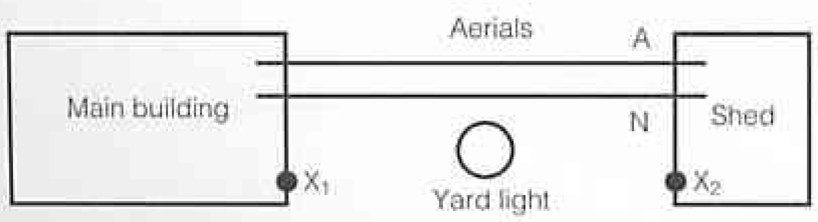
REVIEW QUESTIONS

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. What is the essential difference between a wiring diagram and a circuit diagram?
2. What is the difference between:
   (a) control of a circuit, and
   (b) protection of a circuit?
   Mention one control device for (a) and one protection device for (b) in your answer.
3. In a circuit diagram of the wiring and control circuit for a motor, where would you expect the motor terminals to be shown: on the right or left hand side of the diagram?
4. State a practical example of:
   (a) parallel-connected equipment, and
   (b) series-connected equipment.
5. If three devices, each rated at 1 A 200 V, were connected in series on 600 V supply and one 'burnt out', would it be wise to short-circuit the defective unit to restore supply to the other two units? Explain the reasons for your answer.
6. Draw a circuit diagram showing how two parallel-connected lamps may be controlled from two alternative switching positions.
7. Could a switch rated at 10 A 240 V marked 'ac only' be used successfully for 5 A 240 V dc?
8. ★ State one situation in which the use of double-pole switches would be compulsory.
9. What is the principle involved in the method known as 'looping-in'?
10. Make a neat diagram to illustrate the 'looping-in' principle for a surface conduit system.
11. An exhaust fan and a lighting point in a bathroom are controlled by the one switch. Separate switching of the exhaust fan is required. Explain a number of ways in which this could be done.
12. Redraw the circuit of question 10, making all necessary joins in a junction box.
13. Two light outlets, A and B, are to be arranged for selective control so that **either** A **or** B is on, but never both at the same time. In addition, A must be able to be switched off from its own independent control position. Draw a diagram of the circuit.
14. In the diagram below, the shed is supplied from the main building with 240 V ac. A yard light is required where shown, with alternative control from positions X_1 and X_2. Draw a circuit for the most economical method of wiring for the light.



15. Draw a circuit diagram to illustrate how a light outlet may be controlled from five separate positions.
16. Give a practical example in which it would be an advantage to use the circuit of Figure 6.15.
17. Why are power outlets usually wired in parallel?
18. *Clause 4.14.5.2* permits the control of adjacent plug sockets by one switch. Draw a circuit diagram for this arrangement.
19. Where and what is a hanging beam in a timber-framed house?
20. What is 'nogging'?
21. Explain the difference between a ceiling rafter and a ceiling joist.
22. In what type of building would suspended ceilings be found?
23. The electrical plan of a small flat is shown in Figure 6.53 below. No separate electrical specification is available for the job, but consultation with the builder reveals the following:
    1. Wiring, including the submains, will be installed using thermoplastic-insulated and sheathed cables throughout.
    2. Construction is brick veneer, hip-roofed, with a rise of 1500 mm.
    3. Submains route from the main switchboard and metering position to the distribution board position has a length of 6 m.
    4. Outgoing circuits from the distribution board are to be protected by circuit breakers.
    5. The wall luminaires and kitchen fluorescent units are to be supplied by the owner and installed by the electrician. All other light outlets are to be bayonet cap batten holders, pending the tenant's selection of luminaires.
    6. All GPOs are to be of the flush-mounting type, and all except one (for a refrigerator) are to be protected by a 30 mA RCD.
    7. The air conditioner is rated at 3.6 kW.
    8. The storage water heater has a capacity of 100 litres and a rating of 4 kW and is classed as continuous (ie is not on controlled-load tariff).

    With reference to the figure, prepare a materials list for the electrical wiring of the flat. List the materials under the separate headings of:
    (a) submains
    (b) distribution board
    (c) lighting
    (d) GPOs
    (e) range
    (f) air conditioner
    (g) hot-water system.

