range of resistance measurement is possible with the multimeter-type instrument if it is used intelligently, with an appreciation of its practical limitations. It is pertinent here to point out the importance of electrical theory background, using the multimeter as an example.

The multimeter of Figure 11.9 is quite adequate for measurements of resistance, but does not necessarily **test** a circuit to the required or specified voltages. Insulation resistance of a 250 V circuit must be measured with the insulation under a stress of 500 V dc (see *Clause 1.5.2*). The type of multimeter illustrated rarely has a testing voltage of more than 9 V. The 500 V insulation tester shown in Figure 11.14 would be suitable for this test, or the Polytester illustrated in Figure 11.10, which can test at 250 or 500 V.

On the other hand, if a 500 V testing voltage were applied to the 'solid-state' components of a light dimmer, they would be ruined. Some electronic components can be destroyed by the application of a potential as low as 4.5 V if the potential is applied incorrectly, so it is important to check always that the instrument to be used is suitable for the test being carried out.

When a normal multimeter is used on the 'ohms' scales, the circuit is designed so that the movement of the instrument is actually measuring voltage drop; however, the scale is calibrated in ohms, enabling resistance values to be read directly.

Insulation-resistance testers

In multimeters, a battery is used as the source of emf. A battery may also be employed as the energy source for a solid-state or transistorised circuit to supply an emf at higher voltages. The source of emf may also be in the form of a hand- or motor-driven generator. A well-known heavy-duty insulation-resistance tester is shown in Figure 11.12. It may be hand-cranked or connected to an ac mains supply and is designed for high-voltage heavy-duty work, such as the maintenance and servicing of large industrial installations. Models capable of applying test voltages up to 5000 V dc are available.

The digital insulation tester shown in Figure 11.13 is designed for testing large or complex installations at voltages up to 1000 V dc. It is auto-ranging and therefore gives a direct reading at all test voltages; no multiplication factors have to be applied. An internal battery supply is housed in the instrument casing.

Figure 11.14 shows a hand-driven 500 V insulation and continuity tester having insulation-resistance ranges

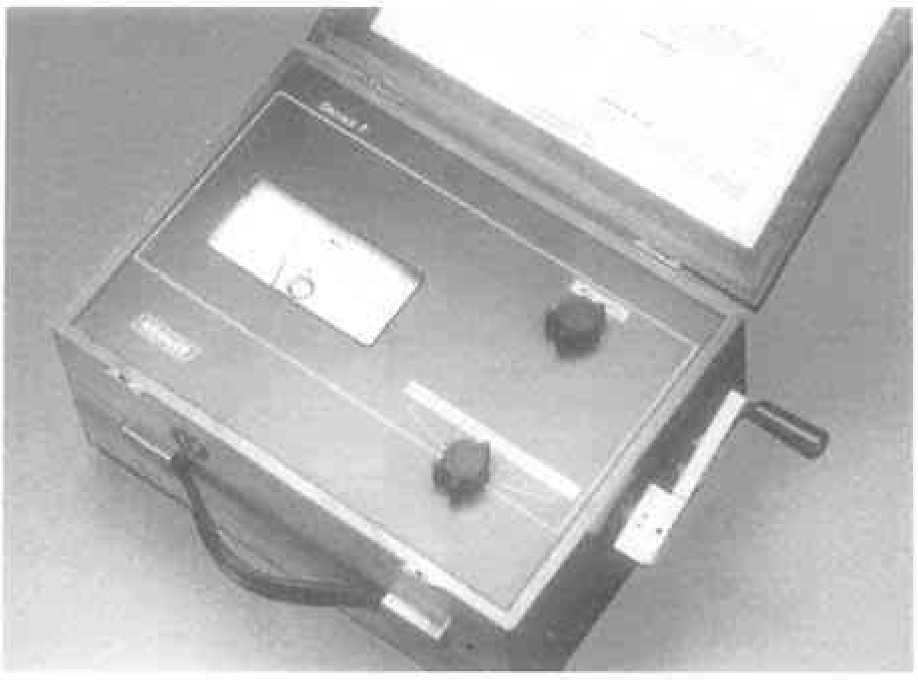


Fig. 11.12 *Heavy-duty insulation-resistance tester* NILSEN INSTRUMENTS

of 0–1000 MΩ and infinity. The instrument also has a voltage-measuring facility, range 0–300 V ac.

The electronic battery-operated type of instrument is very popular, because it is light and compact and may be held and operated in one hand, as there is no generator to turn. High testing voltage is produced by an electronic circuit, which uses an internal battery as an energy source. The instrument in Figure 11.15 has a range of 0–100 MΩ and infinity at a testing voltage of 500 V. It has the same voltage-measuring facility as the hand-driven insulation tester in Figure 11.14.

Another battery-operated tester suitable for measuring insulation resistance and continuity is shown in Figure 11.35 on p. 277.

For full descriptions of the instruments mentioned in this chapter, you are referred to trade literature produced by the instrument manufacturers and to textbooks on their construction, design and operation.

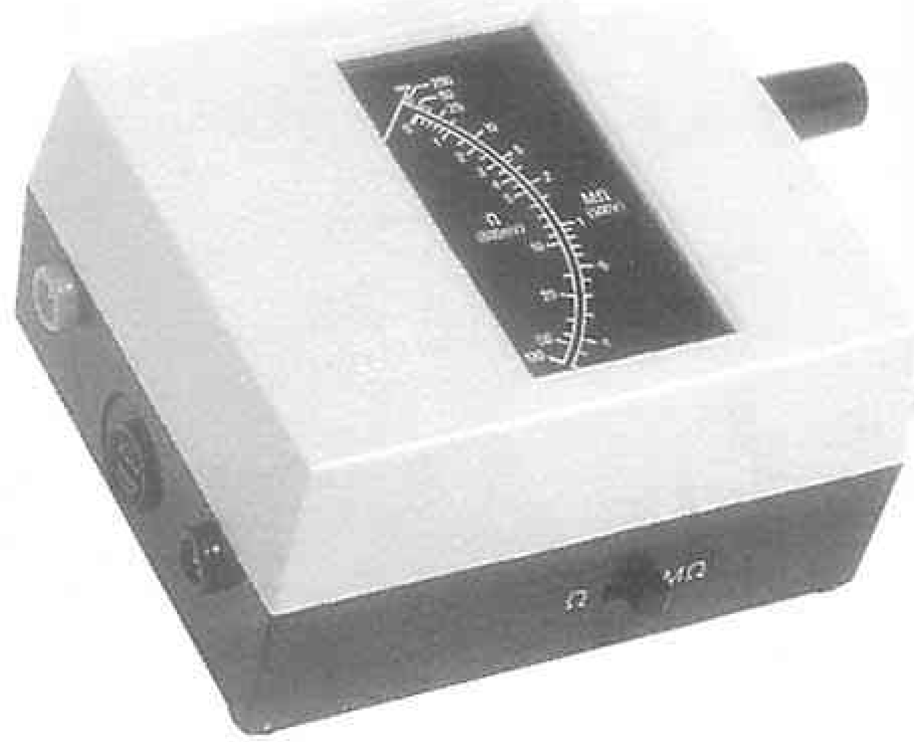


Fig. 11.14 *Hand-driven insulation and continuity tester* NILSEN INSTRUMENTS

Testing accessories

A number of purpose-designed accessories and testing devices are used specifically to improve the accuracy and efficiency of testing an installation. This type of equipment has been used in the past by energy distributors' inspectors. More recently it has been adopted by many electrical contractors as a result of changes to legislation, requiring them to conduct safety testing of their installation and to ensure that the installation is safe to connect to the supply.

Fig. 11.13 *Multivoltage digital insulation-resistance tester* NILSEN INSTRUMENTS

Fig. 11.15 *This battery-operated insulation-resistance tester is light and compact* NILSEN INSTRUMENTS

Figure 11.16 shows equipment designed by Testing Inspection Services Pty Ltd for 'dead testing' the polarity of final subcircuits, transposition of earth and neutral, connections betweeen circuits and the number of points on a circuit. The resistor box (a) provides six values of resistance to differentiate between the active and neutral conductors of three different circuits. It is used in conjunction with the Light Stix, dead (b) and the GPO tester, dead (c), each of which has a two-position switch for testing the connections of the active and neutral conductors. A trailing lead (d) is a useful testing accessory, and the probe (e), which is designed to plug into the earth receptacle of a socket outlet, enables connection with the earthing conductor on a final subcircuit.

A 'Light Stix' for 'live testing', with a built-in extension rod for testing earth connections and continuity at light fittings and other exposed metal, is shown as part (a) in Figure 11.17. The series lamp and flasher unit (b) are for connecting into a final subcircuit at the switchboard to differentiate between active and neutral conductors. The GPO tester (c) incorporates earth and neutral take-off terminals, earth-continuity testing, and testing for transposition of earth and neutral conductors. It also has a push button to test active to neutral and active to earth.

The 'installation test box' (Figure 11.18) provides functions for checking the continuity of test lamps, the accuracy of an ohmmeter used for earth-continuity testing and the output voltage of an insulation tester. Other functions include a load, a flasher, and a resistor for differentiating between conductors when conducting

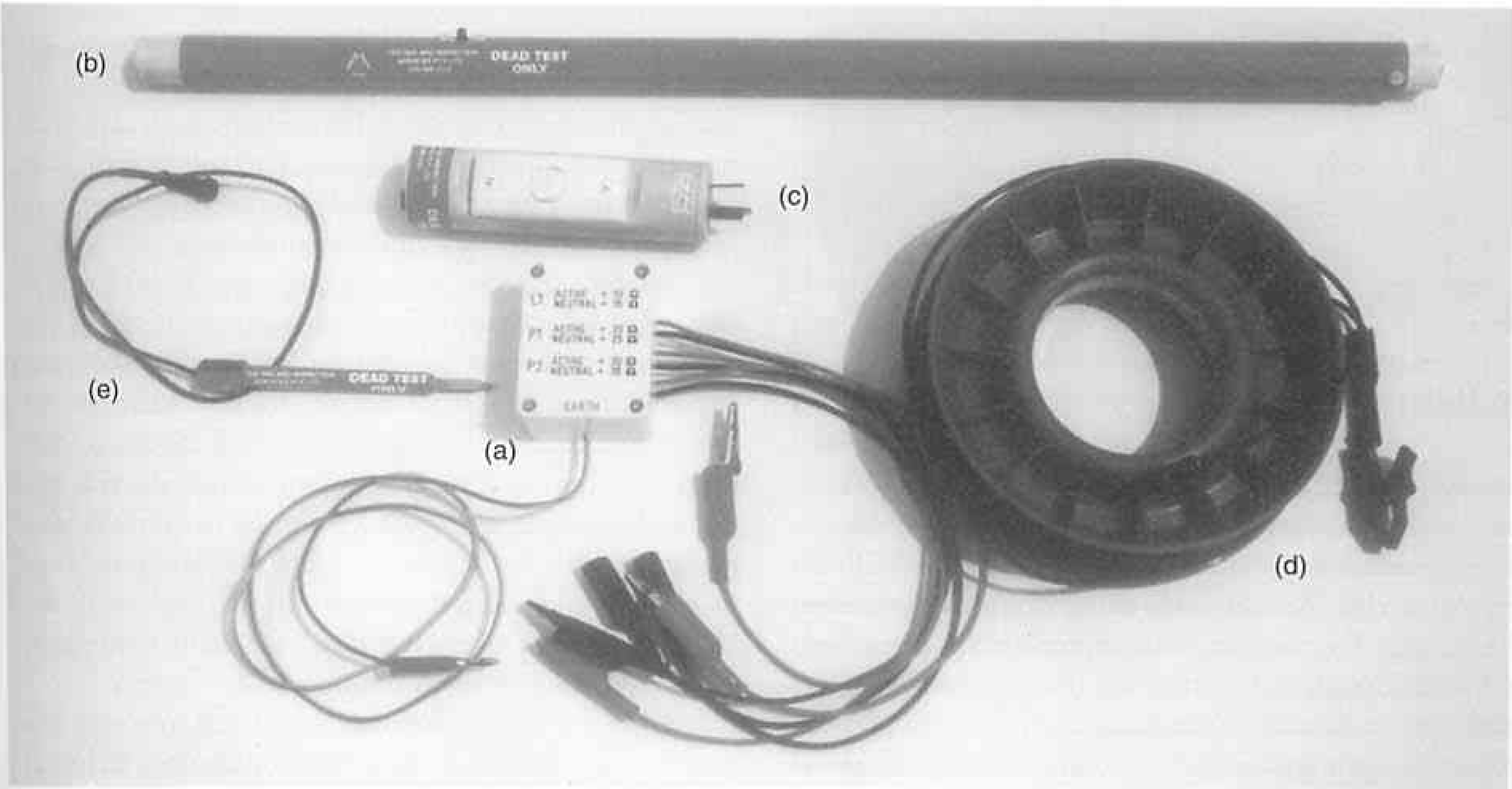
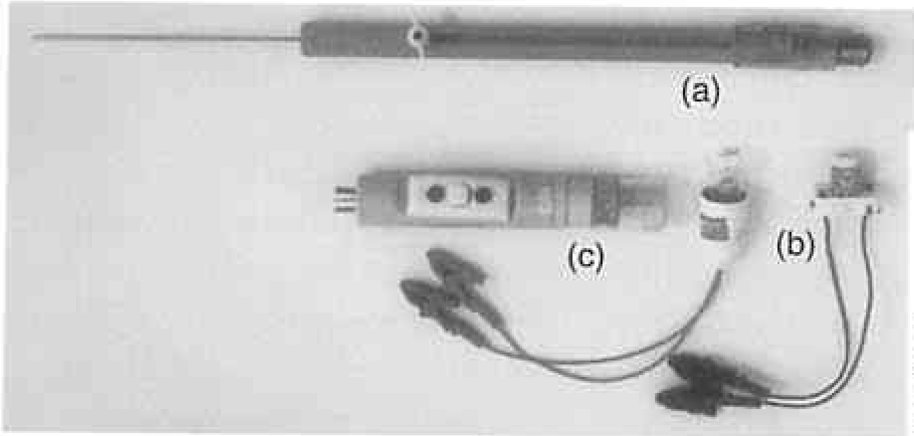


Fig. 11.16 *Accessories designed to improve the efficiency and accuracy of 'dead testing':* **(a)** *resistor box for differentiating active and neutral conductors in three different circuits;* **(b)** *'dead test' 'Light Stix';* **(c)** *'dead test' GPO tester;* **(d)** *trailing lead;* **(e)** *probe used in testing earth receptacle at socket outlets* TESTING AND INSPECTION SERVICES



YONG ZHI LI

Fig. 11.17 *Accessories used in 'live' testing:* **(a)** *'Light Stix' with built-in extension rod for testing earth connections at lighting points and for testing exposed metal;* **(b)** *series test lamp and flasher unit for differentiating between active and neutral conductors;* **(c)** *GPO tester* TESTING AND INSPECTION SERVICES

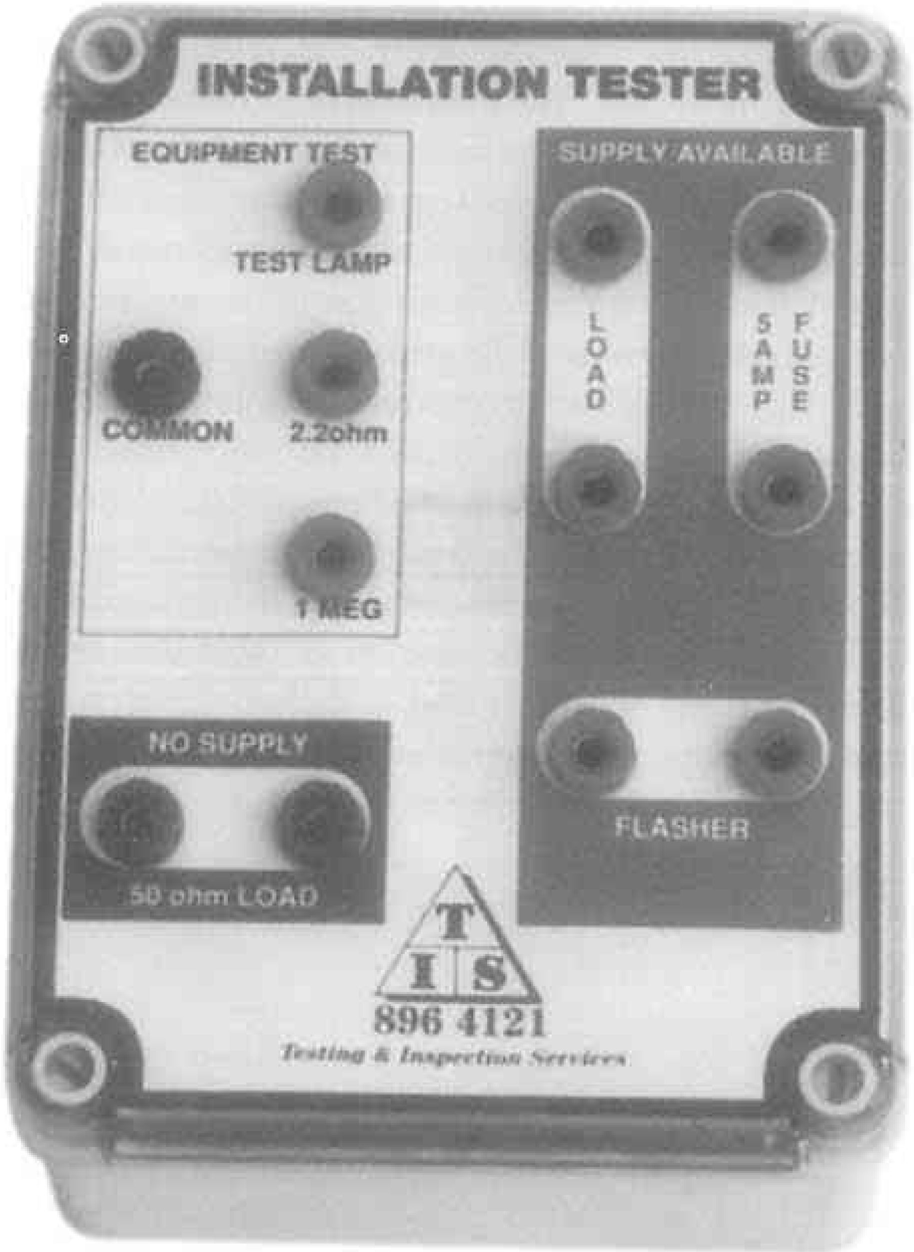


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Fig. 11.18 *Installation test box* TESTING AND INSPECTION SERVICES

various tests. Circuits protected by residual current devices (RCDs) present a difficulty when live testing, as a test between active and earth will cause the RCD to trip (as it should) and cause nuisance interruptions to the testing. To overcome this, the installation test box is equipped with a 5 A fuse for the purpose, bridging across the line and load terminals of an RCD to prevent nuisance tripping during live testing and at the same time ensuring that the circuit is protected.

It must be remembered that these devices are intended to help improve the safety and efficiency with which tests are carried out. The testing principles remain the same and must be understood before the benefits of using such devices can be fully realised.

11.4 Testing safely

Like the many activities involved in electrical work, control measures adopted to limit the risk of death or injury must be followed—no more so than when testing electrical circuits and equipment. Dead testing is obviously safer than live testing and some tests, such as an insulation-resistance test, can be performed only with the supply disconnected. Most faults in circuits and equipment can, theoretically at least, be detected by dead testing. In some areas, for example in Victoria, mandatory testing of new or altered installation must be conducted with the supply **disconnected**. In any case, with new installations the supply may not be available at the time the tests are to be carried out. However, live testing is often preferred as it can be more efficient and may in some instances be the only effective way to diagnose a particular fault.

Risk factors in testing

Unless some caution is exercised when electricians are required to work on or near live conductors, injury due to electric shock or burns due to arcing may occur. Burns generally account for more serious accidents than electric shock when installations are being tested, and the arcing is usually due to 'flashover' caused by the use of unsatisfactory test probes. This applies particularly to installations with high energy levels, because once the arc has started it can, and often does, ionise the surrounding air, making the air conductive and providing a path to earthed metal in the vicinity of the arc. The risk is greater in confined areas, such as electrical equipment enclosures or small switchrooms with limited ventilation.

When testing an extra-low-voltage (ELV) installation, the risk of burns from arcing is minimal if the system energy level is low, but care still needs to be taken to avoid causing a short circuit. Storage batteries, for example, are capable of delivering high discharge currents to a short circuit; in addition, there is the risk that the hydrogen gas given off during the battery-charging process may be ignited by the arc. This may cause a cell to explode and cause chemical burns to anyone in the vicinity. The risk of electric shock is usually minimal in a dry environment when testing an ELV system.

All of the above risks can be reduced to a very low level by the electrical workers' developing their technical knowledge and skill and using suitable test equipment. They should start by considering the causes of accidents that can happen when testing live equipment. These causes include:

- using a test probe with excessive length of bare metal at the tip, which could bridge live conductors or a live conductor and adjacent metal. The probes and leads also may not be insulated for the voltage under test;
- setting multimeters on the wrong range when measuring voltage, or the maximum working voltage of the instrument exceeded. This has caused many accidents. It is preferable to use a suitable test lamp or voltage detector of correct voltage rating for the job, rather than a multimeter, where it is necessary only to establish the presence or absence of voltage;
- using testing devices with exposed live terminals;
- a lead coming adrift from a meter terminal while either the lead terminal or the meter terminal remains live.

Selection of equipment

The risks associated with testing installations can be considerably reduced by selecting equipment with the following features:

- For testing for the presence or absence of voltage, probes should be designed so that the exposed metal tip is the minimum size possible for the job, really 2 mm or less. They should be shaped so as to avoid inadvertent hand or finger contact with the live conductors under test. Note the finger barriers on the fused probes shown in Figure 11.19. The use of fused probes is strongly recommended when **detecting ac voltage** using a test lamp, voltmeter or voltage indicator on systems having high energy levels. It is advisable to use them for detecting voltage on any ac system; in Queensland the use of fused probes for this purpose is recommended for testing all installations.

  High-rupturing-capacity (HRC) fuses having a low current rating are incorporated in the probes for protection against excess current; the ones illustrated have a category of duty of 440 V ac or 230 V dc and a maximum prospective overload of 33 000 A. Because they have a high impedance, fused probes are unsuitable for continuity testing.

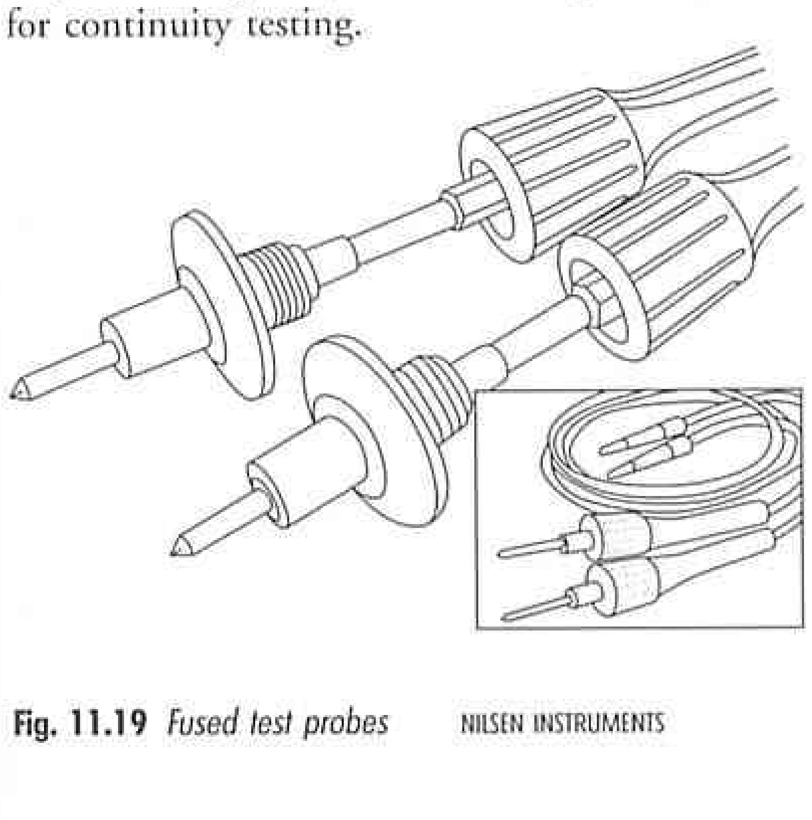

Fig. 11.19 *Fused test probes* NILSEN INSTRUMENTS

- Leads should be adequately insulated and coloured, usually red and black, to distinguish one from the other. They should be long enough for practical use but not long enough to be unwieldly. Their connection at the test device end should not be accessible for inadvertent contact with a person's finger if a lead becomes detached from the device or from a probe.
- Test lamps should be designed so that the glass bulbs are protected from mechanical damage (see Figure 11.3(a)).
- Terminals on a testing device should be shrouded or designed to avoid finger contact when being used for testing.
- Test lamps and any other devices used to detect the presence or absence of voltage should be marked to indicate maximum working voltage and, if applicable, any short time rating for the device.
- All testing equipment should be in good working order and be regularly inspected and tested.

Precautions

When carrying out electrical tests, always keep in mind the importance of safe working procedures and test with the circuit de-energised or 'dead' if this is at all practicable. For example, before conducting dead testing, circuits should be isolated, tagged and locked off in accordance with safe working procedures.

Whatever the testing device employed, **test for its correct functioning before the test and again after the test.** This precaution is particularly important when testing live circuits or equipment.

When using a test lamp, voltmeter or similar equipment, try to arrange the circuit so that any 'roving lead' is at earth or neutral potential or that a lamp or current-limiting resistance is in series with the lead to limit the current, should a fault occur (see Fig. 11.20 as an illustration of this point).

Note: Test probes in the diagrams used in this chapter are represented by arrowheads, and the HRC fuses used in some probes are not shown. **The use of fused probes with test lamps and other devices for detecting ac voltage is recommended, particularly where high energy levels exist.**

When testing de-energised wiring, the testing device should also be checked before and after the test; an insulation-resistance tester, for example, would give a reading of 'infinity' on all tests if a lead on the instrument were open-circuited.

Always check that the testing instrument selected is suitable for the job (e.g. voltmeter, ohmmeter), that it is suitable for the supply (ac or dc), and that it is set to the correct range. If a multirange instrument is being used and if it is practicable, set the range switch initially to the maximum range, and then switch down if necessary to the range most suitable for the quantity being

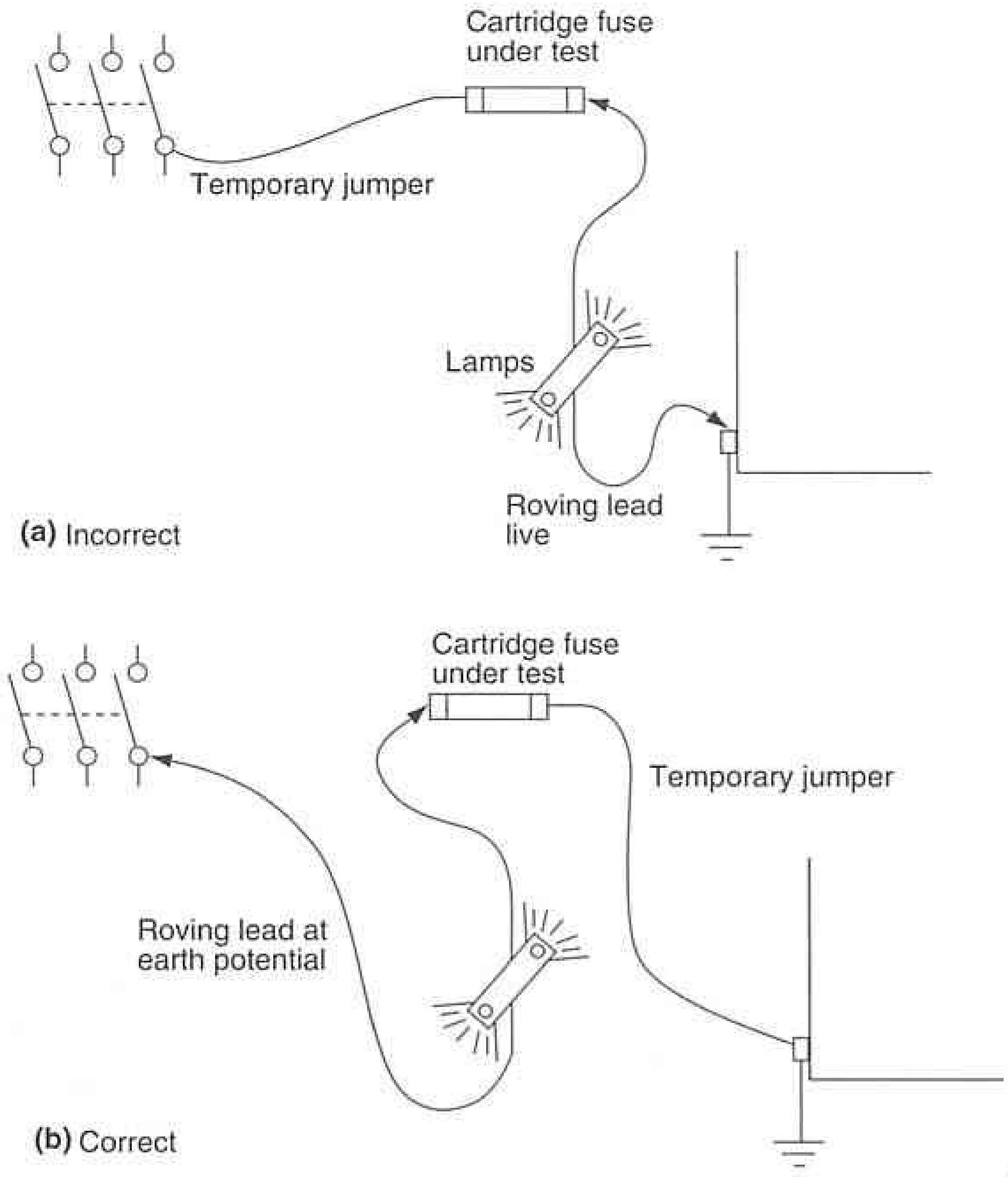

Fig. 11.20 *Use of testing device with a roving lead*

measured. On completion of the test, reset the range switch to the maximum range, ready for the next test.

Testing **safely** requires the adoption of thoughtful and methodical procedures. No person should be in danger of contact with live parts while the test is being carried out. At the completion of each test, conductors disconnected for testing purposes must be reconnected correctly and all covers of accessories and appliances replaced. The installation must be left in a safe condition, either safe to operate as proven by the testing or disconnected from the supply and tagged to notify that it is unsafe to use. No single test will prove that an installation is safe. It is the combination of necessary tests that will show the safety of an installation. If a polarity test reveals an incorrect connection then, after the connection is corrected, insulation and earth-resistance tests may need to be repeated.

11.5 Testing and checking the installation: general requirements and precautions

Any new installation or addition or major repairs to an existing installation must be tested and checked to ensure that it is safe and complies with regulations. This must be done before the new work is connected to the supply. In the recent past, energy distributors' inspectors carried out installation testing and inspections and issued defect notices when the installation did not comply with regulations. Testing and checking the installation is now the responsibility of the electrical contractor or electrician carrying out the installation work, who must notify the energy distributor in writing when the installation is safe, complies with regulations and is ready for connection to the supply.

In some circumstances an electrical contractor may be given authority to connect the installation to the supply, provided it has been tested and proved safe. In most areas the energy distributor's inspectors have a responsibility under regulations to inspect consumers' mains, main switchboards, high-voltage installations and any wiring within a hazardous area, as defined by *Clause 9.0.1* of AS 3000. The responsibility also includes a schedule of random inspections to check that electrical installation standards are being maintained.

Electrical conditions such as the resistance of leakage paths and the value of conductor resistance cannot be seen, and to determine these conditions suitable tests with instruments must be carried out. Furthermore, a visual inspection of the whole installation must be made to ensure that it complies fully with all legal requirements, specifications, *SAA Wiring Rules* and any applicable codes. Thus testing and inspection are two separate procedures, but in practice are carried out concurrently.

The electrical tests include:

- tests for the effectiveness of the main earth
- tests of continuity and effectiveness of the earthing system and required equipotential bonding
- insulation-resistance tests of wiring, including consumers' mains, submains, busways, rising mains, final subcircuits and fixed wired appliances
- polarity testing of active and neutral connections of consumers' mains, submains, and final subcircuits
- tests for incorrect connections, such as interconnections between circuits, transposition of neutral and earthing conductors and short circuits
- operation of RCDs
- other testing required by local regulations.

The **visual check** must include inspection of the following:

- main earthing conductor and main earth connection, for correct rating, size and conductor type and for compliance with the Rules;
- all subcircuit and auxiliary earthing, earthing bonds and earthing of equipment frames, for general compliance with the regulations;
- main switchboard and distribution boards, for correct fuse and circuit-breaker ratings and correct labelling, including correct labelling of neutral conductors. Switches, fuses and circuit breakers should be checked as having adequate fault-current ratings (see Chapter 13, Volume 2), as well as for their working current rating. Fuse clearances and layout of equipment should be checked to ensure that layout is neat and logical to correspond with a neat and logical back-of-panel wiring. In addition, space at the front and sides of the switchboard, distance from the floor, clearance at the rear and correct panel thickness need to be inspected;
- wiring, for suitable cable types and for correct current ratings and voltage-drop conditions for the length of run. Derating factors (e.g. in cables affected by thermal insulation) may need to be applied;
- existing or potential, mechanical or chemical, hazards that may be present, such as dampness, high temperature, explosive gases, vapours or dust;
- all appliances, to ensure that their operation will not introduce a hazard or cause overcurrent or overvoltage conditions;
- equipment and accessories, for their suitability to be connected in the location in which they are installed (e.g. in a swimming pool area or in the restricted zone of a bathroom or laundry);
- fixing and support of electrical equipment, to check their adequacy and that equipment is not subject to mechanical damage;
- number of 'points per circuit', to determine that the number is within the limits permitted by the Rules;
- provision for separate final subcircuits to appliances that require them;
- consumers' mains, point of attachment and metering facilities, for compliance with appropriate Rules.

The final testing and visual checks of an installation form part of an ongoing process of planning, testing and checking that professional electricians use to assure the quality of their work. Many potential defects in electrical installations can be avoided by good planning and checking and testing while carrying out the installation work. For example, a cable installed with insufficient current-carrying capacity is often the result of poor planning; and incorrect connections at a light point or GPO come about from not checking or testing at the time they were connected. Rectifying defects after the event can be a time-consuming and costly exercise, quite apart from the poor impression given to the customer.

11.6 Testing techniques 1: earthing system

The maximum resistance of the earthing system of an installation is specified as 2 Ω by *Clause 1.5.3*, which also states that its value must be low enough to permit sufficient fault current to operate the protection; so with high fuse or circuit-breaker ratings the value could be well below 2 Ω. To ensure compliance with the Rule, the resistance of the earthing system of an installation must be tested. In New Zealand, the maximum value of resistance of the earthing system is 0.5 Ω.

The object of the test is to determine the resistance value of the earthing system between the main earth connection and **any** part of the system: for example, to the earthing terminal of a three-pin plug socket, to the frame of a motor or to the metal enclosure of a fluorescent luminaire. If the multiple-earthed neutral (MEN) system is employed, this test is from any part of the earthing system to the main earth connection at the neutral link. This test must yield a resistance of 2 Ω maximum. In addition, the resistance from the neutral link to the earth electrode must be within a 2 Ω limit (see *Clause 1.5.3.3(b)*, also Figs 11.21(a) and (b)).

Where a water supply system is metallically continuous from inside the building in which wiring is installed to its point of contact with the ground, an equipotential bonding conductor must be installed. This is to maintain the water pipe system at earth potential. The bonding conductor may be connected at any point on the main earthing conductor or at the earth bar at the switchboard in a MEN system. Its resistance should

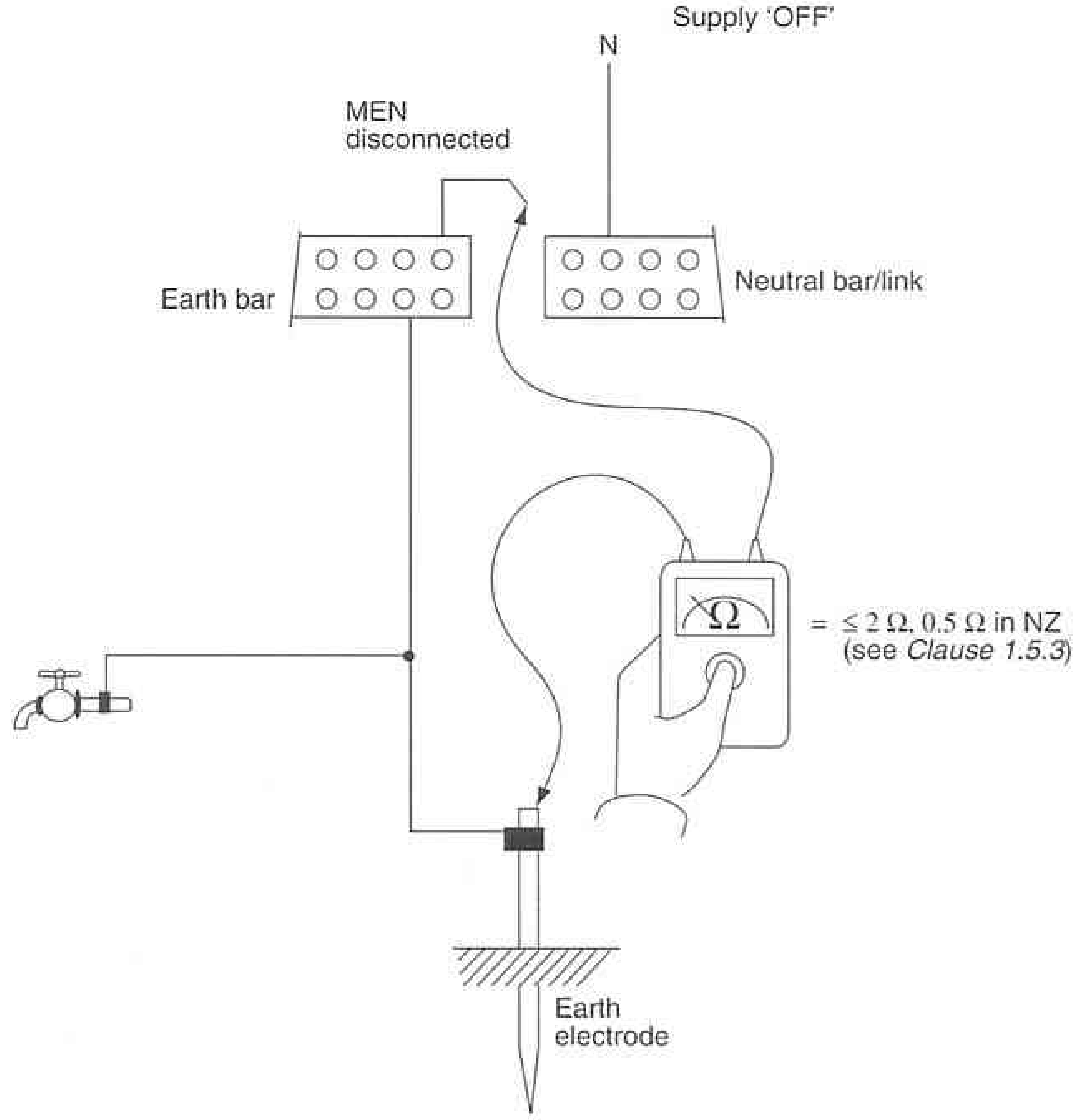

Fig. 11.21(a) *Resistance test of main earthing conductor*

not exceed 2 Ω. Some appliances, such as a hot-water system, may be connected to earth by the metallic water supply, in which case the circuit earthing conductor to the appliance should be isolated and tested as having earth continuity resistance not exceeding 2 Ω.

Figure 11.21(c) shows typical test results for a circuit protected by a 16 A circuit breaker. Using the test results shown:

resistance of test leads
$= 0.378\ \Omega$
resistance of return earthing system
$= 1.4 - 0.378$
$= 1.022\ \Omega.$

This value of resistance complies with *Clause 1.5.3*, but in any case for the circuit shown the maximum resistance of 2 Ω specified in *Clause 1.5.3* would permit sufficient fault current to flow and operate the fuse or circuit breaker:

$$I = \frac{V}{R} = \frac{240}{2} = 120\ \text{A}$$

which is sufficiently high to operate a 16 A circuit breaker quickly and which is approximately four times the fusing current required to melt a 16 A rewirable fuse.

When carrying out earth-resistance tests, the metal frames of all appliances and luminaires should be checked, because:

- They are usually mass-produced in the factory; and, although manufacturers are required to keep the resistance between the earthing terminal and frame to 0.1 Ω or less as specified in *Clause 5.3.4* of AS 3100, sometimes the internal earthing bonds of earthing terminal connections are defective when the appliance leaves the production line.
- The process of painting often affects the earth continuity between frame parts.
- Most appliances are handled while in operation; so effective earthing of the appliance is essential.

Visual inspection of the earthing system should also be made where it is accessible, both on new installations and when testing existing installations. As an example:

1. An earth-continuity test is made between the appliance frame and the main earth connection on the installation shown in Figure 11.22. Resistance value measured is 6 Ω, which is obviously too high.
2. On making a check closer to the commencement of the conduit run, an acceptable resistance of 1 Ω is measured from point A to main earth.

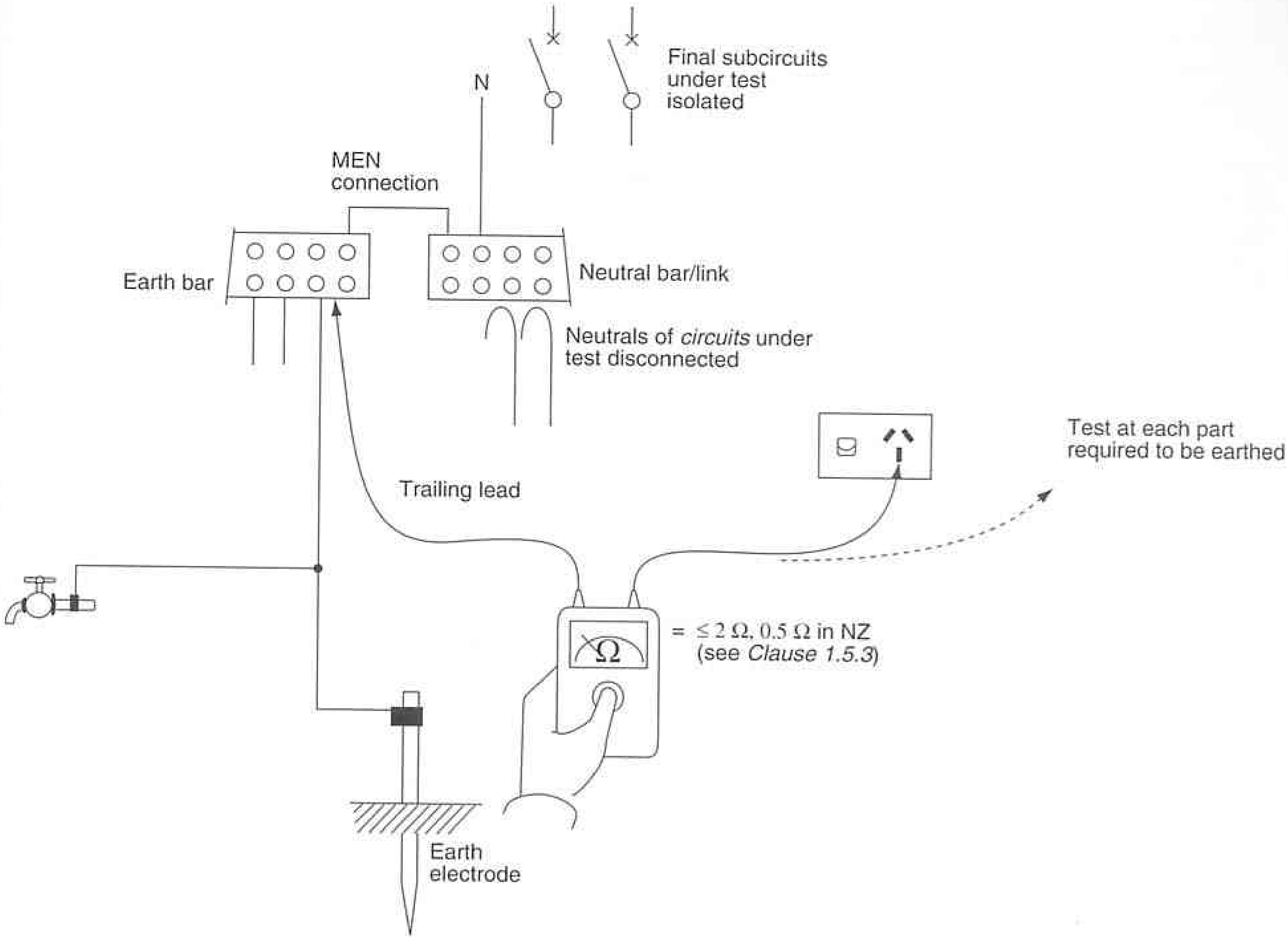

Fig. 11.21(b) *Resistance tests of other earthing and equipotential bonding conductors*

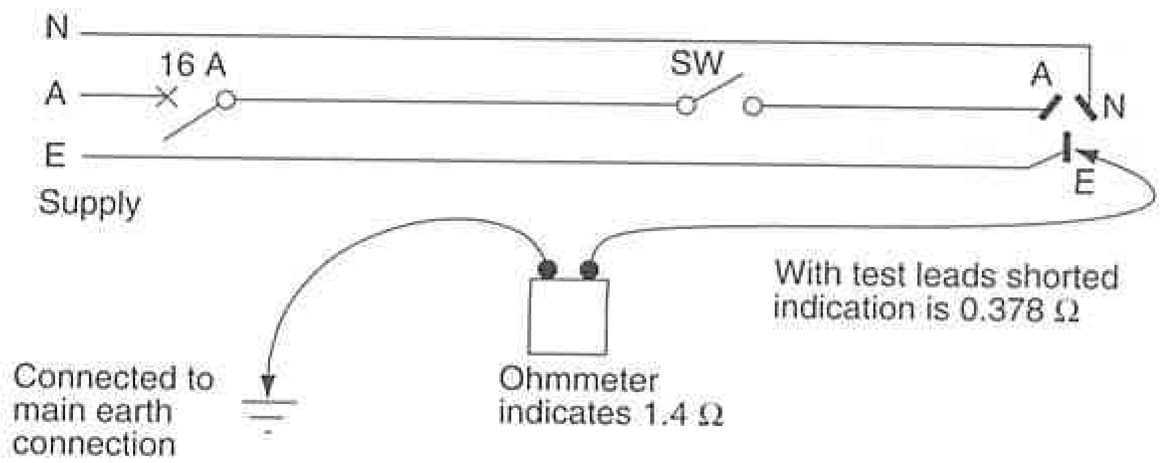

Fig. 11.21(c) *Resistance of the earthing system must be low enough to permit sufficient current to operate the fuse or circuit breaker*

3. A visual check is made for any apparent high resistance between point A and the appliance, as this is the high-resistance route, and it is noted that the galvanised metal conduit is painted with polyvinyl acrylic (PVA) paint as protection for the threaded entries to the tee fittings. As PVA paint is non-conductive, this could cause the high-resistance joint (see *Clause 3.26.5.6*).
4. To confirm the apparent cause of the high-resistance path to earth, a reading is taken across the tee between points A and B; it is found to be 4.95 Ω (see Fig. 11.22(a)). This resistance must be reduced by cleaning the conduit threads and repainting with a metallic paint, graphite jointing compound or a paint type that will not affect conductance, before screwing the conduit back into the tee.

As the Rules stand at present, the simple ohmmeter test is satisfactory to check for compliance with *Clause 1.5.3* 'Resistance of the earthing system'. Remember that these tests are applied for the purpose of testing the consumer's earthing system as a whole, or for determining the resistance of a particular section, and that the earthing system finishes at the main earth connection on the earthing electrode.