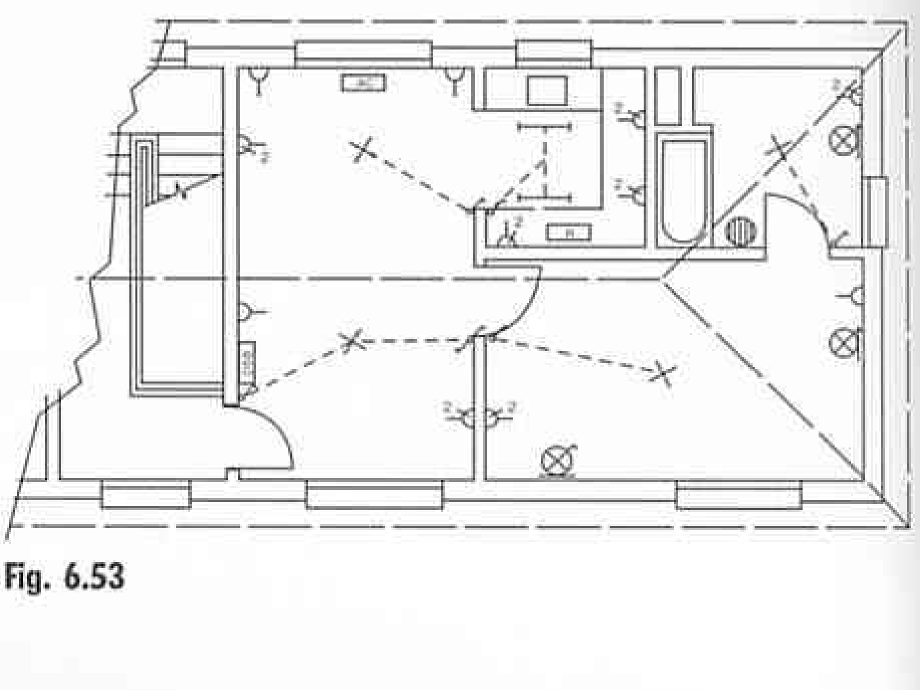


Fig. 6.53

6

Electrical drawing interpretation—wiring diagrams and circuits

This chapter deals with drawings necessary in electrical work and how they are used, including:

- wiring diagrams and circuit diagrams
- series and parallel circuits in wiring
- control of lighting circuits
- power wiring and motor circuits
- building construction types, terms and materials
- plans and standard symbols
- electrical specifications and schedules
- interpretations of plans and schedules
- preparation of materials lists
- use of computers in estimating.

6.1 Introduction

The training of electricians includes practical work involving the control of light and power circuits, and to perform this work efficiently they must work with, and be able to interpret, electrical diagrams. The electrician must also have a plan for the precise location of equipment, outlets and control positions; this infers a working knowledge of building construction methods and sequence. In addition, the conduit runs and layout require planning; and, unless a job is a small one, a diagram of switchboard layout and wiring is usually necessary.

The actual wiring circuits and connections require reference to wiring diagrams unless they are standard simple types, in which case the diagram is carried as a mental picture, but remembering even the simplest wiring circuit or layout initially requires the study of relevant diagrams and circuits.

In the case of a simple installation, such as an additional light point or general-purpose outlet (GPO), both the wiring layout and the necessary job materials would also probably be retained in the memory of the electrician on the job. However, even in this simple example, although there is no written record, the requirements still exist.

The conclusion is that for all jobs, no matter how simple or how complex they may be, it is essential that plans, specifications, materials lists and appliance schedules be prepared. The number and extent of these will depend on the extent and complexity of each job. This chapter is concerned with the development and interpretation of electrical drawings and specifications and how they are used in preparing materials lists.

6.2 The wiring diagram and the circuit diagram

To describe adequately the exact manner in which the electrical components of even the simplest electrical circuit are connected and interact could take pages of writing. Some 'short-cut' method or 'picture' is necessary, and for the electrician this is achieved by the electrical diagram.

The diagram is a shorthand picture that uses standard, commonly known symbols and methods, so that interpretation is easy to any tradesperson familiar with the common language of electrical drawing practice.

There are two basic types of diagrams:

- the wiring diagram
- the circuit diagram.

The **wiring diagram** is very close to being a pictorial representation of the circuit, with the components shown in their actual relative physical positions, together with connecting cables, connections, cable sizes, colour, terminating particulars and any other details required. The wiring diagram (some manufacturers use the term 'connection diagram') can be termed a 'point-to-point' diagram, giving exact details of the complete wiring layout.

With the aid of a good wiring diagram, even an inexperienced person would be able to 'wire up' the circuit. The skilled electrician would use it as a reference for the actual physical layout of a job, such as a large control board. This type of diagram is often provided for electrical service or maintenance use on appliances similar to automatic washing machines and ranges, and it assists in 'tracing out' the location of defective devices or wiring once a fault has been diagnosed.

As electricians become more experienced, they tend to depend on and prefer the circuit diagram to the wiring diagram. It would be almost impossible to design or efficiently to test or install involved electrical equipment without the use at some stage of a circuit diagram.

The **circuit diagram** ('schematic' in American terminology) depicts the 'scheme' of the electrical circuit wiring, in logical sequence from left to right and top to bottom, in a 'cause–effect' order (see Fig. 6.1(a)). The circuit diagram is not a wiring diagram—the main difference being that controls, contacts, connections and conductors are not shown in their relative physical positions in the circuit but are arranged in their electrical relationship to each other.

Figure 6.1(a) illustrates the difference between a 'wiring diagram' and a 'circuit diagram'. Sometimes in the case of a relatively simple device, a wiring diagram is considered to be sufficient: that is, the simplified circuit diagram is not necessary. Figure 6.1(d) shows the wiring diagram of a direct-on-line motor starter.