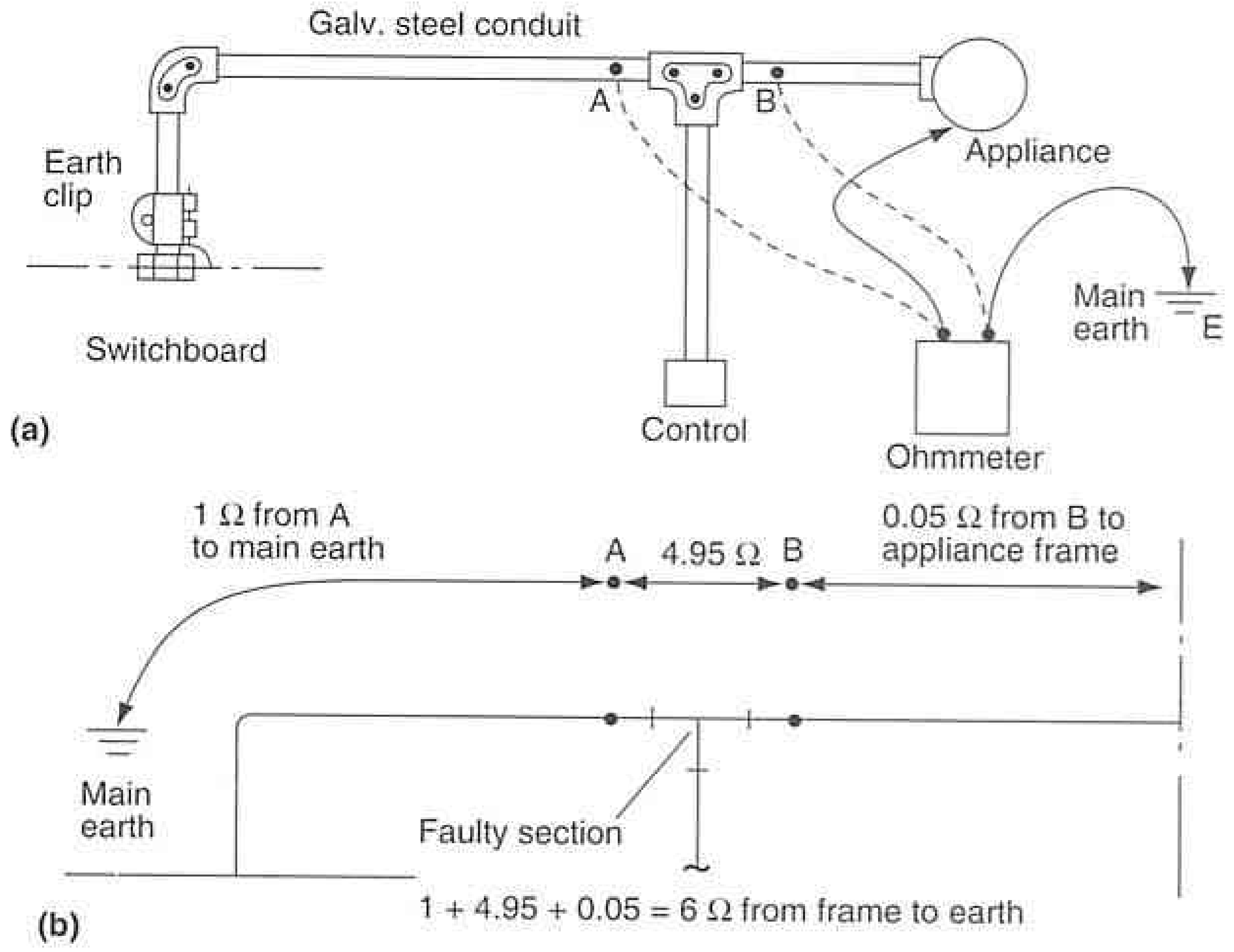

Fig. 11.22 *Confirming a high-resistance fault observed in a visual check of the earth continuity*

The testing of the earth electrode resistance, that is, the resistance between the electrode and the general mass of earth, usually requires one of the special types of earth resistance testers, such as that shown in Figure 11.10.

11.7 Testing techniques 2: insulation resistance

Clause 1.5.2 specifies the insulation resistance of either the whole or part of an installation as being a minimum of 1 MΩ. Note that only the **resistance to earth** is specified (refer to section 3.9 of Chapter 3 for a numerical example).

The installation must be tested for compliance with the above Rule, and, because it is only the wiring that is under test:

1. All lamps are removed and appliances disconnected. (Note that, although this is specified, if the value of insulation resistance is well above the minimum in practice the appliance will remain connected.)
2. All control switches are closed to the 'on' position. If the installation is incomplete, the necessary temporary connections should be made.
3. For large installations the testing proceeds in sectionalised groups, but for small installations the test for the whole installation is carried out as a single test.
4. Appliances and other equipment must be tested separately (see *Clause 1.5.2.4*) and in general must have a minimium insulation resistance as specified in AS 3100, *Clause 8.3.1.* Despite this, *Clause 1.5.2.4* of AS 3000 permits exceptions, with values down to 0.01 MΩ for an element-type heating appliance (e.g. a permanently connected electric range).
5. Busways also require separate testing (refer again to *Clause 1.5.2.3* and to the reference in section 3.9 of Chapter 3).

To carry out an insulation resistance test, there must be available a source of dc with a minimum value of 500 V and an ohmmeter capable of indicating high values. Because scales of insulation-resistance testers are normally calibrated in megohms, a suitable instrument would be one of the insulation-resistance testers illustrated in Figures 11.13, 11.14 and 11.15. The source of dc may be a hand-driven or motor-driven generator, or the popular electric supply fed from an internal battery (see Fig. 11.15).

When conducting an insulation-resistance test, the following precautions should be observed:

1. Make certain that the section to be tested is isolated from the supply.
2. Check that **only** the section to be tested is included in the test. Make sure that there are no stray parallel leakage paths.
3. Ensure that the instrument is suitable for the test and that its operating voltage is safe to apply to the circuit, especially to an electronic circuit such as a lamp dimmer. Normally, dimmers are disconnected during the test.
4. Check the instrument for pointer index or any other preadjustment necessary.
5. Check the operation of the meter and test leads,

indicated by an infinity sign on open circuit and zero indication with leads short-circuited.

6. When testing, avoid any large masses of iron or stray magnetic fields.
7. Use well-insulated leads in good condition to avoid stray leakage paths.
8. Operate the instrument as recommended by the manufacturer.
9. If there are any capacitors in the circuit, ensure that they are discharged both before the test and after the test is completed. Also, be wary of false readings due to capacitance during the test.
10. Before touching cable ends after testing, discharge any energy that may have been stored in the cables during the test. This is most likely to occur in long runs of larger cables due to their capacitance.

Figure 11.23 shows insulation-resistance test connections for a complete installation. Fuse links are in circuit or circuit breakers 'ON' and lamps have been removed, appliances disconnected and all switches left on. Because the earthing system is MEN, the main earth connection at the neutral link has been opened (see *Clause 1.5.2* 'Insulation resistance'). The scale indication on the insulation-resistance tester will be the value of the insulation resistance of the **complete** wiring between conductors and earth.

If the value indicated is below that permitted, a logical procedure for isolation of the faulty section would be:

1. Open the main switch to isolate the fault as being on either the active or neutral conductor.
2. If the fault appears to be on the neutral, isolate the faulty neutral by progressive disconnection of load neutrals at the neutral link.
3. Should the fault appear to be on the active, isolate the fault by the opening of circuit breakers or the withdrawal of circuit fuses in turn.
4. If a fault has been determined as being on the active of a particular subcircuit, the fault may be further isolated by progressively opening switches on the subcircuit, thus checking whether the low resistance to earth is on one of the 'switch lines'.

Once the low-reading section of wiring has been found, it is necessary to determine the exact point at which the circuit fault has occurred. Although modern insulation is of high quality and reliability, it is possible, but most unlikely, that the earth leak is via the insulation, especially on a new installation.

The most probable positions for earth leakage, however, are at the ends of runs, where the cable emerges and the end of the conductor has been stripped of its insulation to facilitate connection to an accessory. This leads to the possibility of surface leakage or mechanical failure. These positions should be checked for dampness, moisture, humid conditions or accumulation of dirt or dust. The leak can also be due to mechanical damage, the action of heat or chemical action. A careful visual check for these possibilities should be made.

Assuming that these checks have not resulted in location of the actual leakage point, the faulty circuit conductor should be opened at a convenient connection as close to the centre of the run as possible, thus halving the extent of the faulty section. This process of sectionalisation should be repeated until the fault is located and any necessary repairs or replacements effected. Figure 11.24 shows insulation-resistance testing preparation for individual circuits.

11.8 Testing techniques 3: polarity tests

The importance of carrying out polarity tests on all parts of an installation cannot be overemphasised. In a survey of one Australian state a significant number of installations were found to have incorrect polarity connections; this could lead to a fatal electric shock.

For example, a most dangerous condition arises if the polarity of a consumer's mains is incorrect where a MEN system is employed. In this condition current will flow through the main earth to the earth electrode (see Fig. 11.25). The current is not likely to be sufficient to operate any circuit-protection device, placing any person in the vicinity of the installation at risk of electric shock. The same dangerous condition exists if the polarity of a submain is incorrect where it supplies a portion of an installation with a separate MEN connection.

Although testing the polarity of consumers' mains is usually carried out before the supply is available, a check must be made that they have been disconnected from the supply before tests are carried out. The test is a straighforward continuity test, preferably done with an ohmmeter, between the consumer's terminals and the line terminal of the main switch to identify the active conductors, and between the consumer's terminals and the main neutral connection at the neutral link to identify the neutral conductor, as shown in Figure 11.26. All main switches and circuit-protection devices must be open to avoid false readings from feedback that may occur through a final subcircuit.

Clause 2.20.1.2 of the *SAA Wiring Rules* stipulates that switches must be connected to operate in the active conductors, and *Clause 4.13.4.2* in effect restricts the polarity of a Goliath Edison screw lampholder to that of active for centre terminal and neutral for the outer or screw base.

In *Clause 4.14.8* the recommended polarity for all socket outlets is stated as being earth, active, neutral in a clockwise direction viewed from the front of the outlet,

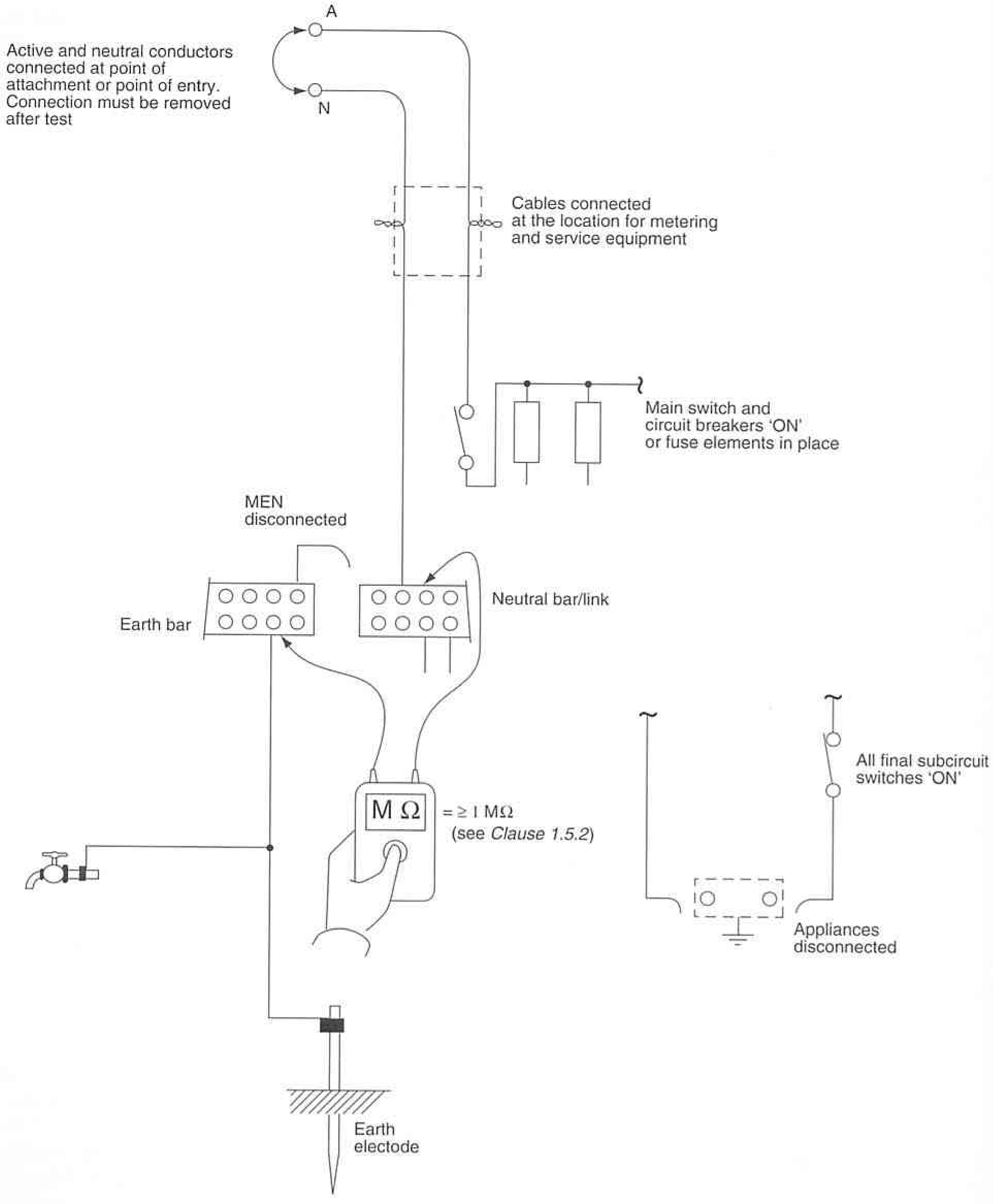

Fig. 11.23 *Testing the insulation resistance for a complete installation*

and this sequence of connection is mandatory for general-purpose outlets (GPOs) and for 15 A and 20 A socket outlets. It is obviously necessary to carry out 'polarity tests' to ensure compliance with these Rules. The tests should include a check of the supply active, earth and neutral, together with a check of the outgoing circuit connections at the main switchboard.

A testing method that checks the polarity of active and neutral as well as the earth and neutral connections at socket outlets is shown in Figure 11.27(a). Tracing out the test circuit shows that a correctly connected socket outlet will give the following test results:

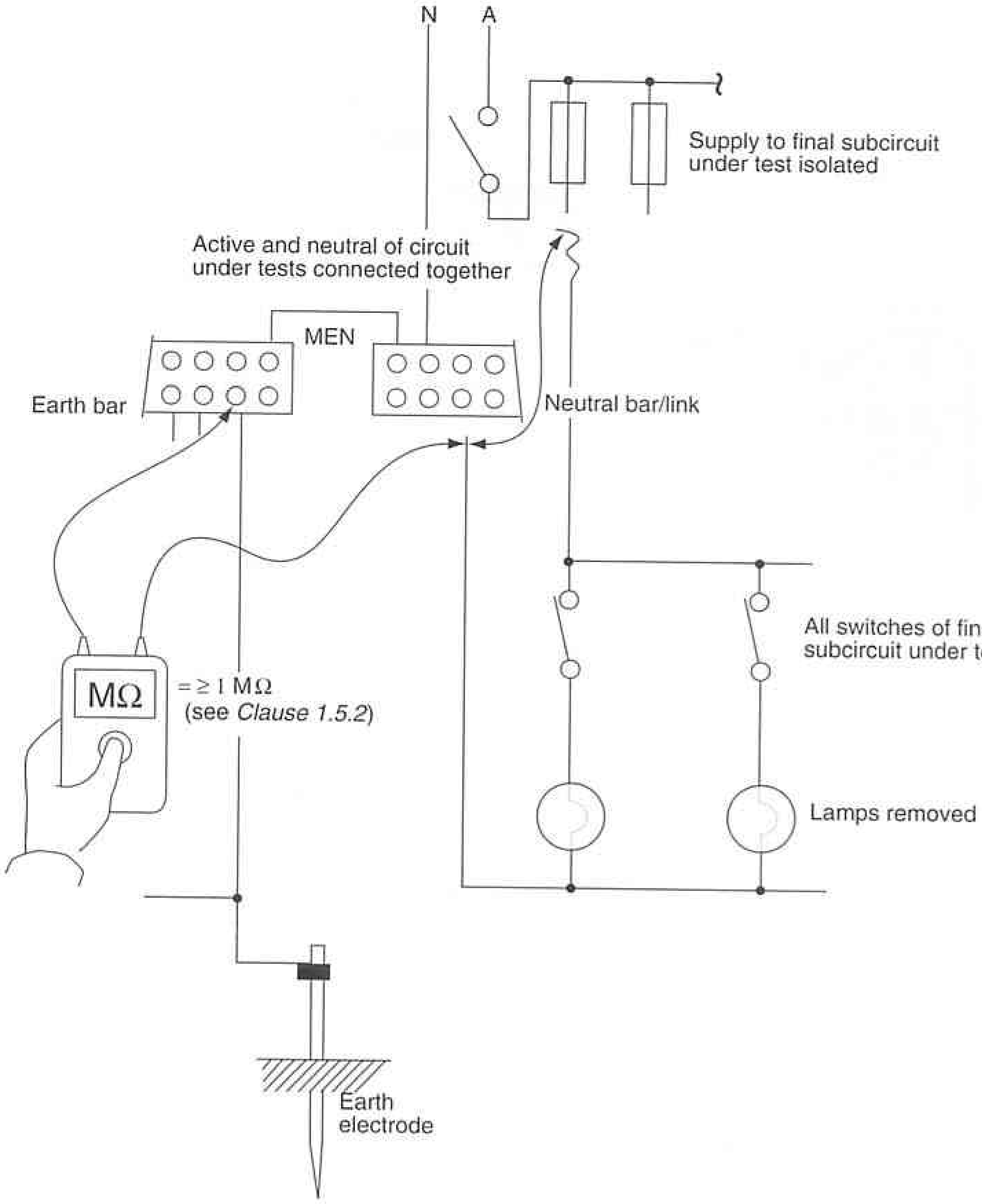

Fig. 11.24 *Testing the insulation resistance of individual circuits*

Test points	Switch position	
	Off	**On**
A N	Infinity	20 Ω
A E	Infinity	15 Ω
E N	5 Ω	5 Ω

Any other results indicate an incorrect connection. For example, with active and neutral connections reversed, the A to N test results will be the same as above. However, the A to E test results will show 5 Ω with the switch 'on' and the N to E test will indicate 15 Ω with the switch 'on' or 'off'.

The simplest polarity tests on the outlets are made with the circuit energised at normal voltage, using a suitable 'voltage indicator' such as a test lamp, neon tester or voltmeter (see Fig. 11.27(b)).

Any testing device used on a circuit protected by an RCD must draw less than the specified tripping current of the RCD to ensure that it does not trip during a polarity test. Otherwise it will be necessary to bridge out the RCD while the test is being carried out. If the RCD is incorporated within the circuit-protection circuit breaker, then bridging of the RCD should include a fuse or circuit breaker to maintain circuit protection while testing is being carried out.

Referring to Figure 11.27(b), the indications for correct polarity would be:

- test lamps connected between A and E, switch open (i.e. off)—no glow;

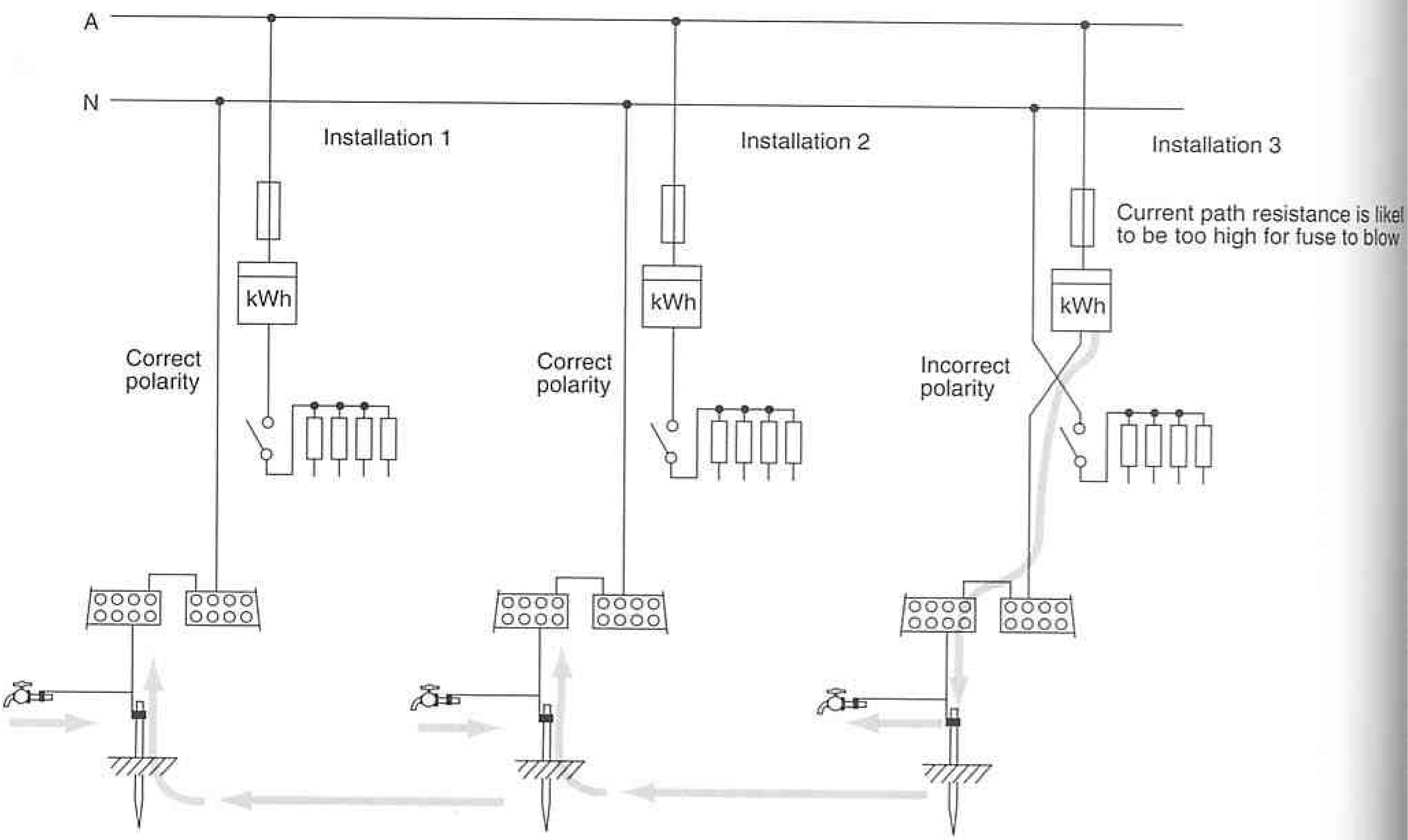

Fig. 11.25 *Earthing system is carrying current due to incorrect polarity of a consumer's mains at installation 3. Any person in contact with earth or earthed metal in the installation or adjacent installations with separate MEN connection is in danger of electric shock. The shaded arrows indicate possible current paths*

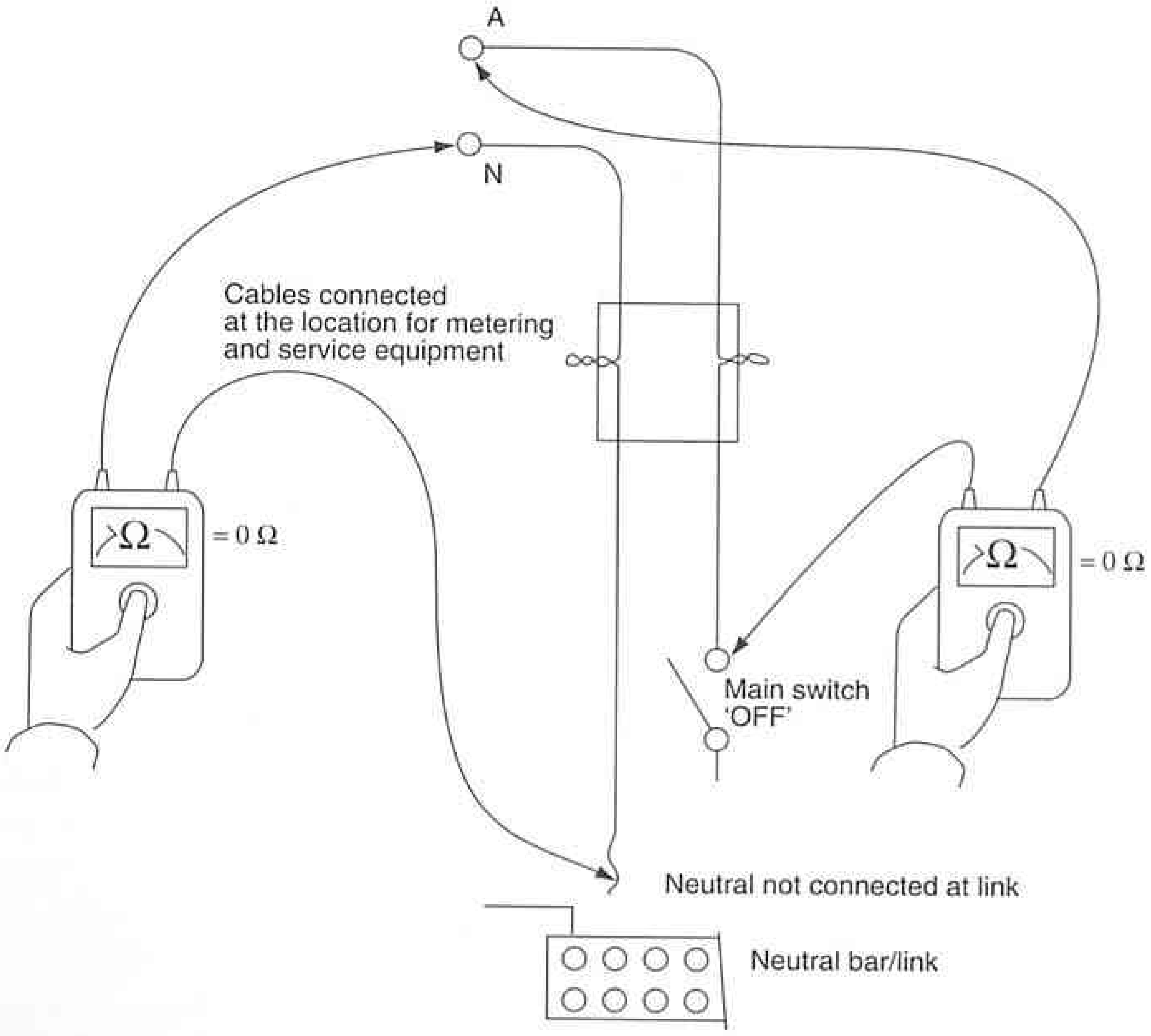

Fig. 11.26 *Testing the polarity of a consumer's mains prior to connection. Similar procedures are used for testing the polarity of submains*

ce is likely
to blow

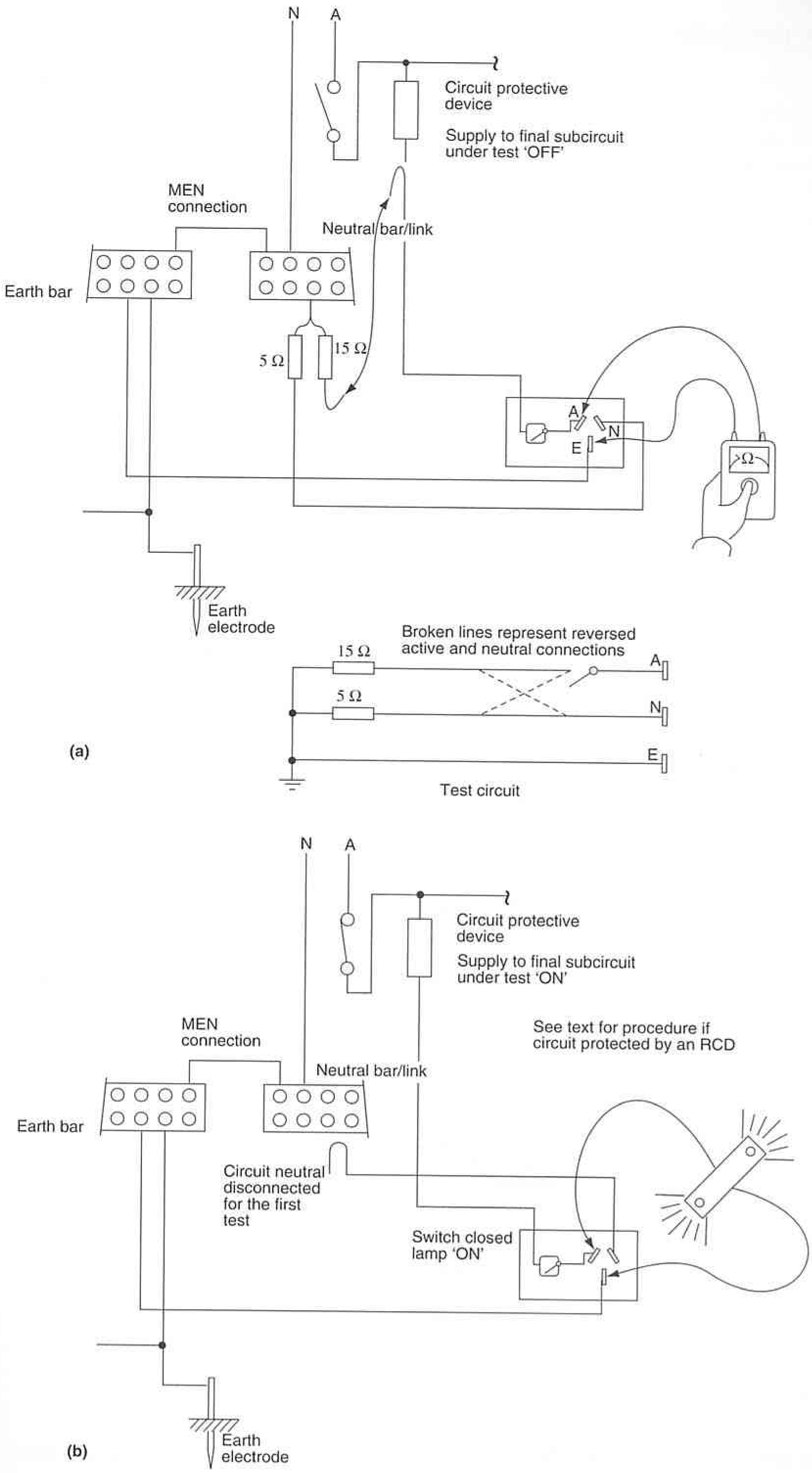

Fig. 11.27 *Testing the polarity and correctness of connections at socket outlets:* **(a)** *dead testing;* **(b)** *testing with supply connected*

- test lamps connected between A and E, switch closed (i.e. on)—lamps glow;
- test lamps reconnected between N and E, switch closed—no glow.

Check the test lamps by connecting between A and E with the switch closed. The polarity test should be made with the **circuit neutral disconnected at the neutral link**. Think about this, and check with the diagram. With the neutral disconnected, the test checks that the switch is connected in the active and also that the earth and neutral are in their correct relative positions. There is the possibility that the earth and neutral are reversed in the socket outlet connection, and the test would not detect this faulty connection if the neutral were not disconnected.

A testing method that checks both polarity of active and neutral and the earth and neutral connections of lighting circuits is shown in Figure 11.28. This test requires the same preparation as the test for socket outlets previously discussed. Once again, tracing out the test circuit shows that a correctly connected batten holder and switch will give test results similar to that for the socket outlet test.

A method for checking polarity in lighting circuits is illustrated in Figure 11.29. In this method of polarity testing, it does not matter whether lamps are left inserted or removed from the lampholders, provided that the switch at which the test is made is closed and all other switches are left open. Light to earth indicates correct polarity.

If the lamps in the circuit under test are removed, it does not matter whether the switch at which the test is being made is closed or open.

Now consider the case where the switch controlling one of the lights is in the neutral conductor, as shown in Figure 11.30. With the switch in the 'off' position and the test connection shown, the test lamp is in series with the light outlet, the lamp of which will probably be of much higher power rating (lower resistance) than the test lamp, thus causing test lamps to light and giving the false impression that the active is switched. If a volt-

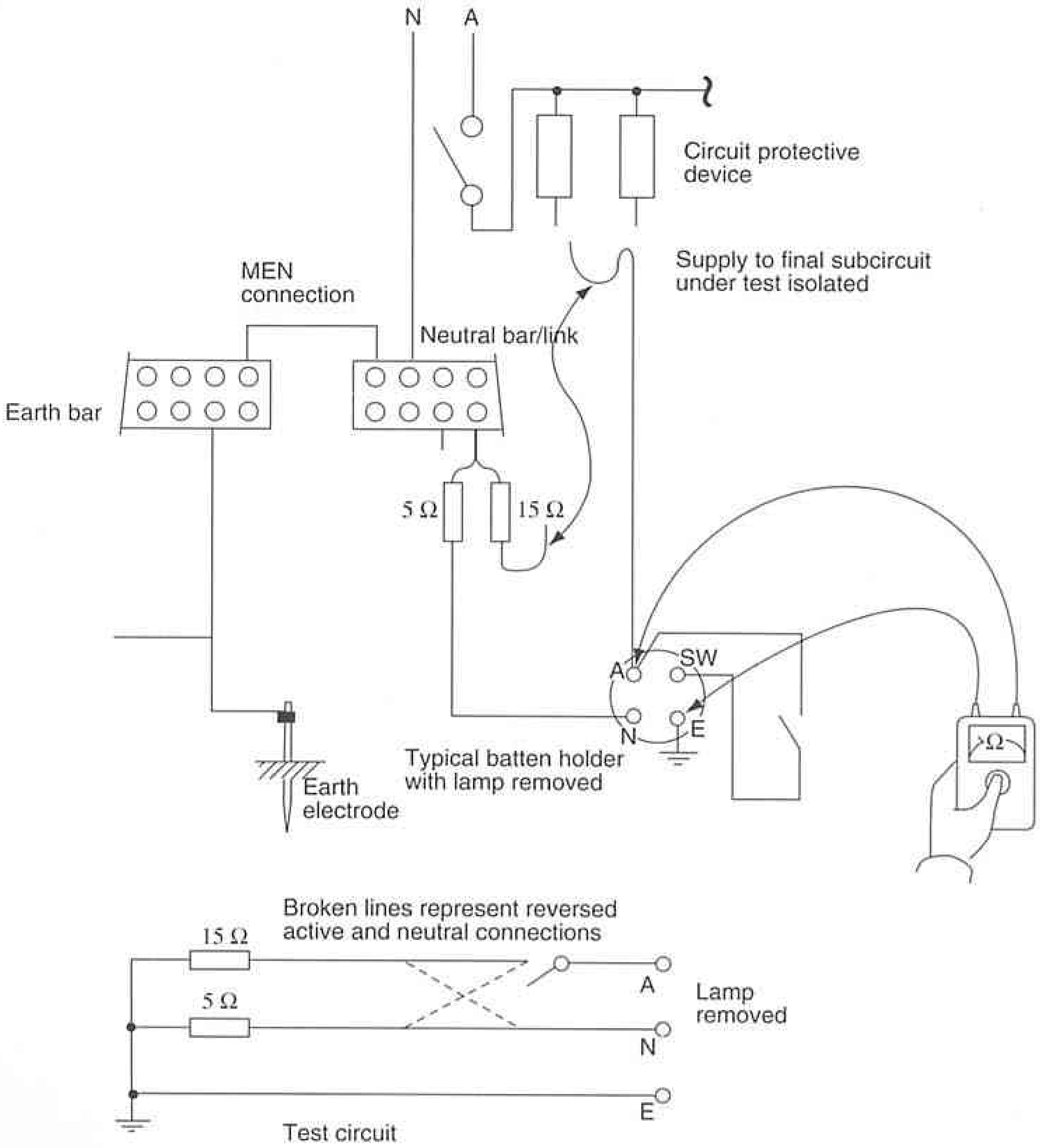

Fig. 11.28 *Testing the polarity and correctness of connections at batten holders and switches of lighting circuits (dead testing)*

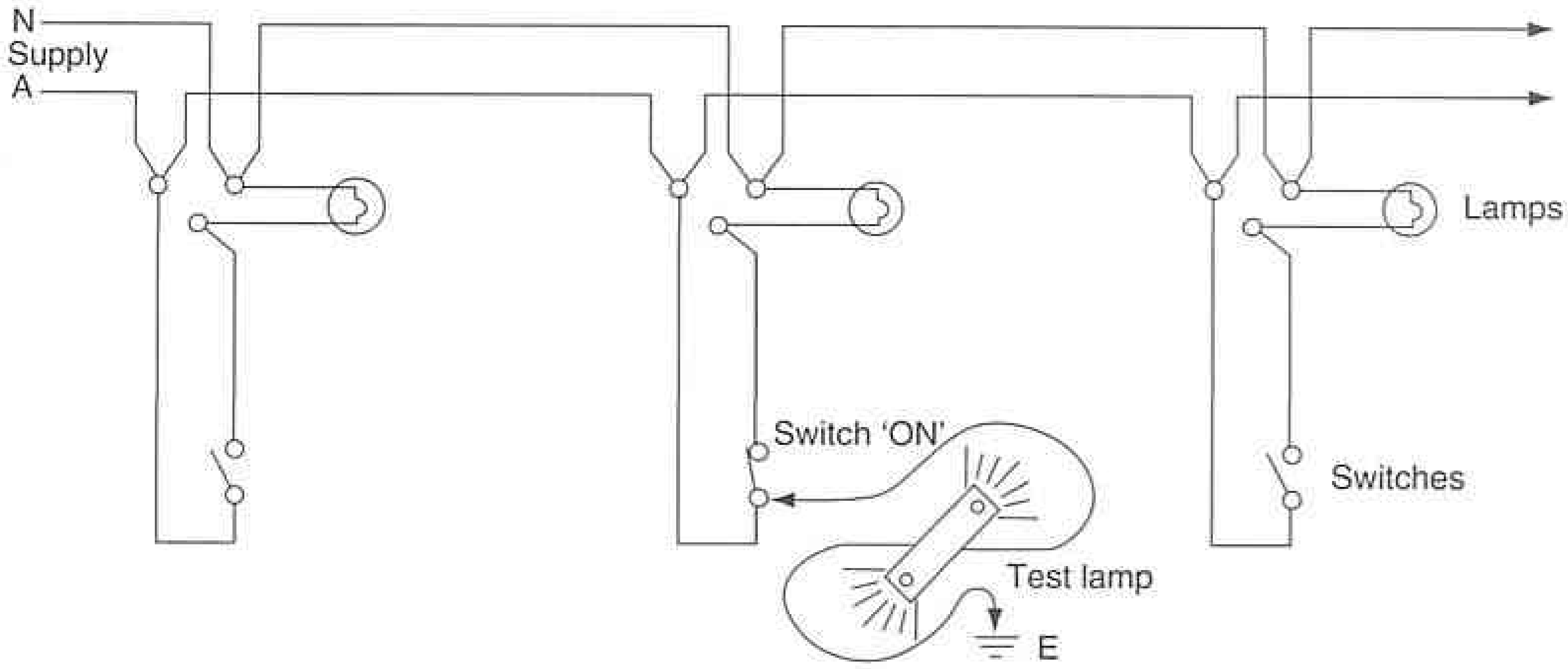

Fig. 11.29 *Simple method of checking that light switches are in active conductors*

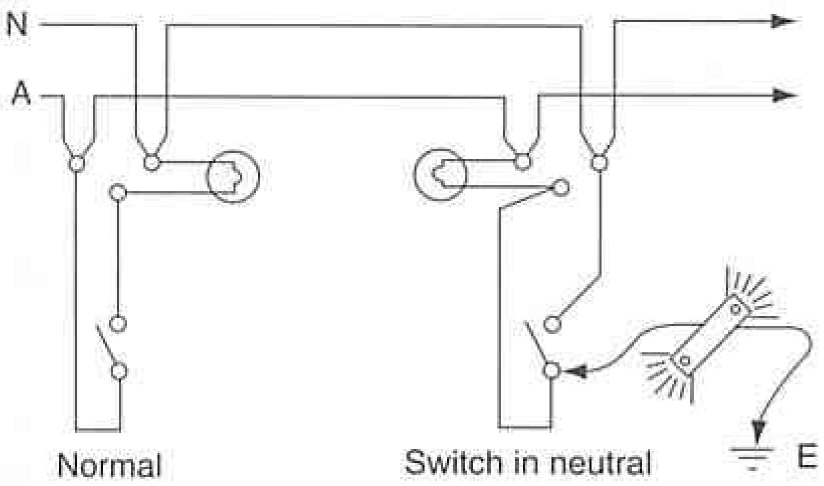

Fig. 11.30 *Detecting a light switch in the neutral*

meter were being used for the test it would indicate full-supply voltage (240 V) irrespective of the lamp rating, again leading to the false impression that connections were correct. Immediately the switch was closed, however, the lamps would cease to glow and a voltmeter would indicate zero, showing that there is a neutral at the switch instead of an active—an incorrect connection.

In this case, if the lamps are removed, no active will appear at the switch and the incorrect connection will be apparent without the switch being closed. However, in practice, it is usually easier to close a switch than to climb up and down ladders removing and replacing lamps.

Referring again to the polarity test shown in Figure 11.29, it will be recalled that all switches are to be open **except** the one being tested. If this is not done, the polarity test will be valid, but by opening the other switches the wiring connections are in effect checked at the same time, ensuring that no switch is functioning as a 'master' control.

Study Figure 11.31. In this circuit all the polarities are correct and lamp L2 is correctly wired, but switch S2 is connected as a master switch so that there is no active supply to the rest of the circuit unless S2 is closed.

In the case of the multiway control, using two-way and intermediate switches, it is best to bridge temporarily all the switch terminals and test to earth as before. Study the circuit diagram of Figure 11.32(a), and imagine the polarity reversed.

Figure 11.32(b) shows the same testing principle, applied for polarity testing of a Goliath Edison screw lampholder. Provided that the test lamp is connected as in Figure 11.32(b) to the centre contact of the lampholder to which the circuit active should be connected, the lamp should glow when the control switch is turned

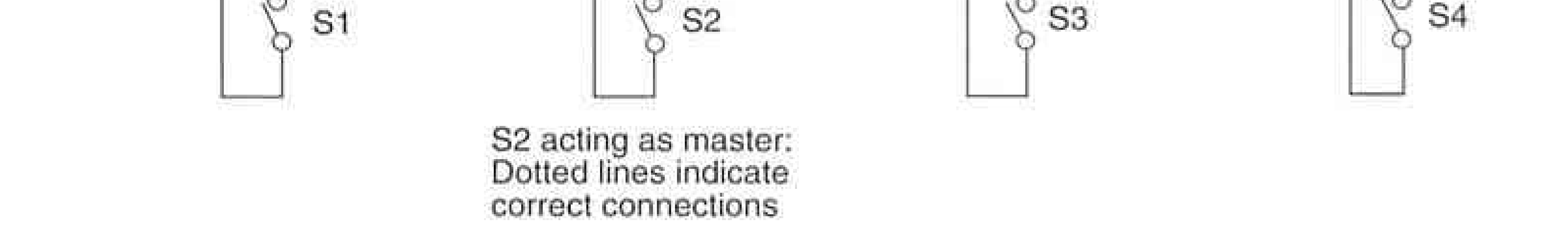

Fig. 11.31 *Incorrect connections causing switch S2 to act as a master switch*

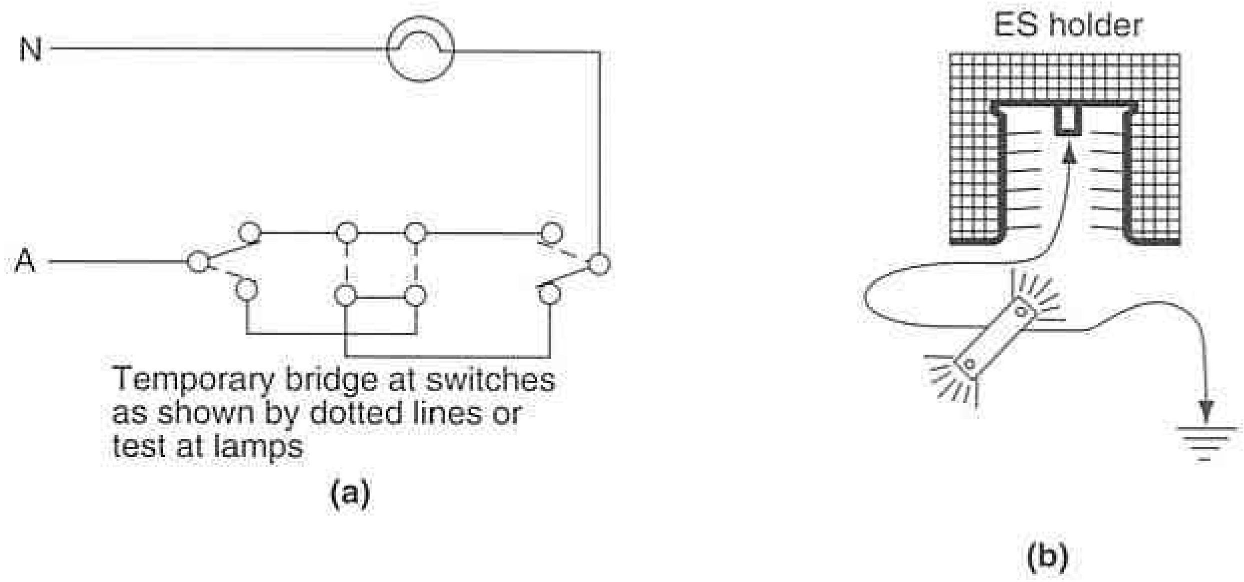

Fig. 11.32 *Polarity testing multiposition controlled lighting and Edison screw (ES) lampholders*

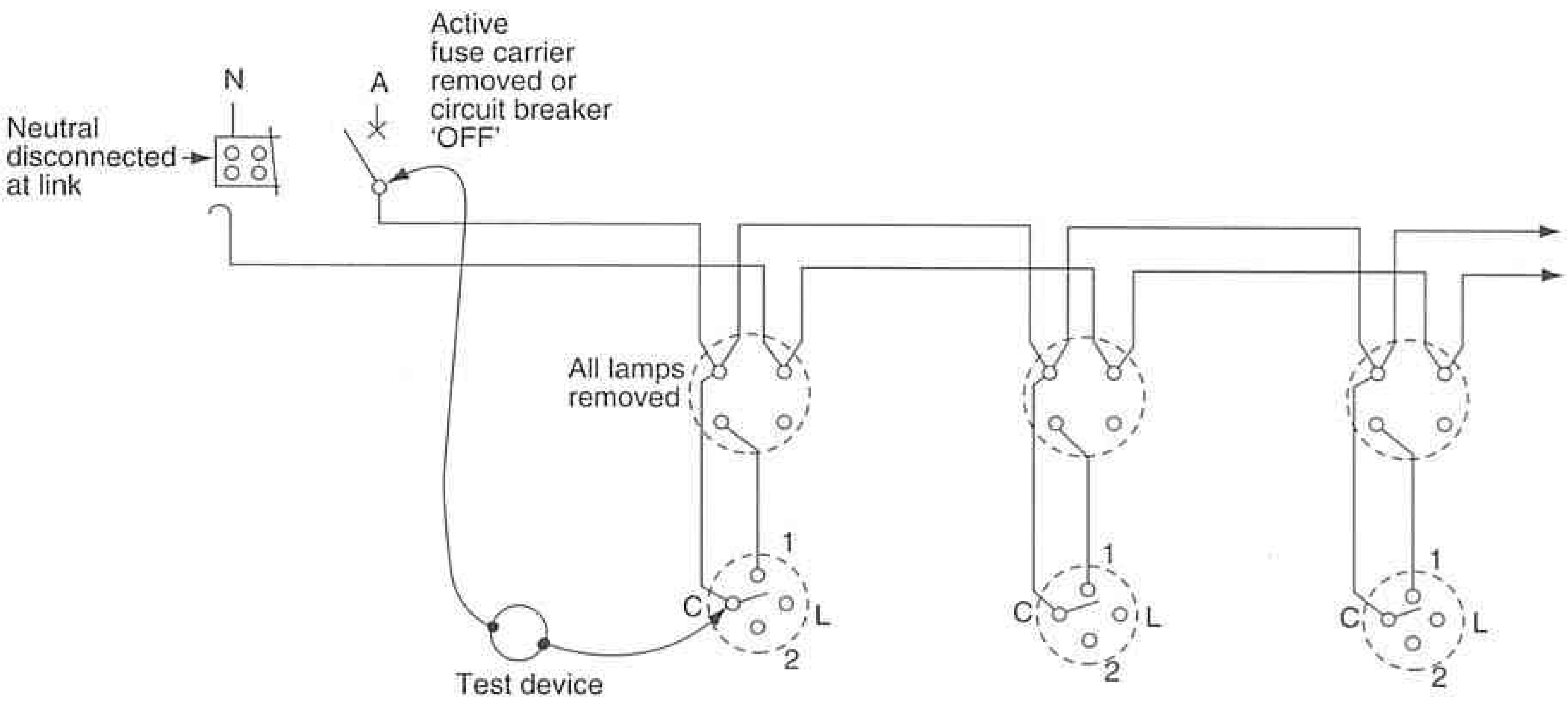

Fig. 11.33 *Polarity testing a light circuit isolated from the supply*

on. If the lamp is extinguished when the control switch is turned off, the polarity of connections to the terminals of the lampholder is correct.