For anyone familiar with electrical work, it is easy to trace out and follow a circuit if the wiring is visible, but in the average electrical installation the wiring is concealed within the structure or hidden within equipment. With the aid of a good circuit diagram the necessary tests for short circuits, leakage paths, open circuits and malfunction of circuit devices may be performed without dismantling equipment or pulling the installation apart.

It is usual in these diagrams to show devices in the unoperated position or mode, unless specifically stated. Conductors of main circuits are distinguished from those of subsidiary circuits by line thickness. If colour can be used it is a great aid to clarity, especially if the colours used are the same as those used in the actual wiring, for example red, white and blue to identify the phases in a three-phase ac circuit.

In addition to the two foregoing important and fundamental types of electrical diagrams, there are other basic graphic methods used in the electrical field, three of which are:

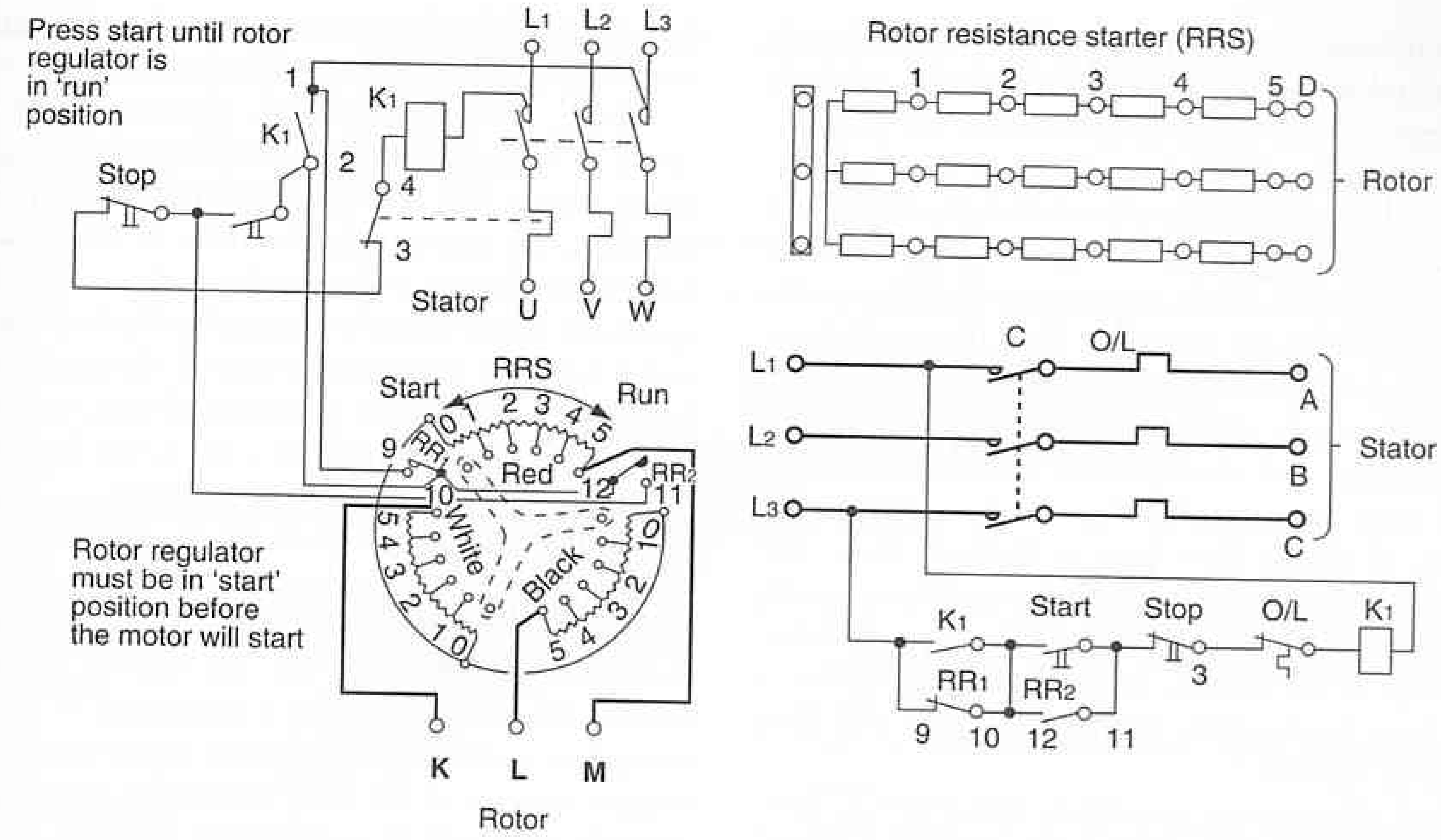


Fig. 6.1(a) *Wiring and circuit diagrams of a three-phase faceplate rotor starter*