Sometimes it is hard to gain access to switch contacts, in which case a special testing device that plugs into the circuit lampholder may be used, such as the 'Light Stix' shown in Figure 11.17, which is for live testing. For dead testing, the 'Light Stix' of Figure 11.16(b) is used. Both 'Light Stix' illustrated incorporate a switch that enables polarity checks to be made.

In the case of a new installation or an installation that has been isolated from the supply, any form of continuity test may be employed to achieve the object of polarity testing, which is to ensure that the active conductor is continuous from the load side of the circuit fuse or circuit breaker to each control position or switch. Always check that the circuit is de-energised first. All lamps should be removed, all switches in the 'off' position, the circuit fuse withdrawn or the circuit breaker opened, and the load neutral disconnected at the neutral link.

Virtually any type of ohmmeter, insulation-resistance tester or ELV testing device may be used for this type of continuity test, provided always that the limitations of the testing device being used are realised. For example, if an ELV source is used to test a long circuit conductor for continuity, the overall length of the conductor and the test leads may be sufficient to increase the resistance to a point where current is reduced to a value below that required to operate the testing device. For the test illustrated in Figure 11.33, the return circuit to the testing device is completed through a roving lead as shown.

If the circuit is continous, an insulation-resistance tester will indicate zero or very close to zero, as the usual minimum scale division is about 10 000 Ω. The average continuity tester, such as that shown in Figure 11.35, also will indicate a near-zero reading on the scale (usually less than 1 Ω on a meter having a full-scale deflection of 100 Ω).

The method described above requires long roving leads, but the lengths of the test leads may be reduced considerably by using sections of the circuit wiring

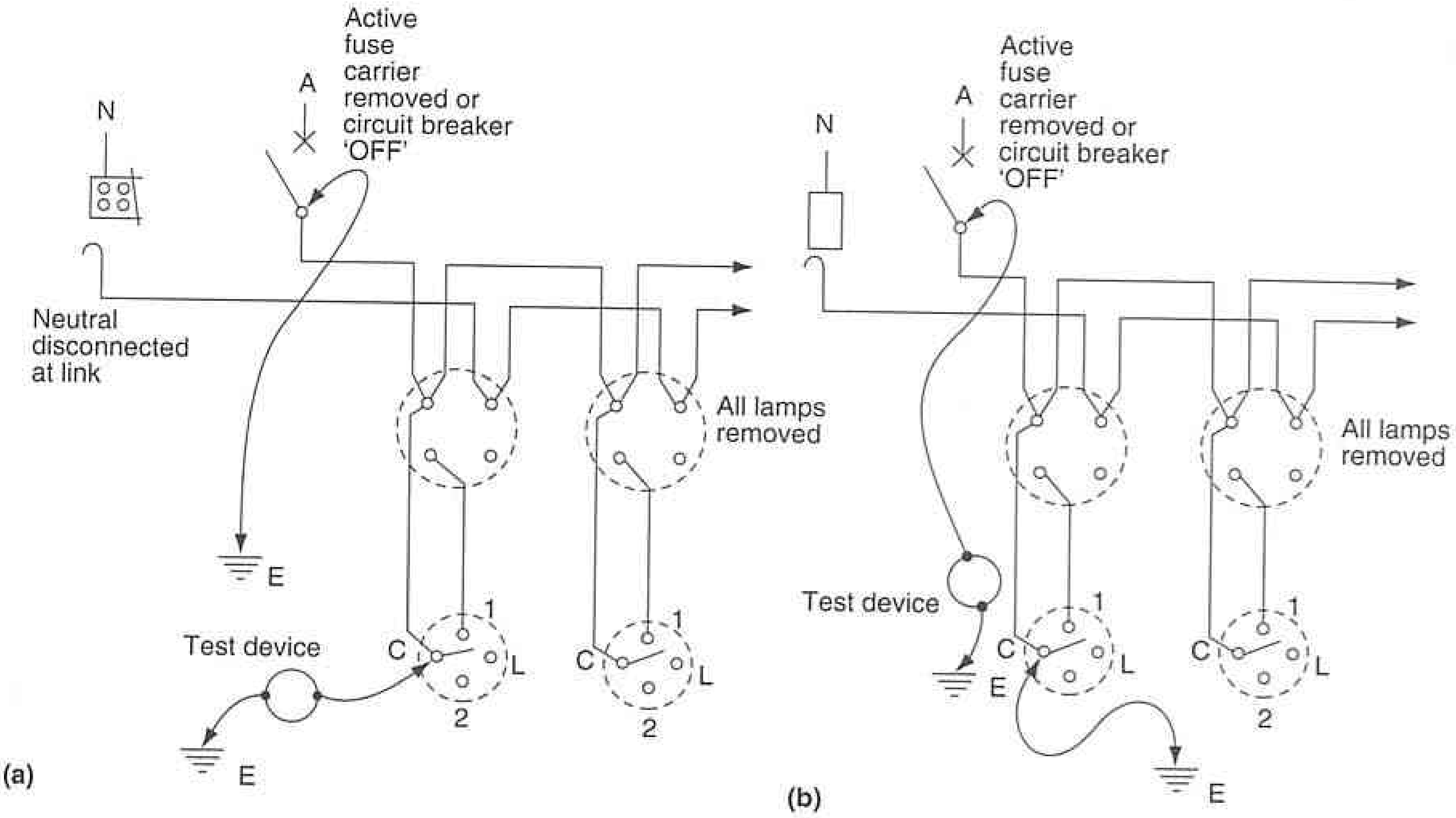

Fig. 11.34 *Methods of reducing the effective length of test circuit*

known to be electrically continuous, or by using the earthing system as the return test path as shown in Figure 11.34(a).

Figure 11.34(b) shows an alternative, where the switch terminals (or light outlets) are 'shorted to earth' in turn, giving the same indications as the previous two tests. Trace the test circuit out to check this.

It is important to note that the validity of the tests so far described depends on there being no short circuits to earth or between conductors in the circuit under test, so that **in practice insulation tests are carried out as a preliminary measure before continuity or polarity tests are applied.**

If a polarity test reveals an incorrect connection, then after the connection is corrected insulation- and earth-resistance tests may need to be repeated.

Fig. 11.35 *Analogue/digital insulation and continuity tester*
NILSEN INSTRUMENTS

11.9 Testing techniques 4: correctness of wiring circuits and connections

Some of the polarity checks described have utilised continuity testing to determine that the active feed is continuous, that it follows the correct circuit route, and that it is correctly connected. Continuity testing is also used to identify conductors prior to connection and to check the correctness of circuits and connections. Apart from checking for correct polarity, this includes checking that there are no short circuits, that there are no interconnections between circuits, and that circuit loads, active conductors and corresponding neutral conductors are correctly identified at their switchboard of origin.

Interconnection of conductors between different circuits has been the cause of a number of electrical accidents. Anyone working on such an installation is exposed to the risk of electric shock even though it may appear that the circuit has been isolated correctly. An interconnection between circuits is likely to be an 'incorrect' connection at a junction box or the looping terminal of an accessory, or the result of insulation breakdown. An 'incorrect' connection may result in the direct connection of conductors of separate circuits, as shown in Figure 11.36(a), or in a load supplied by active and neutral conductors of different circuits, as shown in Figure 11.36(b).

Testing between neutral conductors of all circuits and active conductors of the same circuits at the switchboard will show any direct interconnection faults. In

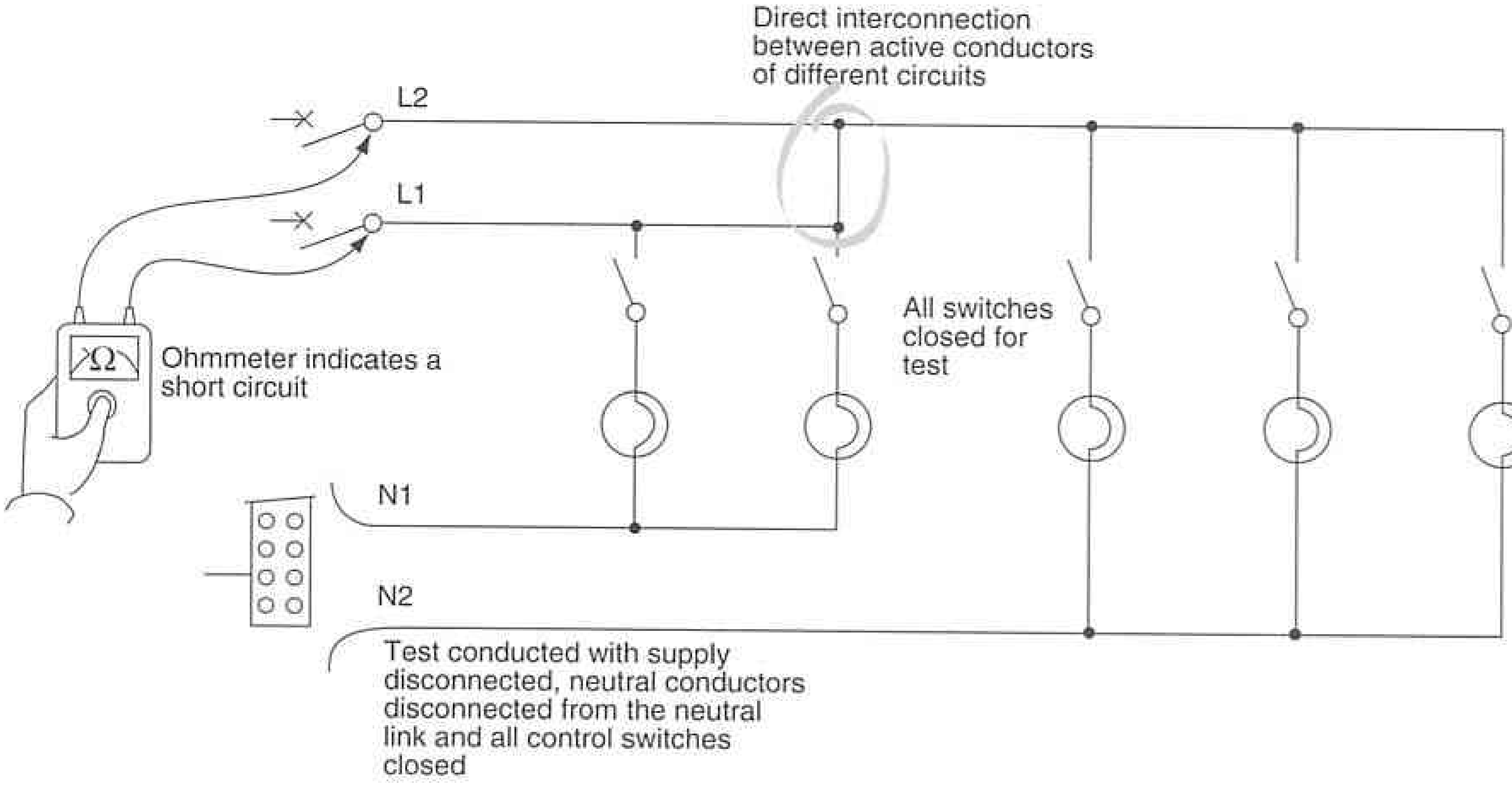

Fig. 11.36(a) *Testing for a direct connection between conductors of different circuits, revealing an interconnection between active conductors of different lighting circuits*

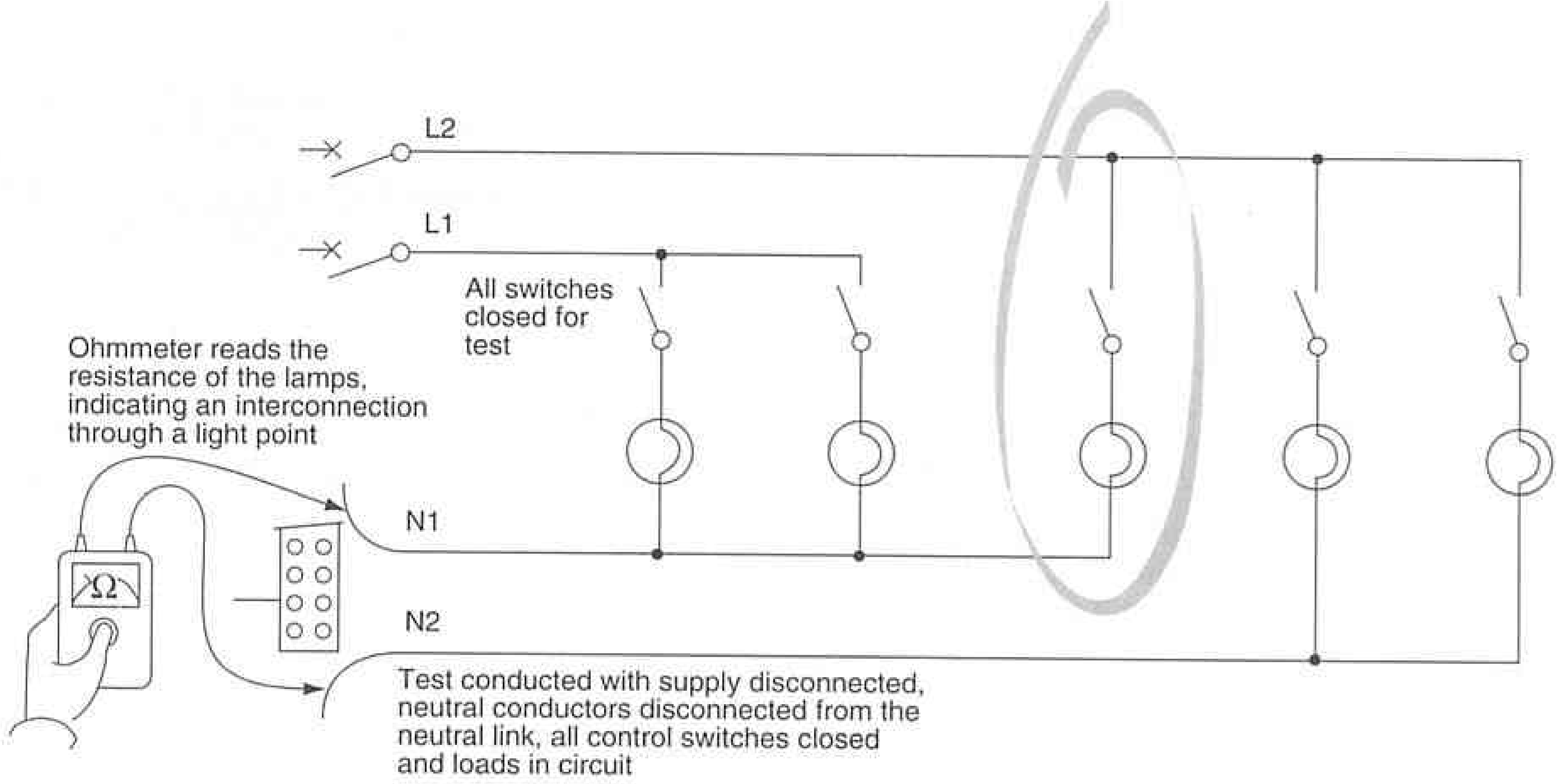

Fig. 11.36(b) *Testing for an interconnection between circuits, revealing a light point connected to active and neutral conductors of different circuits*

preparing for the test, the circuit protection devices must be opened, the circuit neutral disconnected from the neutral link, and all controlling switches or contactors closed. Testing with a low-reading ohmmeter will reveal any direct interconnections with the meter indicating a short circuit. If insulation breakdown is suspected, as may be the case in older installations, then an insulation-resistance tester should be used. Any reading below 1 MΩ indicates a problem with insulation either in the wiring or at the terminal of an accessory.

An interconnection where a load is supplied by an active and neutral of different circuits can only be detected with the loads connected. The circuit protection devices must be opened, the circuit neutral disconnected from the neutral link, and all controlling switches or contactors closed. A low-reading ohmmeter is used to test between neutral conductors or between active conductors to show any interconnection between the circuits. For example, tracing out the path of the test circuit in Figure 11.36(b) shows an interconnection fault, with the ohmmeter reading the resistance of two lamps in parallel with one lamp in series. If the test were conducted between the active conductors, the fault would be shown by the same ohmmeter reading. This test can be carried out at the same time as the following test.

Testing with an ohmmeter between the active and neutral conductors of each circuit at the switchboard can be done to check that circuits and corresponding neutrals are correctly identified. Preparation for the test is the same as for the previous test. The ohmmeter will read the resistance of each load. For example, light circuits have a cold resistance from a few ohms up to tens of ohms depending on the type of lamp and the number of points on the circuit. A 4.8 kW water heater will show an ohmmeter reading of 12 Ω, while the circuit supplying a 6.8 kW oven will read 8.5 Ω. In this way each circuit and neutral can be identified.

11.10 Testing techniques 5: general testing

Many other continuity tests are possible and will suggest themselves when electricians are confronted with a particular job situation requiring solution. Electricians should try to visualise the wiring layout and the wiring circuit under test and should remember that, to avoid long trailing leads, it is often possible to use the earthing system or circuit conductors as part of the test circuit. To illustrate this, consider the problem of identifying the ends of conductors in a long mineral-insulated metal-sheathed (MIMS) cable or in the long run of conduit illustrated in Figure 11.37.

Suppose that it is required to identify the load ends of cables L_1, L_2 and L_3 and to label them accordingly. There are several solutions to this problem; one solution is given below.

1. Connect a continuity tester between earth and one outgoing conductor, say L_3, at the supply end, as shown in Figure 11.37. The earth return can be the cable sheath itself (MIMS or metal conduit), in which case connection to the main earthing conductor is not required.
2. Check that the conductor ends are physically separated, making certain that there are no short circuits between conductors.
3. Connect each conductor in turn to 'earth' at the load end. The one giving a test indication of a short circuit is L_3.
4. Change the test lead from L_3 to L_2 at the supply end and repeat.
5. Having located L_3 and L_2, the one remaining is obviously L_1, but it is advisable to check it to ensure that it is not 'open-circuited'.

One variation of this method is to short-circuit successively the leads at the supply end and connect the test set at the load end. You should attempt to devise other solutions to this problem of conductor identification.

A cable tester that provides a quick method of tracing and identifying a large number of cables, say in a large industrial installation or multistorey building, is shown in Figure 11.38. It consists of a transmitter

Fig. 11.38 *Cable tester for multicable runs* GERARD INDUSTRIES

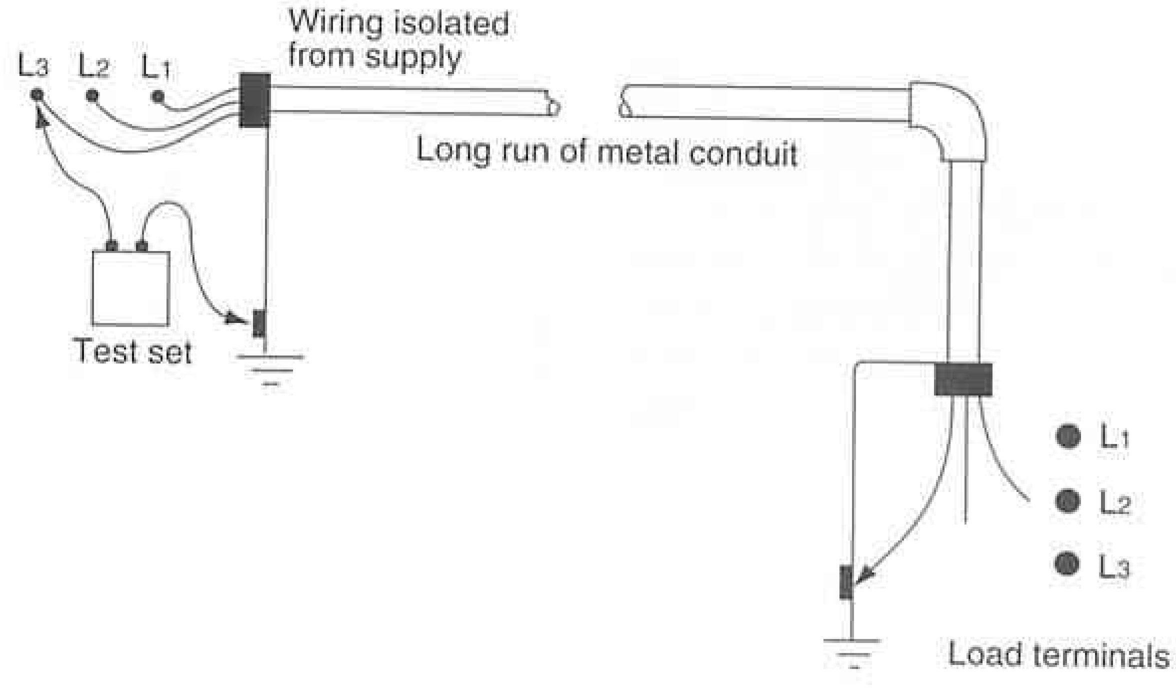

Fig. 11.37 *Continuity testing on a long run of cable*

having sixteen numbered leads, which are attached to unidentified conductors in an installation. A receiver having one contact is attached to one conductor at a time at the other end of the circuit. Pulses are sent to the receiver, which identifies the conductor as a number in the digital display window of the receiver. One wire, say the earth wire in the cable run being tested, must be used as a common (return) wire. The device is satisfactory for a route length up to 500 m and can identify crossed wires.

When testing an installation, you should always remember that any conductive path possesses resistance, and make allowance for this. For example, a 50 m run of 1 mm^2 conductor would have a resistance of approximately 0.89 Ω, and this would affect test results if using an extra-low test voltage as supply.

Resistance of wiring circuits and connections

If, for instance, the resistance of the current-carrying conductors of a circuit needs to be known for the purpose of connecting additional load, or if in the course of a routine inspection conductor resistance is required to be determined, a suitable ohmmeter on an appropriate scale will give a direct indication of the value of this resistance when its terminals are connected to the ends of the conductor. A suitable instrument for general work would be one similar to that shown in Figure 11.9. Intruments of higher sensitivity and special types are necessary for some work and are more expensive. The Bridge Megger and other adaptations of the Wheatstone Bridge also are used.

The resistance of a conductor is directly dependent on its length and the material of which it is made, but varies inversely with its cross-sectional area. Thus, for the resistance of an actual circuit conductor to change it would have to sustain violent mechanical or chemical damage to reduce its cross-sectional area, because both its length and its materials are fixed. This damage is possible, but in practice, when a continuity test reveals a higher than normal resistance value, it is usually due to poor connections at conductor joins in junction boxes or terminals of equipment (high-resistance joints).

A resistance test not only checks that there is a continuous circuit, as do the tests described earlier in this section, but ensures that the resistance of all joints and connections is sufficiently low. Sometimes high-resistance joints can be located by virtue of the fact that they often sustain an increase in temperature caused by the heating effect of the current.

To test for resistance between the two ends of a conductor (or circuit), the conductor or circuit must be isolated from all other wiring to avoid feedback or any parallel conductive paths. If the circuit is at all complex, it may be necessary to consult the circuit diagram to ensure that isolation is complete before testing.