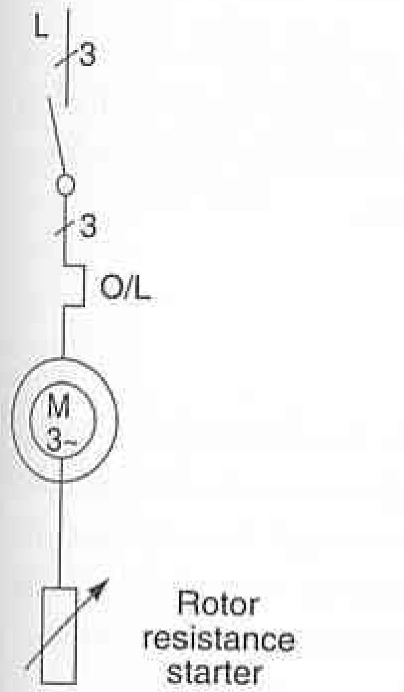


Fig. 6.1(b) *Single-line diagram of starter in Fig. 6.1(a)*

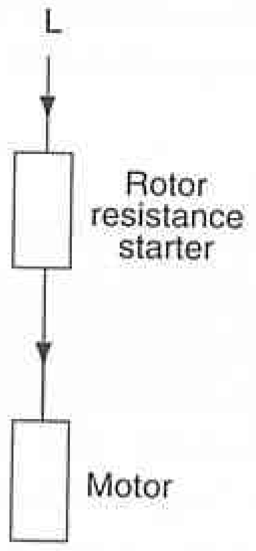


Fig. 6.1(c) *Block diagram for circuit of Fig. 6.1(a)*

- the architectural drawing
- the single-line diagram
- the block diagram.

The **architectural drawing** or plan is used for the purpose of detailing electrical appliance and outlet positions as discussed in section 6.7 of this chapter.

Both wiring and architectural diagrams are known as 'topographical' representation, because the layout corresponds closely to the physical or topographical locations of the equipment (see, for example, Fig. 6.46 of this chapter).

The **single-line diagram** has the purpose of providing circuit information in regard to only essential details, principles and characteristics of the system. This is achieved by illustrating the way the equipment is interconnected. Many details are simplified or omitted: for example, the three conductors of a three-phase circuit would be represented by a single line, marked to

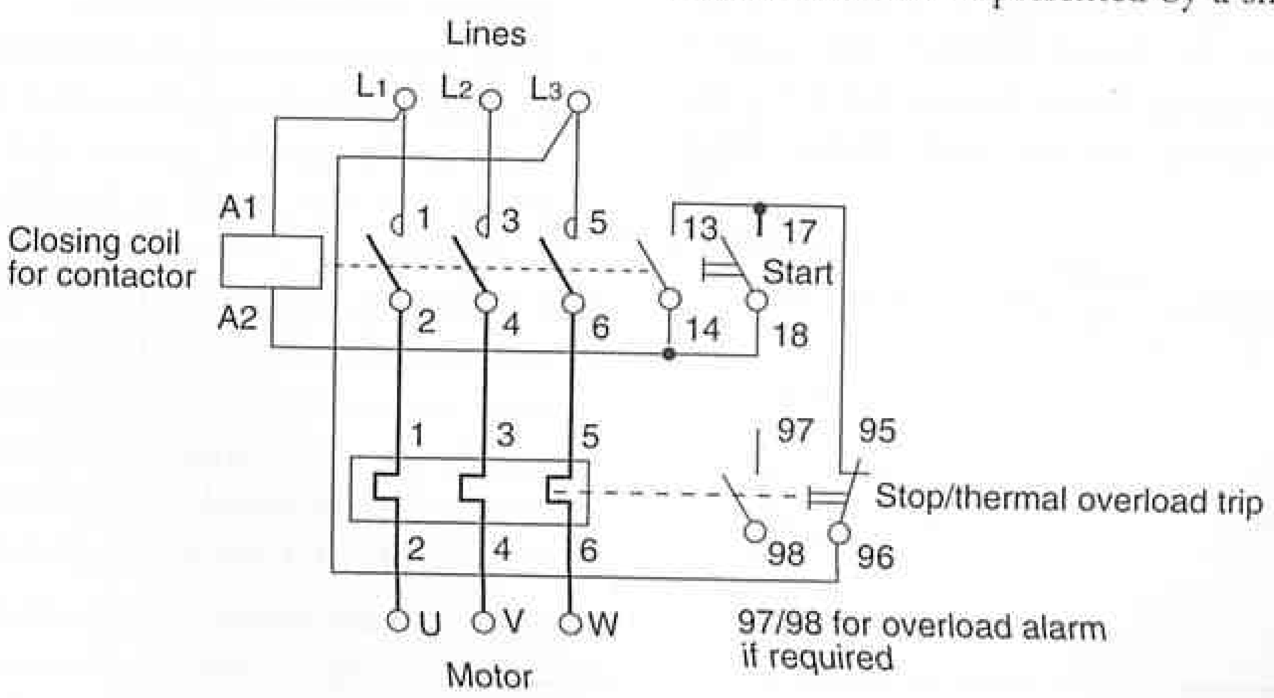


Fig. 6.1(d) *Wiring diagram of a three-phase direct-on-line motor starter with local stop/start* BELL-IRH

indicate the number of conductors; similarly, triple-pole controls and protection devices would appear as single pole. Figure 6.1(b) is a simple illustration (see also Fig. 6.44 of this chapter).