When carrying out a test such as the one illustrated by Figure 11.39, keep in mind that measured resistance values are low, and so:

- All the test connections should be well made and of negligible resistance.
- Prior to any test, the resistance of the test leads should be determined by shorting them together. The value found must be deducted from the value read off the instrument; for example, using the method of Figure 11.39 the following test results were obtained:

resistance of test leads
$= 0.01\ \Omega$
resistance of test circuit read off ohmmeter
$= 1.13\ \Omega$
$\therefore$ resistance of circuit under test
$= 1.13 - 0.01$
$= 1.12\ \Omega.$

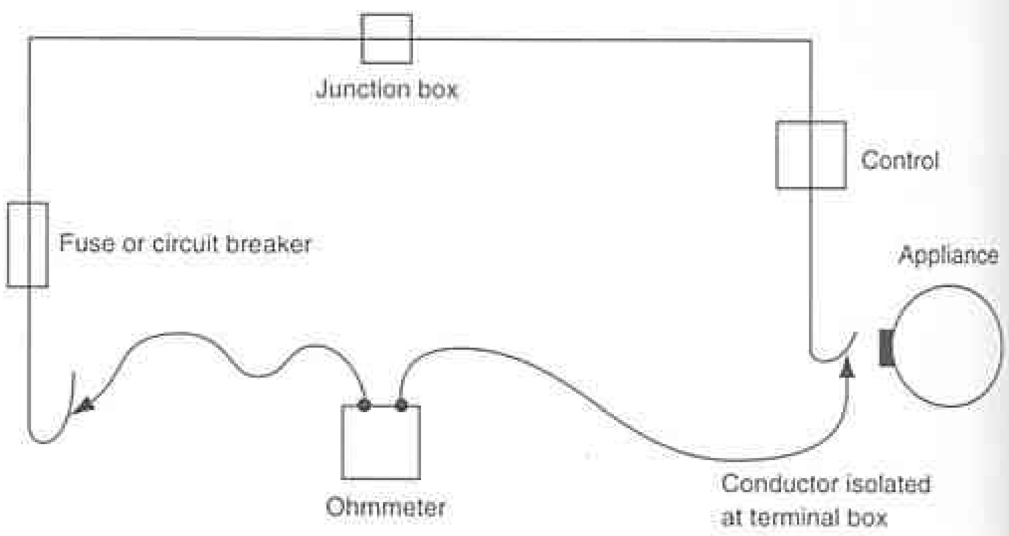

Fig. 11.39 *Checking for suspected high resistance at a fuse, junction box or control device*

Alternative testing methods

The testing and checking techniques for wiring installations outlined in this chapter cover only some suggested approaches to testing new and existing installations.

You should consult other references, such as AS/NZS 3017—1996 *Electrical Installations—Testing Guidelines*. There is also a need to be aware of local requirements and any other prescribed guidelines for carrying out electrical installation testing and checking.

11.11 Appliance testing

One of the most important safety assurance aspects in the use of electricity and requiring ongoing inspecting and testing is that related to portable appliances and extension cords. Occupational (workplace) health and safety legislation requires that all equipment be safe to use. Portable equipment and cords by their very nature are likely to be subject to much greater risk of damage than fixed equipment and wiring, and should therefore be inspected and tested more frequently. AS/NZS 3760: *In-Service Safety Inspection and Testing of Electrical Equipment* sets out requirements for periodic checking and testing of portable appliances.

The periodic tests include earthing resistance, which must not exceed 1 Ω between exposed metal parts for non-double-insulated equipment. Also, insulation resistance must be greater than 1 MΩ measured between live conductors and exposed metal parts. Portable residual current devices (RCDs) must be tested for operation within the maximum tripping time and tripping current for the particular type of RCD (see Chapter 14, Volume 2). Equipment and leads must be inspected for visually obvious damage or deterioration. Intervals between inspection and tests vary from 3 months to 5 years, depending on the activities of the environment in which they are used. For example, use of equipment on a construction site requires more frequent attention than equipment used in an office environment.

Testing equipment described in this chapter may be applied to testing portable equipment. However, purpose-built testing devices are available that help assure the accuracy and improve the efficiency of such testing.

The British version of an instrument specifically designed for testing portable appliances, and commonly used in Australia, is illustrated in Figure 11.40. It will perform five tests on an appliance, which should be carried out in the following sequence:

1. *Earth bond test:* Continuity between the exposed metal of earthed equipment and the earthed terminal of the plug is checked. For double-insulated appliances, this test is omitted and the test sequence starts with test 2.
2. *Insulation test:* A test voltage of 600 V dc is applied to check insulation resistance between live conductors and the exposed metal of the appliance.
3. *Flash test:* A test voltage of 1.5 kV is applied to an earthed appliance in the same way as for the insulation test. A flash test voltage of 3 kV is applied to double-insulated appliances via a high-voltage test probe supplied with the instrument. For operator protection, short circuit current is limited to 6 mA in both cases.
4. *Load test:* Appliance is supplied with 6 V ac as a pretest of normal appliance operation without the problem of high currents damaging the appliance or testing instrument.
5. *Operation test:* Appliance is tested under normal operating conditions at mains supply voltage, and the power consumed is compared with the nameplate rating.

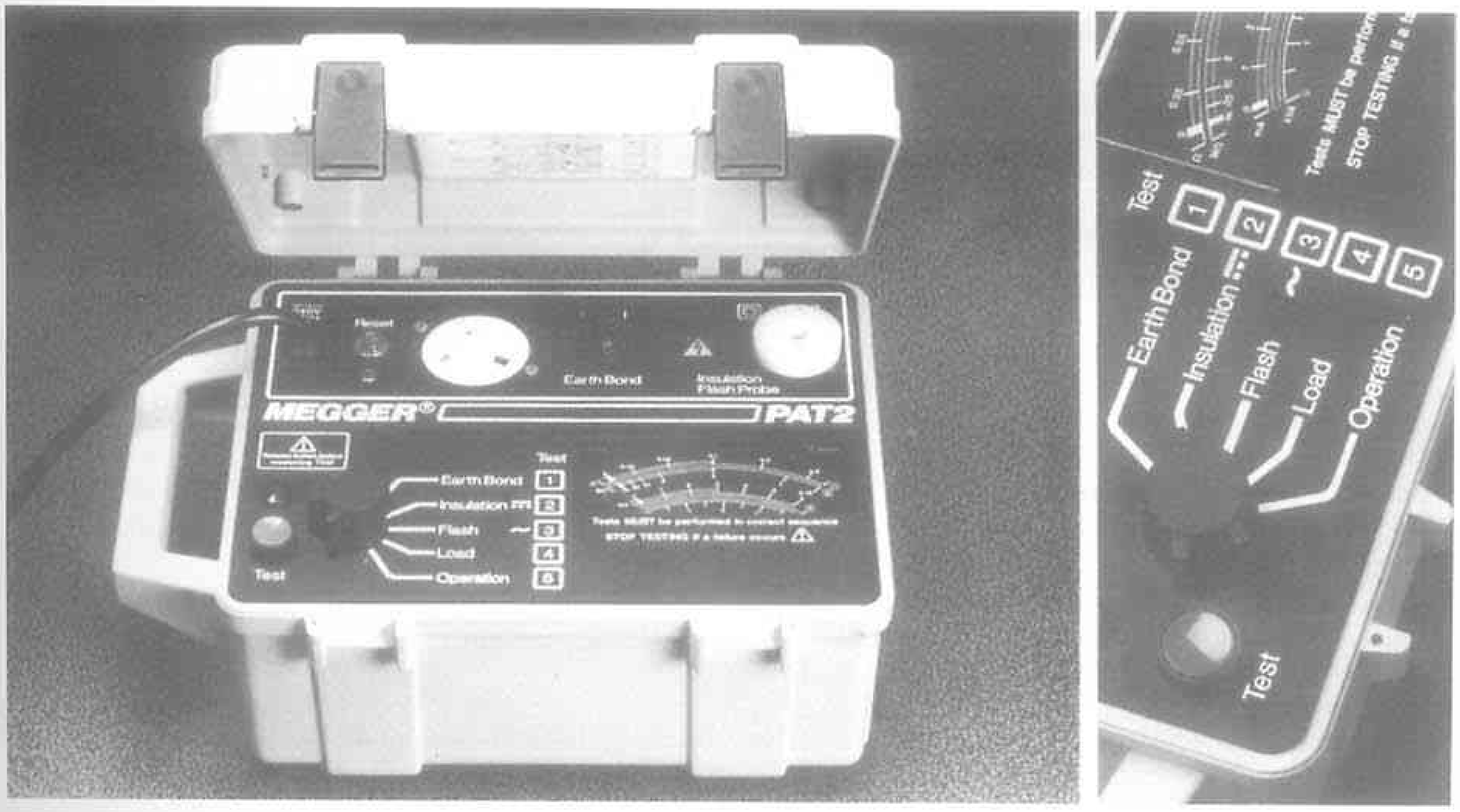

Fig. 11.40 *Portable appliance tester* NILSEN INSTRUMENTS

SUMMARY

- Testing of electrical circuits and wiring is carried out:
  - during the installation of wiring to avoid costly defects,
  - at the completion of an installation to ensure that it is safe and complies with the *SAA Wiring Rules*, service and installation rules and state wiring regulations, and
  - during routine maintenance and to locate faults when circuits and wiring malfunction.
- Regulations require that mandatory tests be conducted on all new and altered installations to ensure that the earth system is adequate, that the insulation is safe, that there are no incorrect polarity connections, and that the installation operates as intended.
- A sound knowledge of Ohm's Law and understanding of wiring arrangements is required if testing is to be carried out effectively.
- In electrical testing an energy source is connected to the circuit under test and indicators or meters are used to monitor the circuit's behaviour.
- Testing a conductor or circuit to determine whether it is electrically continuous using a testing device with an inbuilt energy source is referred to as 'continuity testing'.
- 'Dead testing' is carried out with the supply disconnected from the circuit under test, using testing devices with an inbuilt energy source.
- 'Live testing' is conducted with the supply connected to the circuit under test, the supply being used as the energy source.
- Visual indicators are the most widely used testing device; they include 480 V series test lamps, neon testers such as the neon test pencil, and high-impedance voltage testers with voltage level indicator.
- Analogue meters provide a visual indication through the movement of the pointer, and may be preferred to the digital-type meter where precise measurement is not required.
- Instruments must be suitable for the supply and set to the correct range to avoid damage to the instrument and creation of a safety hazard.
- The most commonly used meter for measuring current is the clip-on-type instrument, as no direct circuit connections are necessary, making it quicker and safer to use.
- Multimeters have incorporated in them the functions of several meters, including resistance measurement.
- The energy source in an insulation-resistance tester is a battery with an electronic circuit to boost the voltage to a test level of 500 V or 1000 V, as required by *Clause 1.5.2.*
- Purpose-built testing accessories are used to improve the efficiency and accuracy of testing new installations (see Figs 11.16, 11.17 and 11.18).
- When testing, control measures must be adopted to limit the risk of injury or death.
- Risk factors include:
  - using test probes with excessive bare metal at the tip
  - incorrectly setting meters
  - using devices with exposed terminals
  - leads coming adrift from meter terminals.
- Risks associated with testing can be reduced by selecting appropriately safe equipment, including:
  - fused test probes, particularly when testing systems having high energy levels
  - properly insulated and colour-coded leads
  - approved covered test lamps, marked with their maximum test voltage.
- All test equipment should be checked before, during and after testing to ensure that it works properly and is safe.
- Testing an installation to ensure that it is safe and complies with requirements is the responsibility of the electrical contractor or installing electrician.
- Earth-continuity testing is to check that sections of the earthing system do not exceed 2 Ω or are sufficiently low to ensure the circuit protection device will operate quickly to cut off the supply in the event of a short circuit to earth fault. In New Zealand, earthing system resistance must not exceed 0.5 Ω (see Figs 11.21 and 11.22).
- Insulation-resistance testing checks whether the insulation between live conductors and earth will break down under the stress of the supply voltage. The test is also used to check resistance between live conductors (see Figs 11.23 and 11.24).
- Polarity testing is to check that active and neutral conductors are connected to the correct terminals at socket outlets, that all switches are in the active conductor, and that there is no transposition of neutral and earthing conductors (see Figs 11.25 to 11.34).
- Testing the correctness of wiring circuits and connections includes checking that there are no short circuits, no interconnections between circuits, and that circuit loads, active conductors and corresponding neutral conductors are correctly identified (see Fig. 11.36).
- Other tests are required from time to time, as part of a routine inspection of an existing installation to identify cables prior to connection, or for the purpose of determining additional load capabilities of a circuit (see Figs 11.37 and 11.38).
- Appliance testing includes insulation resistance, continuity of earthing from the earth pin on the three-pin plug attached to the exposed metal of the appliance, and correct operation of switches.

REVIEW QUESTIONS

Where the answer to a review question is numerical or requires reference to the SAA Wiring Rules, the answer is given at the back of the book. These questions are marked ⋆.

⋆ **1.** Why is it necessary to give a completed installation a thorough *visual inspection?*

2. Could an electrical fault be present in a circuit without appearing to affect the normal operation of the circuit? Explain fully.

3. Why is it dangerous to use the single-lamp type of test lamp for tests on 415/250 V supply?

4. Suggest one disadvantage of the neon 'test pencil' that could lead to misinterpretation of a circuit condition.

5. How are:
(a) an ammeter
(b) a voltmeter
connected into a testing circuit?

6. Is it possible to obtain an indication of the value of current in a circuit without making any electrical connection to the circuit? If so, why?

7. State some practical uses for a multimeter.

8. Could the inexpensive small type of multimeter be used for *tests of insulation resistance?*

9. *Is there available* any type of portable battery-powered instrument that is capable of insulation-resistance tests?

10. State common scale ranges for:
(a) *an insulation-resistance tester*
(b) a continuity tester.

11. What features would you look for in a probe intended for detecting the presence or absence of voltage?

12. *When should a fused probe be used?*

13. An apprentice is asked to test a circuit for values of insulation resistance and adopts the following procedure:
(a) connects insulation-resistance tester between active and earth and, with lamps removed, switches closed and appliances disconnected, takes and records a reading (infinity);
(b) repeats step (a) for a reading between neutral and earth (infinity);
(c) as an additional test, checks between active and neutral (infinity);
(d) checks recorded results and hands them to the person who requested the tests.
Name three serious errors made.

⋆**14.** A multimeter has voltage scale ranges of 0–10, 100, 200, 400, 800 and 1600. On what range should it be set before connection to a 240 V circuit?

15. When polarity testing between a switch terminal and earth, should the switch be open or closed?

⋆**16.** What are the required polarity connections for a three-pin socket outlet?

17. *What steps would you take before carrying out a* polarity test on a circuit protected by an RCD?

18. Refer to the identification problem of Figure 11.37, and briefly list the testing steps for a solution other than the ones given.

19. At what positions in a circuit are high-resistance continuity faults most likely to occur?

20. When testing for the continuity of a conductor in a rather complex circuit, what steps must be taken to ensure that the instrument reading is due only to the resistance of the conductor?

21. How is allowance made for the resistance of the test leads in a continuity test on an earthing system?

⋆**22.** What is the maximum permissible value for resistance measured between the main earth connection and any part of the earthing system?

⋆**23.** Do the Rules require that *an insulation-resistance test be made between conductors?*

⋆**24.** What would be the minimum value of insulation resistance to earth for any part of an electrical installation?

⋆**25.** Why are appliances excluded from an insulation-resistance test of the wiring?

26. All switches must be closed for an insulation-resistance test. What is the reason for this?

⋆**27.** What is the usual minimum value for insulation resistance of a heating appliance?

⋆**28.** State the value of the minimum test voltage for an insulation-resistance test on a 240 V circuit.

29. Would an 'insulation-resistance tester' be suitable for indicating the resistance of the element in an appliance such as a hot-water urn?

30. An appliance cord is incorrectly connected as follows:
(a) neutral to the frame of the appliance
(b) active and earth to the motor of the appliance.
What is the result when the appliance is plugged into the supply?
Another appliance is connected as follows:
(a) active to appliance frame
(b) neutral and earth to the motor of the appliance.
What are the possible results of this incorrect connection?

Answers

These answers are to problems with numerical answers or requiring reference to the *SAA Wiring Rules*.

Chapter 1

Q19. *Clause 0.2*

Chapter 2

Q 9. *Clause 3.2.2*
Q14. *Clause 0.5.41*
Q16. *Clauses 0.5.57* and *0.5.58*
Q18. *Clause 6.3*
Q19. *Clause 6.3.6.3*

Chapter 3

Q 2. *Foreword* to *SAA Wiring Rules* and *Clause 0.3*
Q 3. *Foreword* to *SAA Wiring Rules*
Q 4. *Clause 0.2*
Q 5. *Clauses 0.5.3* and *0.5.7*
Q 6. *Clauses 0.5.5, 3.14.1* and *3.15.1*
Q 7. *Clauses 0.5.17* and *0.5.40*
Q 8. *Clause 0.5.31*
Q 9. *Clause 0.5.95*
Q10. *Clauses 0.5.29* and *0.5.30*
Q11. *Clauses 0.5.78* and *0.5.30*
Q12. *Clause 0.5.2*
Q13. *Section 5*
Q14. *Clause 0.5.42*
Q15. *Clause 0.5.64*
Q16. *Clauses 0.5.18* and *0.5.27*
Q17. *Clause 0.5.35*
Q18. *Clause 0.5.54*
Q19. *Clause 0.5.70*
Q20. *Clause 3.24.2*
Q24. *Clause 1.1.5*
Q26. *Clause 1.2.3*
Q27. *Clause 1.4.8.1*
Q28. *Table 1.1,* 0.6 m
Q29. *Clauses 1.1.6* and *2.4.3.2*
Q30. *Clause 1.4.9.3,* 50 mm
Q31. *Clause 1.4.9.3*
Q32. *Clauses 1.4.9.1, 1.4.9.2* and *1.4.9.3*
Q33. *Clause 1.5*
Q34. No, *Clause 1.2.5.2*
Q38. *Clause 1.5.2.4*

Chapter 4

Q 1. *Clauses 0.5.18* and *0.5.27*
Q 2. *Clause 0.5.21*
Q 5. *Paragraph B3.1, Note 2* and text
Q 6. *Clause 3.4*
Q 9. *Clause 3.2.4.2*
Q19. *Table 2.1*
Q20. *Clause 3.2.4.3*
Q23. *Clause 0.5.31*
Q24. *Clause 0.5.58*
Q28. *Clauses 3.9.5.1* and *3.31.4.5*
Q29. *Clause 3.24.2*

Chapter 5

Q 1. *Clauses 0.5.3* and *0.5.7*
Q 2. *Clause 5.5.4.2*
Q10. *Clause 4.8.1*
Q17. *Clause 3.15*
Q23. *Clause 9.5.3*
Q27. *Table 4.1*

Chapter 6

Q 8. *Clauses 2.18(a), 6.11* and *6.14*

Chapter 7

Q 1. *Clause 0.5.54*
Q 8. *Clauses 0.5.40* and *0.5.94*
Q 9. *Clauses 3.14* and *3.18*

Q10. *Clause 6.8.2.1*
Q11. *Clause 3.31.3.2*
Q12. *Clauses 3.31.3.3* and *4.6.1*
Q14. *Clauses 0.5.17* and *0.5.94*
Q17. *Clauses 0.5.35* and *6.4*
Q18. *Clause 6.6.2.2, Note 2*
Q19. *Clause 6.6.4*
Q21. (a) 0.5 m; (b) 0.3 m, *Table 3.7*
Q23. *Clause 3.16.3.1(e)(iv)*
Q24. *Clause 3.36*
Q25. *Clause 3.36.2.2*

Chapter 8

Q 1. *Clause 3.20.2.2*
Q 2. 0.3 m or 20 × minor cable diameter, *Clause 3.20.3.2(a)*
Q 3. (a) *Clause 3.20.3.3(b)(ii)*; (b) *Clause 3.20.3.5(d)*
Q 4. *Clause 3.20.3.2(b)(ii)*
Q 5. *Clause 3.20.2.1(b)*
Q 8. *Clause 3.20.2.2*

Chapter 9

Q 4. 8
Q 5. (a) 50 mm; (b) 63 mm
Q 7. (a) 2.0 m, *Clause 3.26.4.4*; (b) 1.0 m, *Clause 3.28.4.3(a)*
Q 8. *Clause 3.26.1(c)*
Q12. *Clause 3.26.5.6*
Q13. *Clause 3.26.1*
Q14. *Clause 3.26.2*
Q15. *Clause 3.26.1*
Q16. *Clause 3.28.3*
Q17. *Clause 5.4.4.3(b)*
Q18. *Clause 3.26.5.3*
Q19. *Clause 1.4.7.1*
Q20. *Clause 3.26.4.8*
Q21. *Clause 3.16.3* and *Table 3.6*
Q22. 4, *Clause 3.28.4.4(b)*
Q23. *Clause 3.28.3(d)*
Q27. *Clause 3.28.4.2*
Q28. *Clause 1.4.7.1*
Q30. *Clause 5.4.4.2(c)(v)*
Q31. 7, *Table E7*, column 5
Q32. 4, *Table E7*, column 12
Q33. 10, *Table E7*, column 8 (may have to be derated for current)
Q34. No, 3 per cent over limit, *Table E7*, column 8
Q35. No, derated to values shown in columns of *Table B3*
Q36. *Clauses 3.16.3.2* and *3.16.4.2*
Q37. *Clause 3.28.4.4*
Q38. *Clauses 3.25.1(g)* and *3.26.3* and *Table 3.6*

Chapter 10

Q 4. *Clause 2.19.7.2*
Q 5. *Clause 1.2.3*
Q 6. 2800°C
Q 7. 32 A, *Table B4*, AS 3000; 40 A *Table 14*, AS 3008.1
Q 8. (a) 90°C; higher temperature subject to conditions, *Note 5, Table 2.1*
(b) 90°C, *Note 5, Table 2.1*, type V105 sheath
Q16. *Clause 3.21.6*
Q18. *Clause 2.2.5*
Q19. *Clause 3.21.2.2*
Q20. *Clause 5.4.4.3(c)*
Q21. *Clause 3.21.2.3*
Q22. *Clauses 6.3.3.1(a)* and *6.3.3.4*

Chapter 11

Q 1. *Clauses 1.1, 1.2, 1.3* and *1.4*
Q14. 1600 V and step down
Q16. *Clause 4.14.8*
Q22. 2Ω, *Clause 1.5.3.3(a)* (0.5 Ω in NZ)
Q23. *Clause 1.5.2.1*
Q24. 1 MΩ, *Clause 1.5.2.2*
Q25. *Clause 1.5.2.2*; text and *Clause 1.5.2.4*
Q27. 0.01 MΩ, *Clause 1.5.2.4*
Q28. 500 V dc, *Clause 1.5.2.1*

8

TPS wiring systems

In this chapter you will learn about thermoplastic-sheathed (TPS) wiring systems, including:

- characteristics of TPS wiring systems
- basic TPS circuit wiring techniques
- installing methods and requirements
- prefabricated loom-wiring systems.

8.1 Introduction

PVC-insulated PVC-sheathed cables, commonly known as TPS (thermoplastic-sheathed) cables, form the basis of the most widely used wiring system in domestic and commercial premises. This chapter describes the features of TPS wiring and installation practices that help to ensure that the wiring is installed efficiently and that the installation complies with the regulations.

8.2 Characteristics of TPS wiring systems

Both tough rubber-sheathed (TRS) and TPS cables, when used with all-insulated accessories, form a double-insulated wiring system (see *Clause 0.5.58*).

In situations where mechanical damage was not a hazard, the old lead-sheathed cables and plain conduit wiring were first superseded by TRS cable and later, after the development of plastics, by TPS cable. The latter wiring system is now perhaps the most popular system for use in domestic installations, and it is widely used in factory and commercial installations, where both flat and circular TPS cable is often employed. The installation of TRS and TPS cables is covered by *Clause 3.20*, with cross-references.

The main reasons for the current popularity and widespread use of the TPS wiring system, compared with most other systems, are:

- It is quickly and easily installed for surface work.
- Its use as a concealed wiring system is even more convenient and labour-saving.
- If used with all-insulated accessories, it forms a complete double-insulated system.
- Mainly due to the above advantages, its installation cost is usually less than that of other systems.

TPS cable is available with or without an earthing conductor enclosed in the same sheath as the other circuit conductors. Cable with an enclosed earthing conductor simplifies the installation of circuits such as general-purpose outlets (GPOs) in parallel, light outlets, motors and other equipment required to be earthed.

TPS cable does, however, have some disadvantages; for example, it is prone to mechanical damage during installation if not handled carefully, it may be subject to damage by rodents, and it must be protected against mechanical damage in some situations. It is also unsuitable for use in a 'draw-in' system similar to single PVC-insulated cables in conduit.

The PVC sheath is chemically inert to most environments, and only those chemicals listed in section 9.4, Chapter 9, for PVC conduits are deleterious. Note also that an electrician must always be alert for any environment that is suspect; be cautious and consult the manufacturer if in doubt regarding a particular application.