The **block diagram** is one in which blocks (usually rectangles, but other symbols may be used) are drawn in to represent complete component circuits or elements. The blocks are joined by 'flow' lines to indicate the sequence of operation and/or control of the system. The sequence order is the standard from left to right or top to bottom, with the flow lines arrowed and following the same sequence; this sequence may vary for the direction of control flow lines or feedback lines. The block diagram thus provides a much-simplified overview of the wiring scheme by showing the function and interconnection of the 'blocks', omitting internal circuits or details (see, for example, Fig. 6.1(c), where only flow sequence is shown).

Block diagrams are sometimes referred to as 'flow' diagrams and are most useful in the diagnosis of faults and in the planning stages of an installation. They are widely used in the supply industry, for example in system diagrams.

6.3 Series and parallel circuits in wiring

A basic electrical circuit comprises:

- a source of supply
- some form of protection
- some form of control
- the load, which usually converts electrical energy to some other energy form
- return to the source of supply.

An examination of the simple circuit of Figure 6.2 shows that it is a closed-series loop, or closed circuit, from the source of supply 1, which provides the necessary pressure, potential or voltage to establish a current through the protective device 2, thence through the control device 3, to the consuming device (motor, lamp etc.) 4, where energy conversion occurs, and thence back

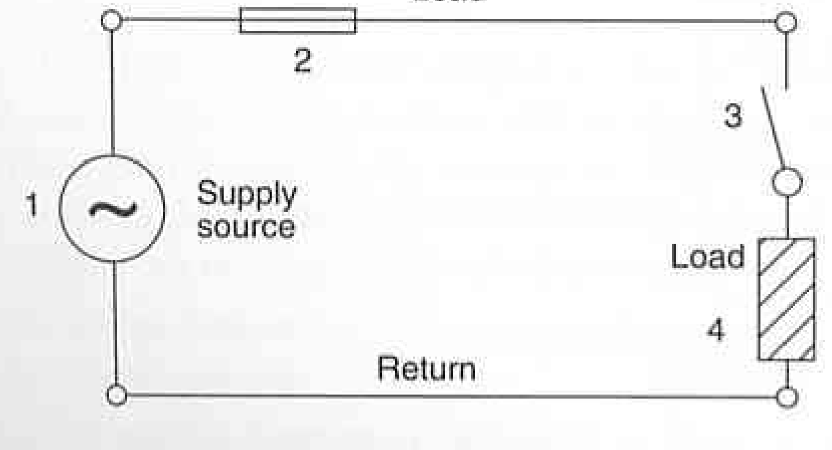


Fig. 6.2 *A basic electrical circuit*

through the return lead to the source of supply, through which the circuit or closed loop is completed.

Being a series circuit, an interruption or open circuit in any path, including the internal circuit of the supply source, will stop the current flow. In a practical circuit, 2, the protection, would be in the form of a fuse, circuit breaker or similar device that automatically opens the circuit under predetermined fault conditions, and 3 would be a convenient control, the simplest form being an 'on/off' switch. (In electrical work, to 'control' means to 'govern' or 'regulate'.) In 4, the load device, the electrical energy is put to useful work.

In the usual circuit, most of the electrical pressure generated by the supply source is expended in driving the current through the load. For a practical circuit, the combined voltage drops of the circuit conductors feeding the load are kept to a minimum, to minimise energy loss and voltage drop and to ensure that the rated voltage appears at the load terminals. As a practical example, on a 240 V supply there could be 239 V at the load terminals, with the remaining 1 V being used to drive the load current through the lead and return conductors.

The voltage rating of the average motor, lamp or appliance is usually that of the supply. If these appliances are all to receive the same voltage, they must be connected in parallel with each other.

Parallel connection

Figure 6.3(a) is a circuit diagram that illustrates the principle of a parallel connection (also termed a 'shunt' connection). Each component is connected 'across' the same supply source, and **all** components receive the same voltage. Suggested rules for connections in parallel are:

1. Connect similar or like ends together.
2. Check the circuit to ensure that each component is connected to a common voltage source.
3. Check to ensure that there are as many parallel paths as there are load components.
4. If the components are individually controlled, which is usual, check that each control switch is connected **only** in the parallel section that it should control. (Note that the switch is in **series** with the section controlled.)
5. Check for correct polarities, to ensure that assumed **similar** terminals are of the same polarity; this is most important (see *Clause 4.14.8*).
6. Check for compliance with *Clause 2.20.1.2*, requiring single-pole switch connection to be in the active conductor (see Chapter 11 re testing).

Because the voltage ratings of most appliances and lamps are similar, it follows that parallel connection is the method commonly used for ordinary wiring. There are many examples of parallel circuits, but by an analysis

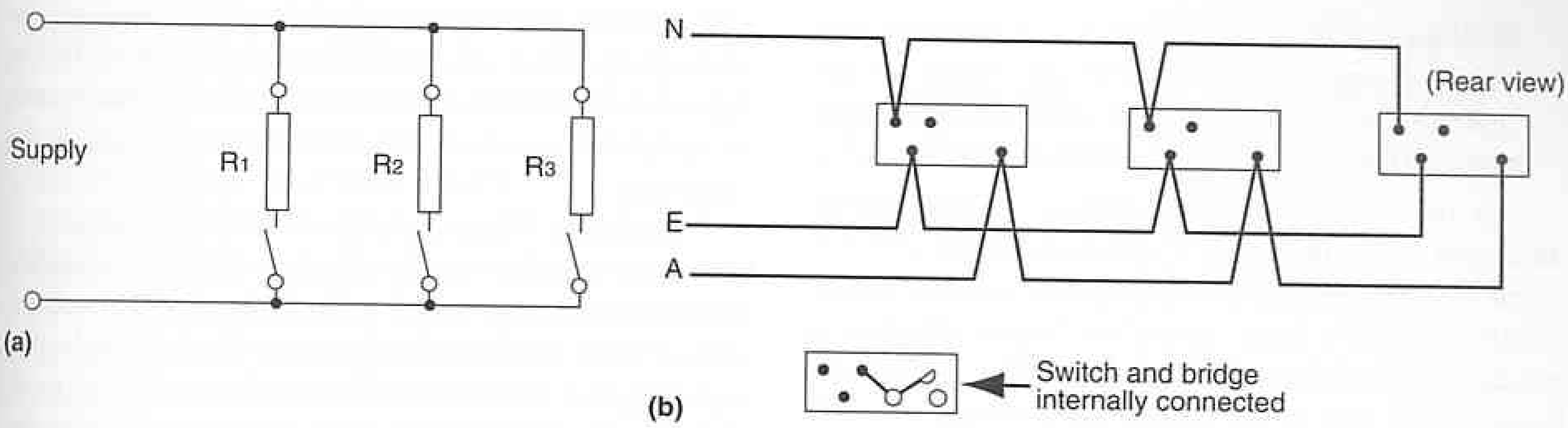


Fig. 6.3 *Parallel connections:* **(a)** *three resistors in parallel;* **(b)** *three power outlets in parallel*

of the basic circuit and simple installation in practical work, the fundamental principles applying to all should be understood.

Series connection

Figure 6.4 illustrates the principles involved in the simple series circuit. All the load components are connected 'end to end', and this series is then connected to the supply. Note that:

1. Unlike or dissimilar ends are joined: the **finish** of R_1 to the start of R_2 in Figure 6.4(a), or + to − in Figure 6.4(b).
2. There is only one path for the current from the supply, through **all** the series components and back to the supply.
3. The current has the same value throughout the circuit.
4. If the ratings of the load devices are different, there will be different voltage drops across each ($V = IR$). The sum of these voltage drops must equal the supply voltage.
5. If there is a break (open circuit) in any part of a series circuit, the full-supply voltage will be present across the break. The reason for this is that, when an open circuit occurs, no current can flow, hence no