Applications include underground wiring, if suitably protected; and because the cable is classed as being 'weatherproof' it may be used in certain situations external to buildings or run as catenary wiring inside or outside buildings.

TPS cable exposed to direct sunlight should preferably be sheathed with a material that has been stabilised against the effects of ultraviolet rays.

Characteristics of a double-insulated fire-rated cable are described in some detail in Chapter 10.

8.3 Basic TPS wiring techniques

The loop-in type of wiring circuit is the one most used, and modern ceiling roses, batten holders and switches have one or more looping terminals provided for this purpose. A system where active and neutral feeds loop from accessories instead of junction boxes is preferable throughout, but sometimes junction boxes are necessary or economical, or are installed to permit later extensions.

At this point you should refer to Chapter 6, in which circuits for 'looping in' are illustrated. Figures 6.7 and 6.8 represent the two most common methods used in TPS wiring of lighting circuits, and the method of Figure 6.7 is the one used in conjunction with the wiring layout shown in Figure 8.1.

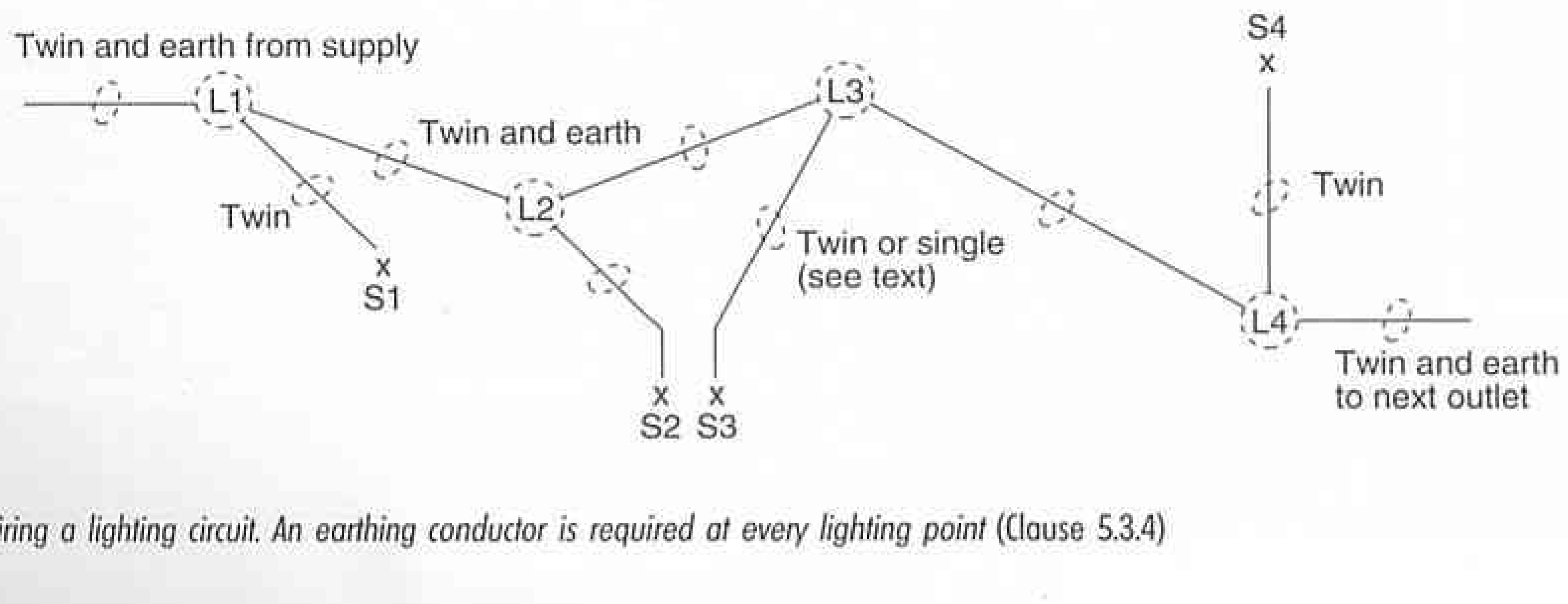

Fig. 8.1 *Wiring a lighting circuit. An earthing conductor is required at every lighting point* (Clause 5.3.4)

Twin and earth 1 mm² cable is looped between light outlets, and twin cable is used from the light outlet to the switch position. The cables need not be specially marked for identification when connecting up, as the switch run is the only two-core cable used.

The adjacent switches S2 and S3 of Figure 8.1 could be connected by two 1 mm² two-core cables, as shown in Figure 8.2(a), or by a two-core and a single-core cable, as shown in Figure 8.2(b).

Where looping is done from switch to switch, the method indicated by Figure 6.8 of Chapter 6 may be applied. Alternatively, twin and earth cable may be used throughout the circuit to maintain the required earth at every lighting point, as shown in Figure 8.3. In this case, the twin and earth cable from each switch to the light that it controls will need to be identified.

Basic circuits illustrated may be used for either surface or concealed work, with variations to suit the type of building construction and other wiring conditions.

Three-core and three-core with earth are popular cables for wiring three-phase motor circuits where the TPS system of wiring is being used.

8.4 Installing TPS cables

The general approach to the installation of a TPS wiring system has commonsense rules similar to those for other systems; that is:

1. Cable runs should be planned for speedy installation and the economical use of material. Appearance will also be a factor in surface work.

   The usual fixing accessories for TPS cable are pin clips of soft brass in four sizes, suitable for

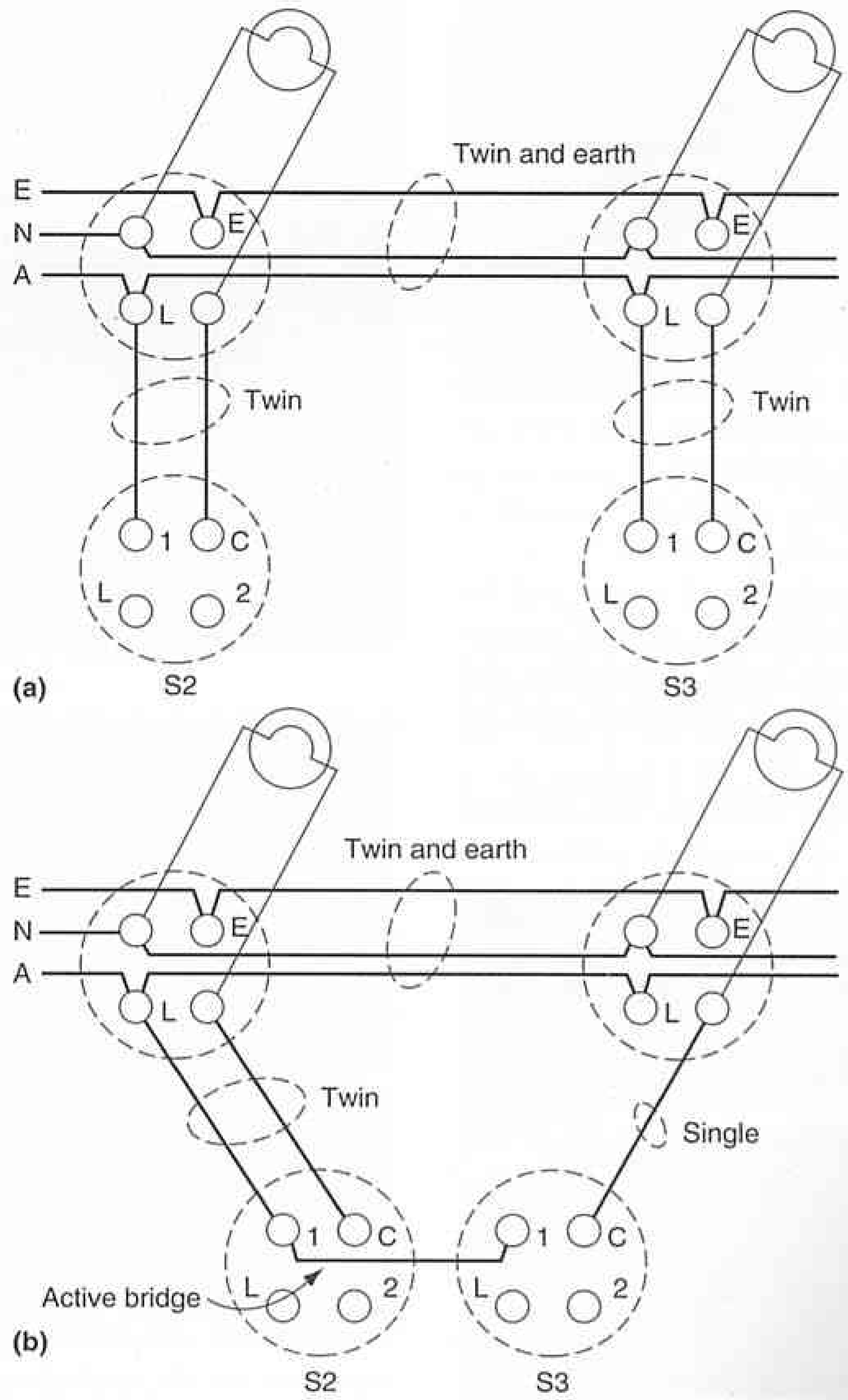

Fig. 8.2 *Two methods of wiring using looping at lights:* **(a)** *where switches are apart;* **(b)** *where switches are adjacent*

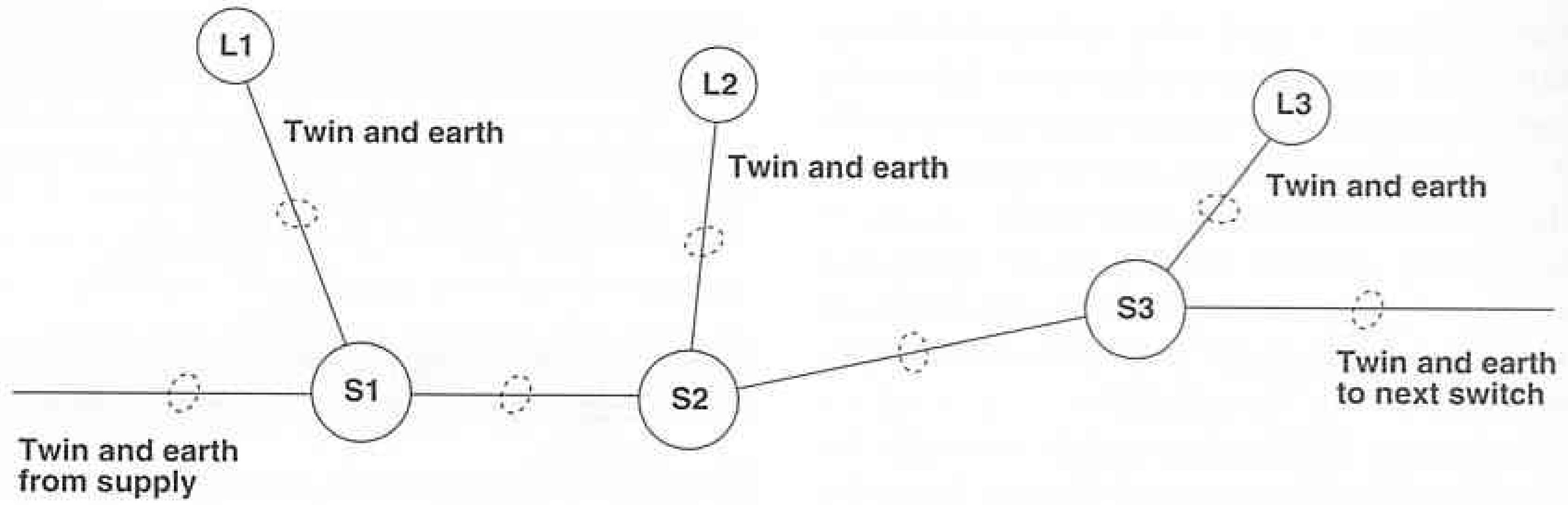

Fig. 8.3 *Wiring a lighting circuit looping at switches*

different cable sizes (aluminium clips also are made for special purposes), plastic cable clips as shown in Figure 8.4(b) and nylon cable ties (see *Clause 3.20.3.6* 'Means of fixing').

2. If the wiring is on the surface, installed in a position where it is likely to be disturbed (*Clause 3.20.3.2*), and metal pin clips are to be used, these may be installed in short sections and the cable then clipped in, making sure that it is installed with no sharp twists or bends in the cable run. Alternatively, the more commonly used plastic cable clips or other fixings, such as cable ties, may be used. It is usually best practice to use metal pin clips on long runs, where you can install the clips for the whole run prior to fixing the cable. This reduces the risk of damage to the cables, which is more likely when they are installed and fixed at the same time.

   With concealed wiring, any fixing necessary is done as the cable is placed in position.
3. When all the cables are fixed and secure, and the wiring into equipment is complete, the final connections are made at junction boxes, switchboards and equipment, and the installation is prepared ready for service.
4. Before the system is put into service, final testing is carried out.

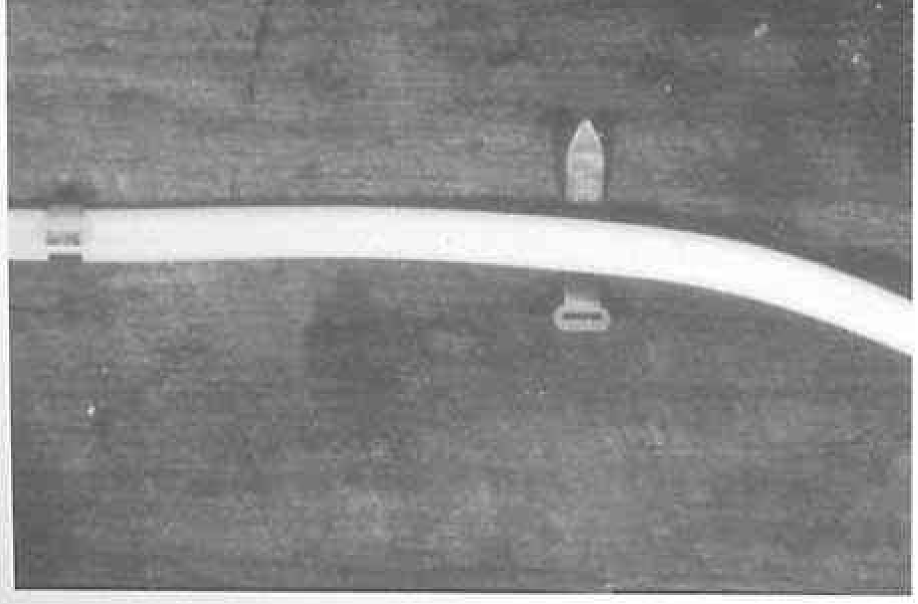

Fig. 8.4(a) *Metal pin clips for TPS cable* UTILUX

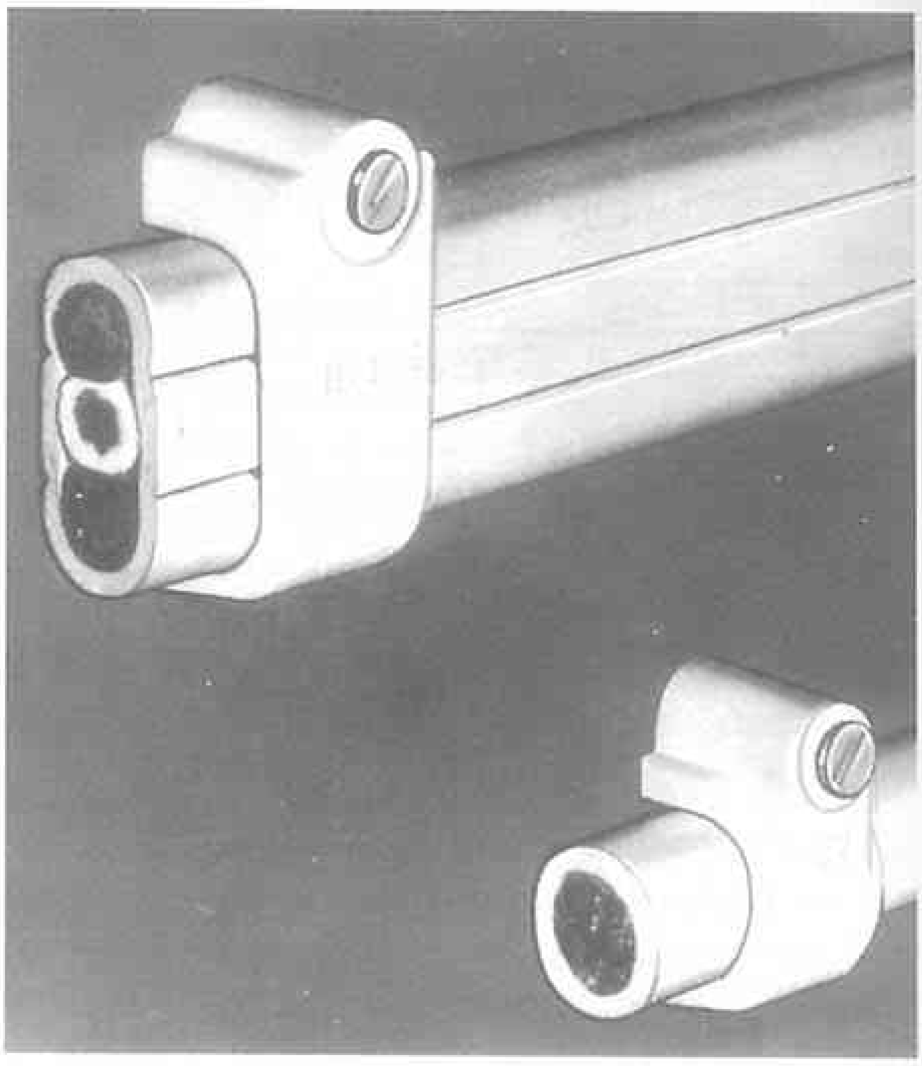

Fig. 8.4(b) *Plastic clips for TPS cable* SPINAWAY CABLES

Although essentially a surface system, TPS wiring may be concealed in roof spaces or cavities or between a floor and an uppermost ceiling. Unless protected mechanically by a suitable enclosure, it must not be buried in concrete, but it may be buried in cement or plaster for vertical runs not exceeding 3 m in length above or below the accessory being supplied in the same room (refer to *Clause 3.20.2.1(b)(ii)*).

One factor to be considered when installing TPS cable is that the current-carrying capacity of a cable is influenced by environmental conditions, such as ambient temperature and ventilation. The effects of surrounding or partially surrounding the cable with thermal insulation may also need to be considered. Other factors dependent on the method of installation of the cable and directly affecting the current rating of the cable are:

- the number of circuits

- whether single-core or multicore cable is used
- the type of enclosure
- the spacing between cables, circuits and the wall or adjacent surface
- whether the cable is run vertically or horizontally.

Figure 8.5(a) shows circular non-armoured, PVC-insulated, PVC-sheathed cables installed on a vertical cable-support system in groups; their current-carrying capacity would be considerably increased if they were spaced further apart (see *Para. B4.3.2(f)* of AS 3000). Construction of this type of TPS cable is shown in Figure 4.11, and circular steel-wire-armoured, PVC-insulated, PVC-sheathed cable is illustrated in Figure 4.7 of Chapter 4.

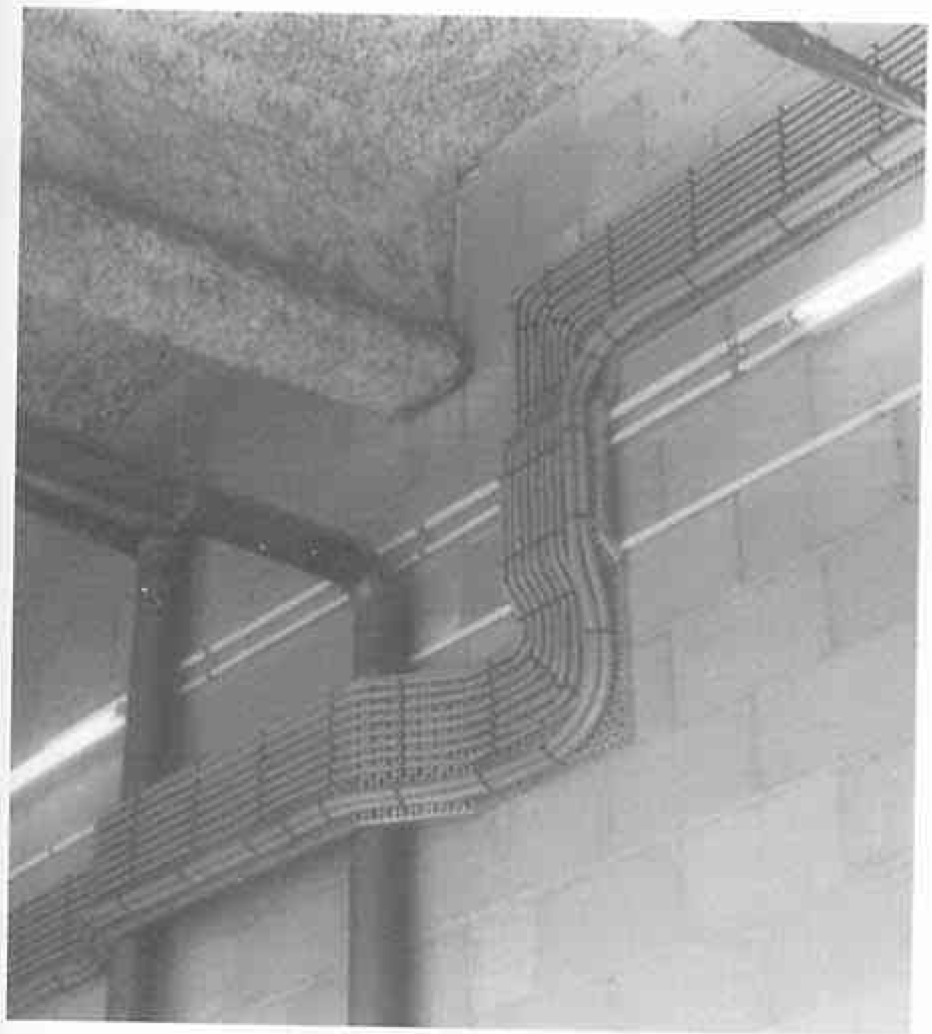

Fig. 8.5(a) *Cables installed in groups. Mutual heating reduces current-carrying capacity of cables*

Fig. 8.5(b) *Cables positioned clear of thermal insulation and to avoid the effects of mutual heating, with consequent derating of current-carrying capacity*

The four circuits in the background of Figure 8.5(b) have been installed to avoid the effects of mutual heating and positioned so that they will not be surrounded or partially surrounded by thermal insulation. Refer to Chapter 16, Volume 2, for a discussion of the selection of suitably rated cables and the use of the tables of AS 3000 and AS/NZS 3008.1.1.

For surface work, or where the cable is **likely to be disturbed**, the maximum distance between fixing is 0.3 m, or twenty times the smaller diameter of the cable, whichever is the greater (see *Clause 3.20.3.2*). Figure 8.6 shows cables installed in a garage without a ceiling.