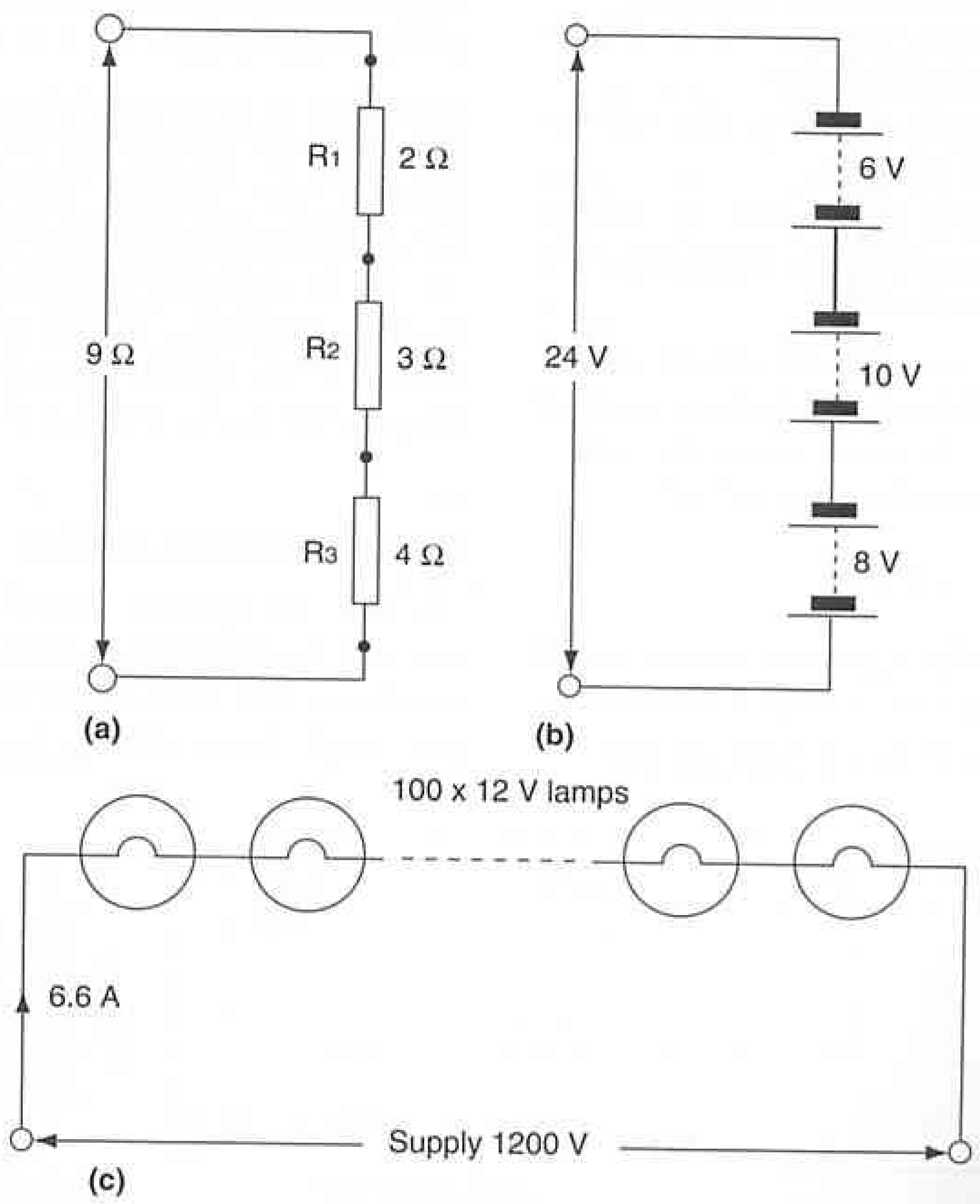


Fig. 6.4 *Simple series circuits:* **(a)** *resistors in series;* **(b)** *batteries in series;* **(c)** series runway lights

IR drops can occur, and there is a continuous path from the opposite polarities of the supply to the 'open circuit'. **Be wary of high voltages across open circuits if working on live series circuits.**

In the older-style airport-runway lighting circuit illustrated in Figure 6.4(c), a constant current of 6.6 A in the circuit is maintained by a special variable-voltage transformer. If a lamp burns out (open circuits), a special film installed in the base of the lampholder breaks down, due to the normal rated voltage of 12 V being exceeded. Then the full-supply voltage of 1200 V is impressed across the terminals of the lampholder. The breakdown of the film by this high voltage short-circuits the lamp and thus restores supply to the circuit comprising the remaining lamps.

Just as in parallel circuits, the basic principles of series circuits must be kept in mind when considering their operation or when testing or installing them. To take an example of the application of these principles: decorative Christmas tree lamps are often series-connected; if one lamp is defective, all the lamps in the series circuit go out. The defective lamp can be located by successively short-circuiting each lamp or the wires entering each lampholder. When the lampholder of the defective lamp is short-circuited, the remaining lamps will light.

Reasoning would be along these lines:

1. The wiring, by inspection, seems sound; therefore a defective lamp is the most likely fault.
2. Perhaps it is only one lamp; therefore, if it is short-circuited, the remainder will light.
3. The question arises, will the increase in voltage, caused by short-circuiting one lamp, impressed across each remaining lamp, be harmful?

To answer the question, consider the case of twenty 12 V lamps in series. With one lamp short-circuited there would be nineteen in series across the supply voltage, and each lamp would be subjected to

$$\frac{240}{19} = 12.6 \text{ V}$$

instead of its rated 12 V. This 5 per cent increase would be permissible, especially for the brief period of testing.

There are many applications for series circuits; and although lamps and power appliances are usually connected in parallel, any control device such as a switch, light dimmer, ballast in a fluorescent unit, motor starter or controller is connected in series with the unit being controlled.

Important: There are only two basic connections—series and parallel—in any electrical circuit. A complete circuit may contain many such connections, in combination with various voltages and devices, including signal sources and sources of electromotive force (emf), all interconnected, but basically the most involved circuitry consists of a multitude of series and parallel connections (e.g. see Fig. 6.5). A study hint is: do not attempt to memorise the numerous circuits available covering specific applications unless you are working on them continually. Learn the basics, and adapt them to the job in hand.

6.4 Control of lighting circuits

Common methods of lighting control by switching are:

- single-pole or one-way control from one position;
- single-pole double-throw (SPDT) or two-way control from two positions;
- two-way and intermediate switch control that achieves control from any number of desired positions;
- switch multipliers.

Note: Various series–parallel combinations are also possible, but the circuits are not common and are not included here. Another method of lighting control (sometimes termed 'proportional control') is achieved by the use of electronic light-dimming circuits, and this method of lighting control is treated in Chapter 24, Volume 2. Fluorescent lighting circuits are dealt with in Chapter 23, also in Volume 2.