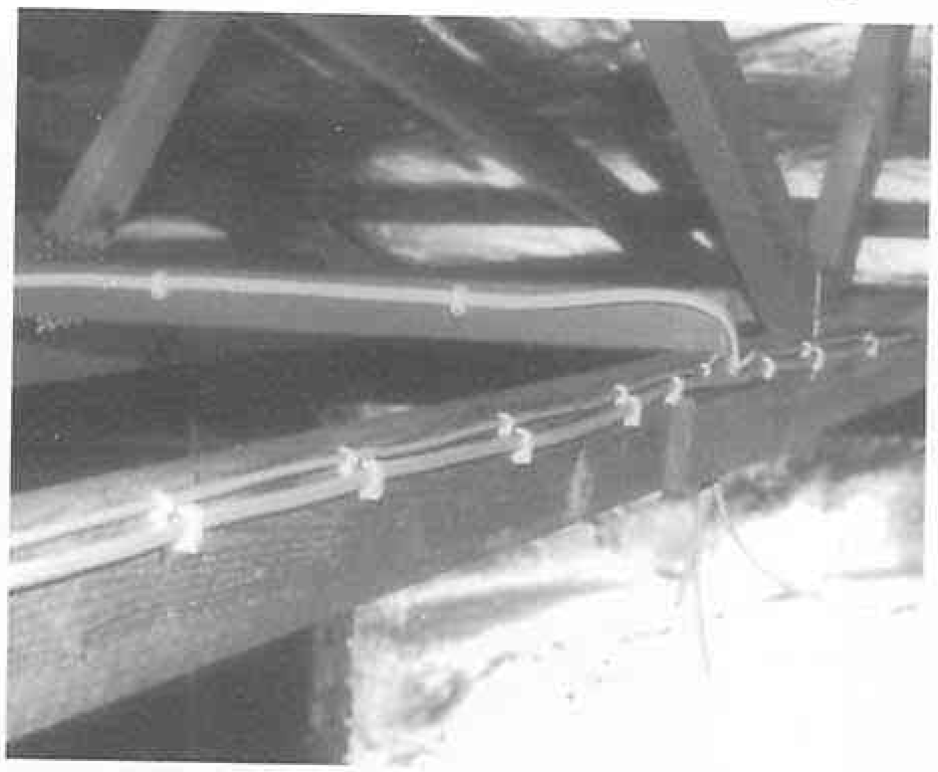

Fig. 8.6 *Cables 'likely to be disturbed'*

If the cable is installed in a ceiling space having an access space exceeding 0.6 m in height, it must be fixed so as to prevent appreciable sagging of the cable, typically fixed at maximum intervals of 1.2 m. This fixing is not required if the cable is laid on a continuous horizontal surface on which a person may not stand, such as the ceiling of Figure 8.8(c). Where TPS cables cross the tops of ceiling joists or other structural members, mechanical protection, say in the form of wooden battens, must be provided.

All the wiring runs in Figure 8.7 and some in Figure 8.8 are in positions **not likely to be disturbed**. No fixing is required if the cables are laid on a continuous horizontal surface; otherwise, support (not necessarily fixing) is required at intervals not exceeding 2 m.

The wiring installed in the suspended ceiling of Figure 8.7(d) is considered to be in a position 'not likely to be disturbed'. The reason for this is that, in practice, the ceiling modules are removed only on rare occasions, to enable access for plumbing or electrical repairs or modifications. Refer to *Ruling C.739/91* to *Clause 3.20.3.3* in *Doc. 3000 R/1—1991, Rulings to SAA*

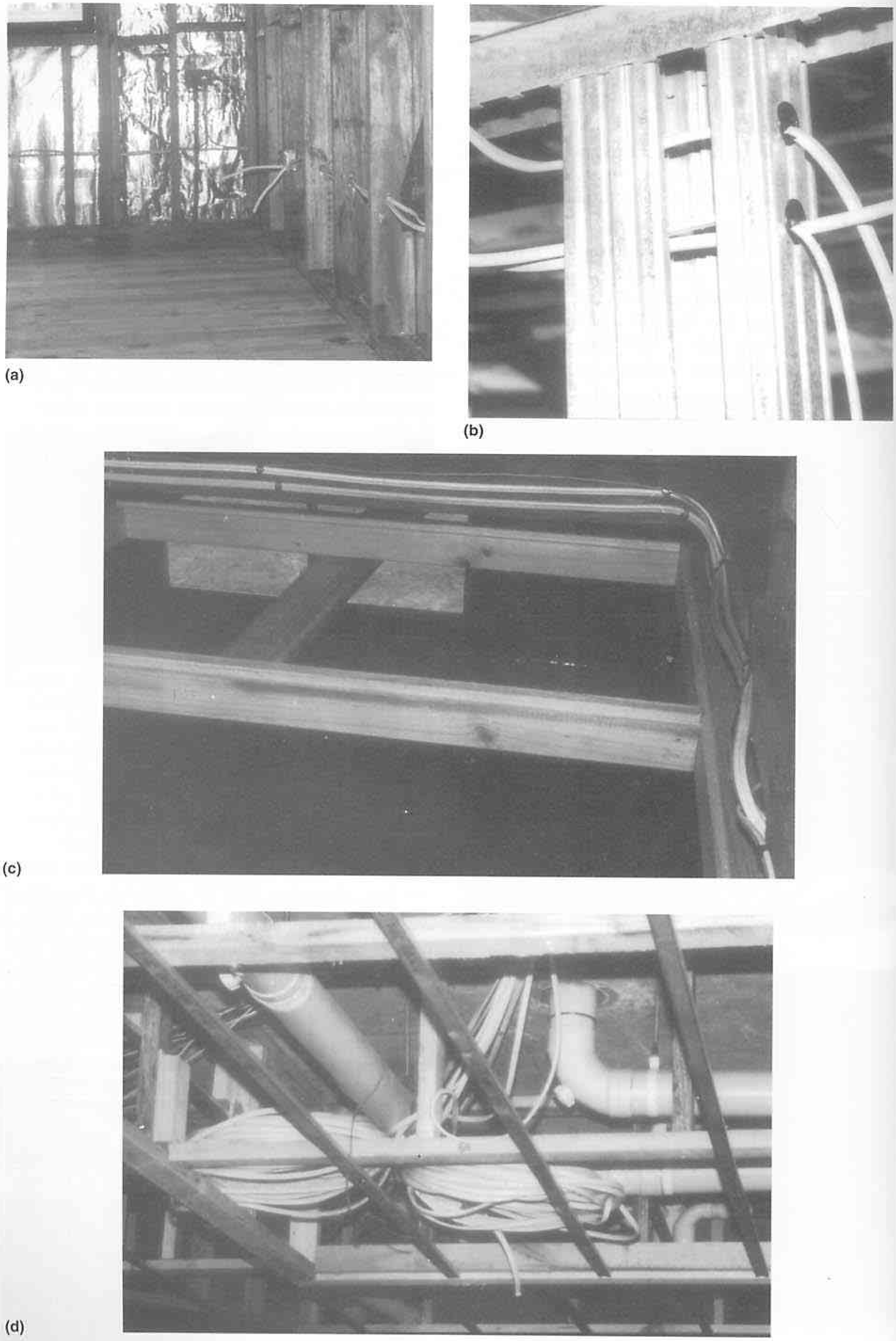

Fig. 8.7 *Methods of installing TPS cables 'not likely to be disturbed':* **(a)** *through or in the space between wall studs;* **(b)** *through grommets provided in steel-framed walls;* **(c)** *on timber work in a ceiling;* **(d)** *in a suspended ceiling*

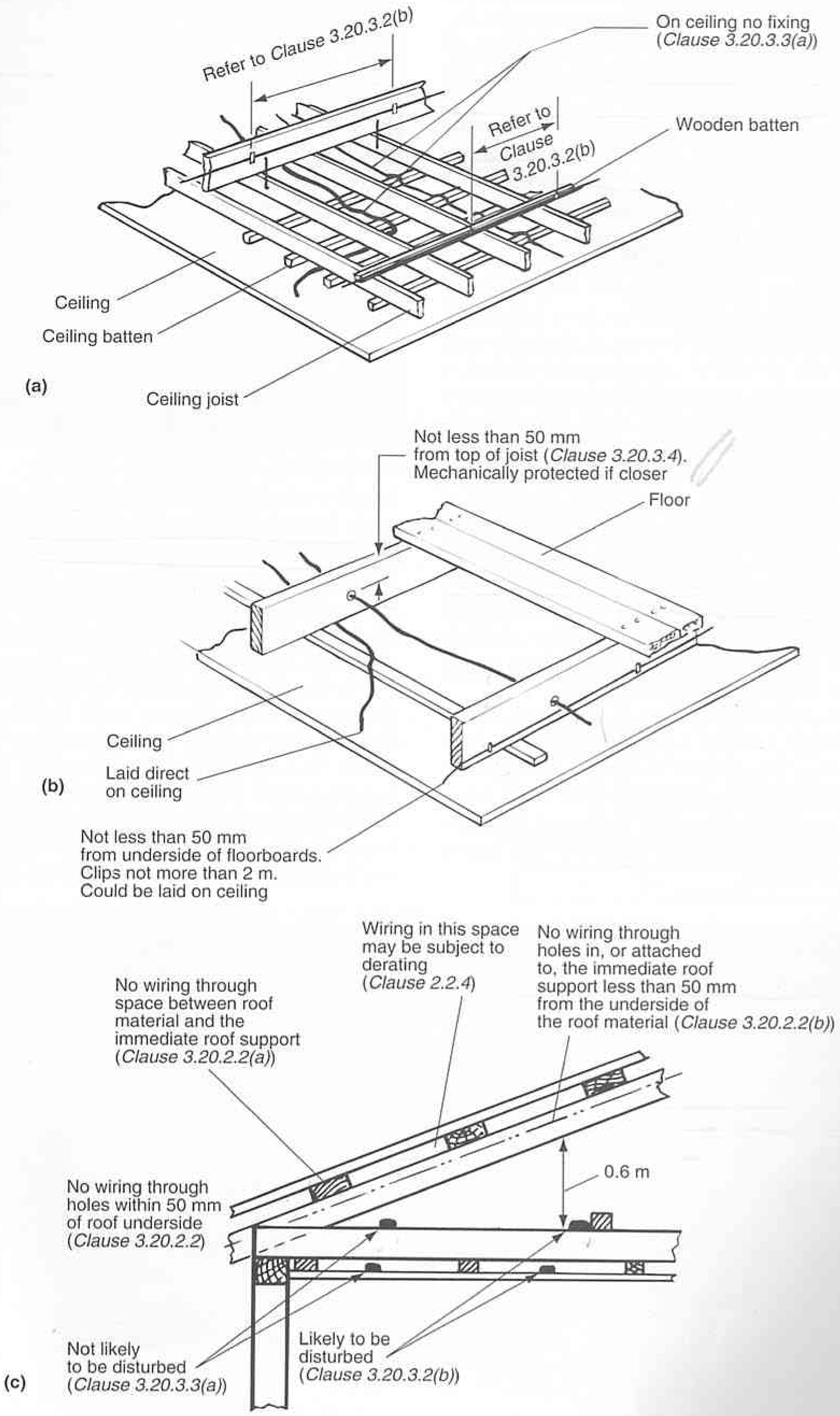

Fig. 8.8 *TPS wiring:* **(a)** *in a ceiling space;* **(b)** *between a floor and an uppermost ceiling;* **(c)** *between ceiling and roof*

Wiring Rules (AS 3000—1991). This document is published by and obtainable from Standards Australia.

Where wiring is installed in the space between the roofing material and the rafter of Figure 8.8(c), it may be subject to derating (see *Clause 2.2.4*). When the temperature in this space is not known (the usual scenario), V75 cable may be treated as if it were partially surrounded by thermal insulation (see *Ruling C.706/91* to *Clause 2.2.2* for further details). Cable ratings are treated in Chapter 16 of Volume 2.

Another case of 'cables not likely to be disturbed' is shown in Figure 8.9, where the cable is supported on wall ties; alternatively, it could have been laid on the wire vermin barrier at the bottom of the cavity wall. Using wall ties to support cables is not permitted in Victoria. In any case, taking the cable through, say, every third stud is good practice. This avoids cable touching the outside wall, and the risk of moisture transmission to inside cladding. The cable clip on the right-hand stud has been used to provide the necessary segregation of the telephone wiring from the power wiring.

Refer to *Clause 3.20.3.3*, and note the requirement for fixing intervals of 7.5 m for unarmoured and 3 m for armoured sheathed cables, in the case of cables installed vertically. Note also the provisions of *Clause 3.20.3.5* to prevent excess mechanical pressure on the cable where there is a change of direction.

Consider too the precautions to be adopted, as outlined in *Clause 3.20.3.4*, for installation of the cable when it is run, for example, in the space between the floor of one storey and the ceiling of the storey below. Again the precautions are against mechanical damage to the cable, due to traffic on the floor or to nails used in the fixing of flooring.

Some spaces in which the installation of TPS wiring is restricted are included in Figure 8.8(c).

Because TPS cable is considered to be weatherproof, it may be installed on the exterior of a building, provided that it is protected from mechanical damage by virtue of its height or position (see *Clause 3.20.2.2*). Manufacturers of TPS cable do not recommend white or coloured sheathing for exterior work; they recommend sheathing material that has been stabilised against the effects of ultraviolet rays.

The installation of TPS cable using catenary support and its use underground are dealt with in sections 7.3 and 7.6 respectively of Chapter 7.

8.5 Loom-wiring systems

Loom wiring

This is a system in which the TPS cables are installed in the space between the underside of a concrete floor slab or roof structure and a false or suspended ceiling, for the supply of plug-in lighting units. One system utilises the socket outlet illustrated in Figure 8.10, which is fixed to the underside of the floor slab or beam at each preselected lighting position.

At floor level the cable is cut to correspond with the intervals between socket outlet positions, and the ends are then prepared and connected to the socket outlets. Thus the whole of the wiring loom or 'harness', including switch drops where required, is made up at floor level with considerable saving of labour. Material is also saved, as the cable 'tails' usually left at each accessory position in an in-situ installation are eliminated.

Fig. 8.9 *Cables supported on wall ties (not permitted in Victoria)*

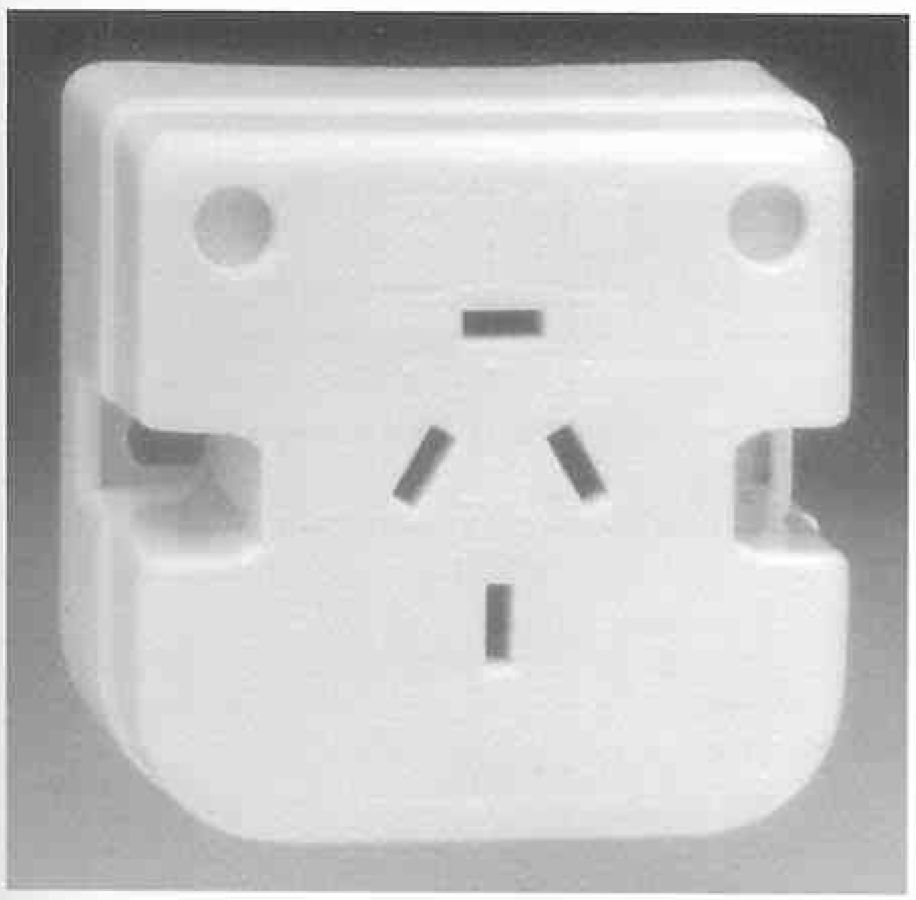

Fig. 8.10 *Four-pin socket outlet designed for loom-wiring system*

After the complete harness is made up, it is lifted into position and the socket outlets are mounted at their preselected positions in the false ceiling. Any switch drops are then run to the preselected switch positions and the luminaires installed and plugged in.

Typical commercial loom-wiring system

HPM Industries manufactures four-pin plugs and socket outlets (see Fig. 8.10) intended for use with a four- or five-wire loom for commercial lighting, including emergency lighting, and for dimming fluorescent luminaires. They may also be used in a system designed to reduce lighting levels by switching selected lamps in a luminaire. For example, a five-wire loom may be used in conjunction with four-pin socket outlets and a three-lamp luminaire; one lamp may be left on continuously and the other two switched on when required. Circuits for this and other applications are available from the manufacturer, which describes the wiring arrangements used with its products as a 'smart system'. Some typical circuits are shown in Figure 8.11.

Note that the plug base of Figure 8.10 is also available as a twin-socket outlet, and that both may be used with a normal three-pin plug if required.

TPS systems are thus seen to be popular to the extent that they have virtually replaced many older types of wiring. Systems using TPS wiring harnesses indicate a modern approach to both reducing labour costs and conserving material, with the advantage of a flexible system for repairs, alterations or additions. Accordingly, TPS loom-wiring systems are finding many applications, mainly in commercial buildings.

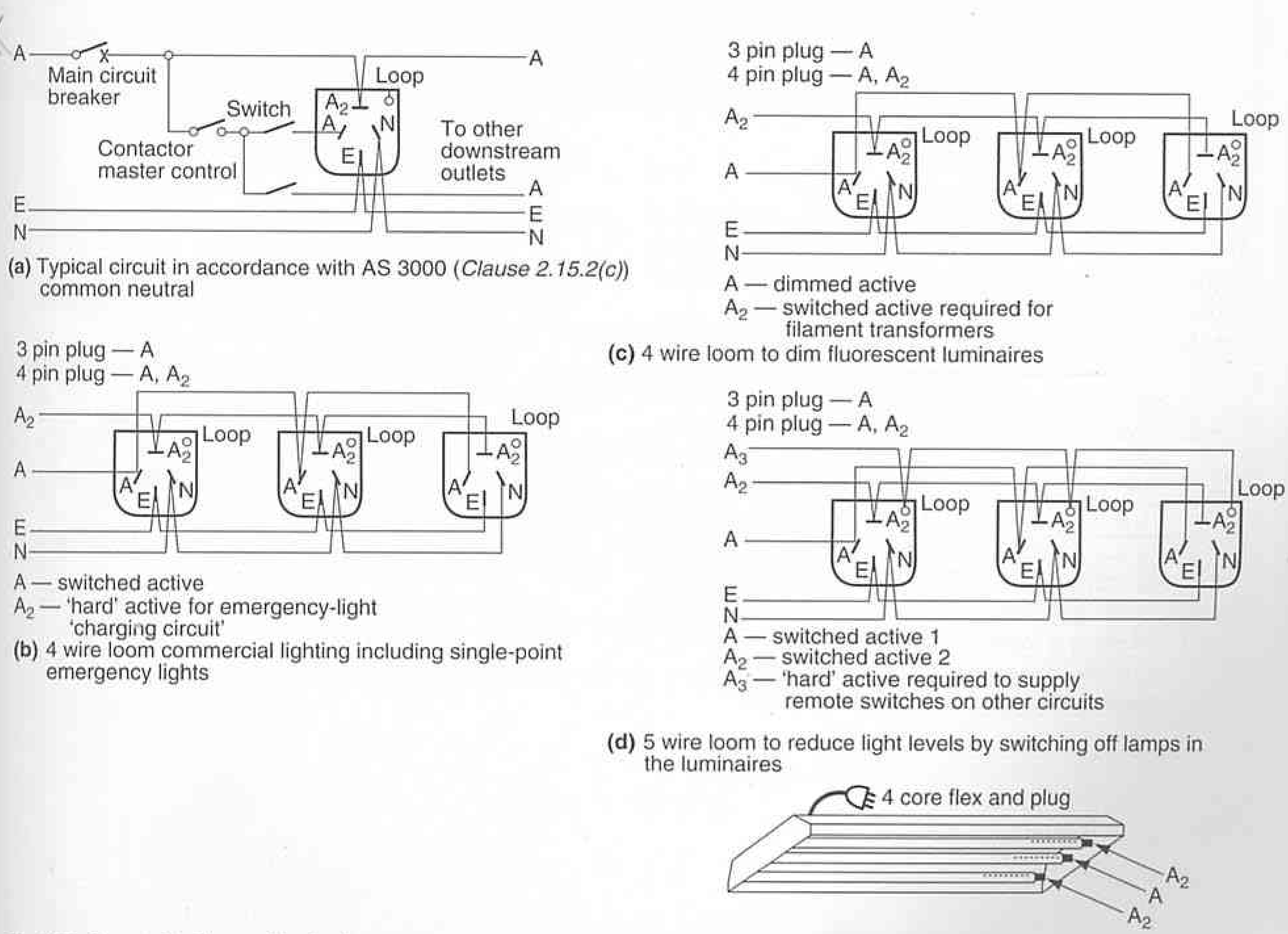

Fig. 8.11 *Some typical loom-wiring circuits* HPM INDUSTRIES

SUMMARY

- Thermoplastic-sheathed (TPS) wiring is the most commonly used wiring system in domestic and commercial installations.
- Advantages of TPS wiring systems are:
  - They are easy to install.
  - They can be used as concealed wiring.
  - They can be used with all-insulated accessories, forming a double-insulated system.
  - They cost less than other systems.
- Disadvantages of TPS wiring systems are:
  - They are prone to mechanical damage during installation if not handled carefully.
  - They are subject to damage by rodents.
  - They must be protected against mechanical damage, which restricts their use.
- TPS cables are used in loop-in-type wiring circuits, with most accessories supplied with looping terminals, eliminating the need for junction boxes.
- A typical TPS loop-in circuit is a twin and earth 1 mm^2 cable, looped between each light point; a twin cable is installed from the light points to the switch position.
- Three-core and three-core-and-earth TPS cables are used for three-phase motor circuits.
- The general installation approach is:
  - Plan cable runs.
  - Where necessary (*Clause 3.20.3.2*), cables are fixed with metal pin clips, plastic cable clips or nylon cable ties.
  - For surface wiring likely to be disturbed, metal pin clips may be installed in short sections. Alternatively, plastic cable clips or other fixings may be used.
  - On long runs, where fixing is required, it is better practice to install pin clips for the whole run before fixing the cables.
  - Once cables are fixed and secure and the wiring into equipment is complete, all final connections are made.
  - The completed wiring is then tested before being put into service (refer to Chapter 11 for the tests required and how to test).
- TPS cabling may be concealed in roof spaces and wall cavities.
- The cable must be protected from mechanical damage by a suitable enclosure.
- Burying the cable directly in concrete is prohibited, and there are restrictions on burying the cable in cement and plaster (*Clause 3.20.2*).
- The current-carrying capacity of the cable will be affected by the installation method and environmental conditions (*Paras B4.2 and B4.3* of AS 3000).
- Loom wiring is a system in which TPS cables are installed in the space between the underside of a concrete slab or roof structure and a false ceiling, for the supply of plug-in lighting units.
- The wiring loom or 'harness' is made up at floor level, then fixed into position. This results in considerable savings in labour and materials.
- Four- and five-wire looms are used where emergency lighting, dimming of fluorescent luminaires or selective switching is required. Special plugs and socket outlets are available for this purpose (see Fig. 8.11 for typical circuit arrangements).

REVIEW QUESTIONS

Where the answer to a review question is numerical or requires reference to the SAA Wiring Rules, *the answer is given at the back of the book. These questions are marked ★.*

★ **1.** Could a section of thermoplastic-sheathed (TPS) cable be installed along a wooden skirting board? Give reasons for your answer.

★ **2.** What is the maximum distance specified for fixing TPS cables where they are used for surface wiring?

★ **3.** A TPS cable is to be dropped a vertical distance of 11 m in a cavity. What provisions are necessary for:
(a) support of the cable weight in the vertical drop?
(b) prevention of mechanical damage where cable is run over a sharp brick on the cavity edge?

★ **4.** TPS wiring is to be run across ceiling joists in an accessible ceiling space. What measures should be taken for mechanical protection of the cables?

★ **5.** Is it permissible to bury TPS cable in:
(a) a concrete floor?
(b) a cement-rendered wall?
(c) a floated plaster wall?

6. State some applications for TPS cable.

7. What circumstances would warrant the use of cable trays as a cable support system?

★ **8.** Name two positions in a roof space where TPS wiring is prohibited.

9. State four distinct advantages of TPS systems.

10. State three disadvantages of TPS systems.

11. What are three chemicals that could affect the PVC sheath of TPS cable?

12. State the recommended sheath type for TPS cable exposed on the exterior of a building.

13. Where is loom wiring used?