Control from one position

The first and simplest control is from one position by one switch connected in series with one line or active conductor. The trade description for the switch is single-pole single-throw (SPST), but it is usually termed a

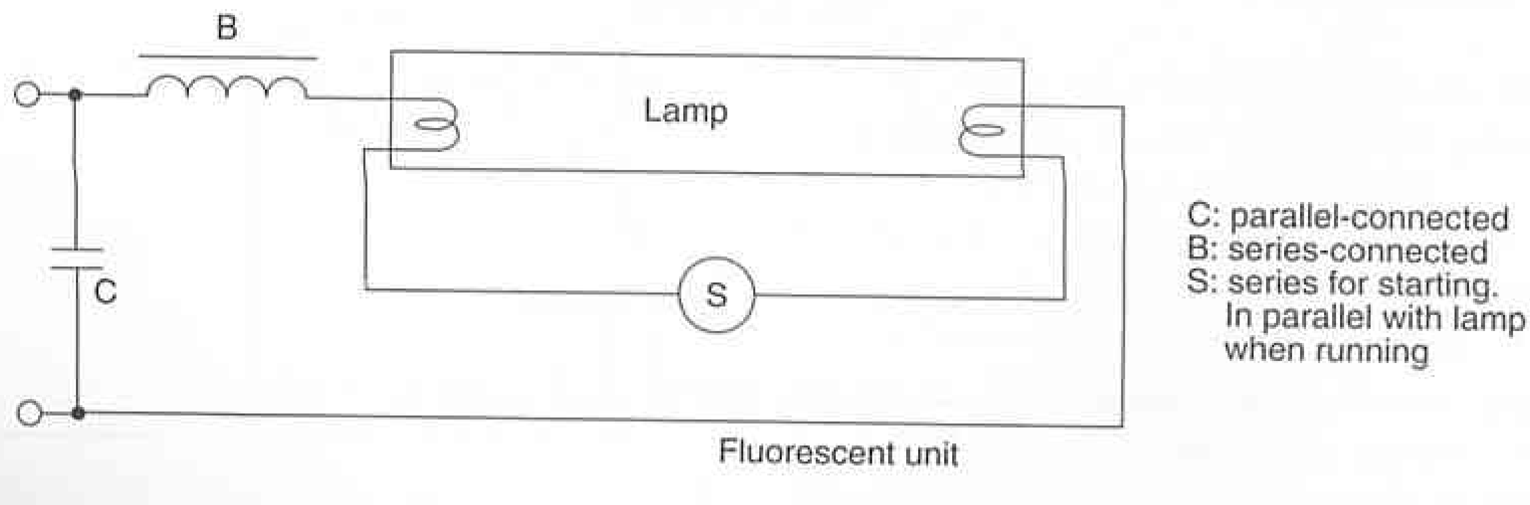


Fig. 6.5 *Example of a series–parallel circuit*

'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

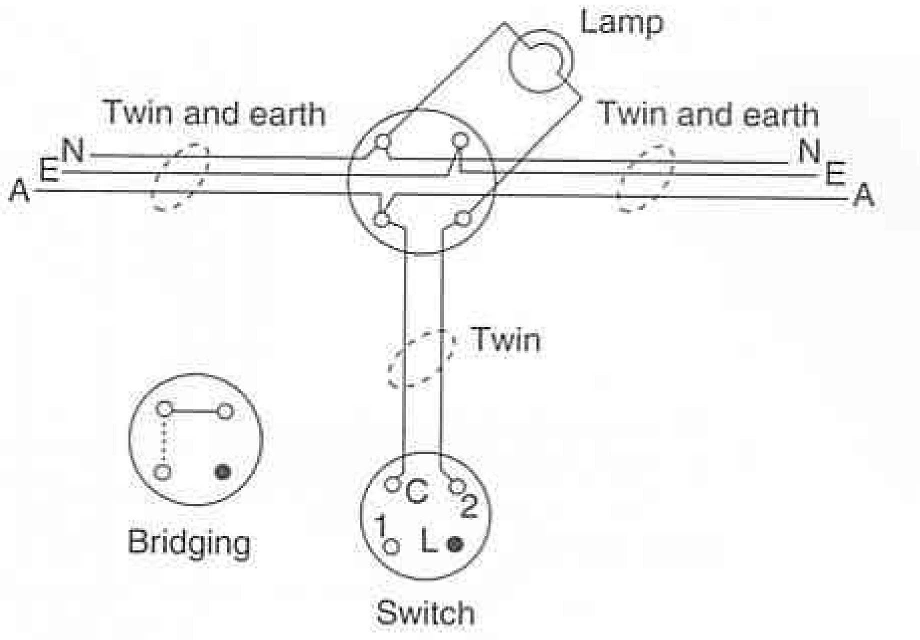


Fig. 6.7 *Looping-in at batten holder or ceiling rose—looping terminal not used*

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

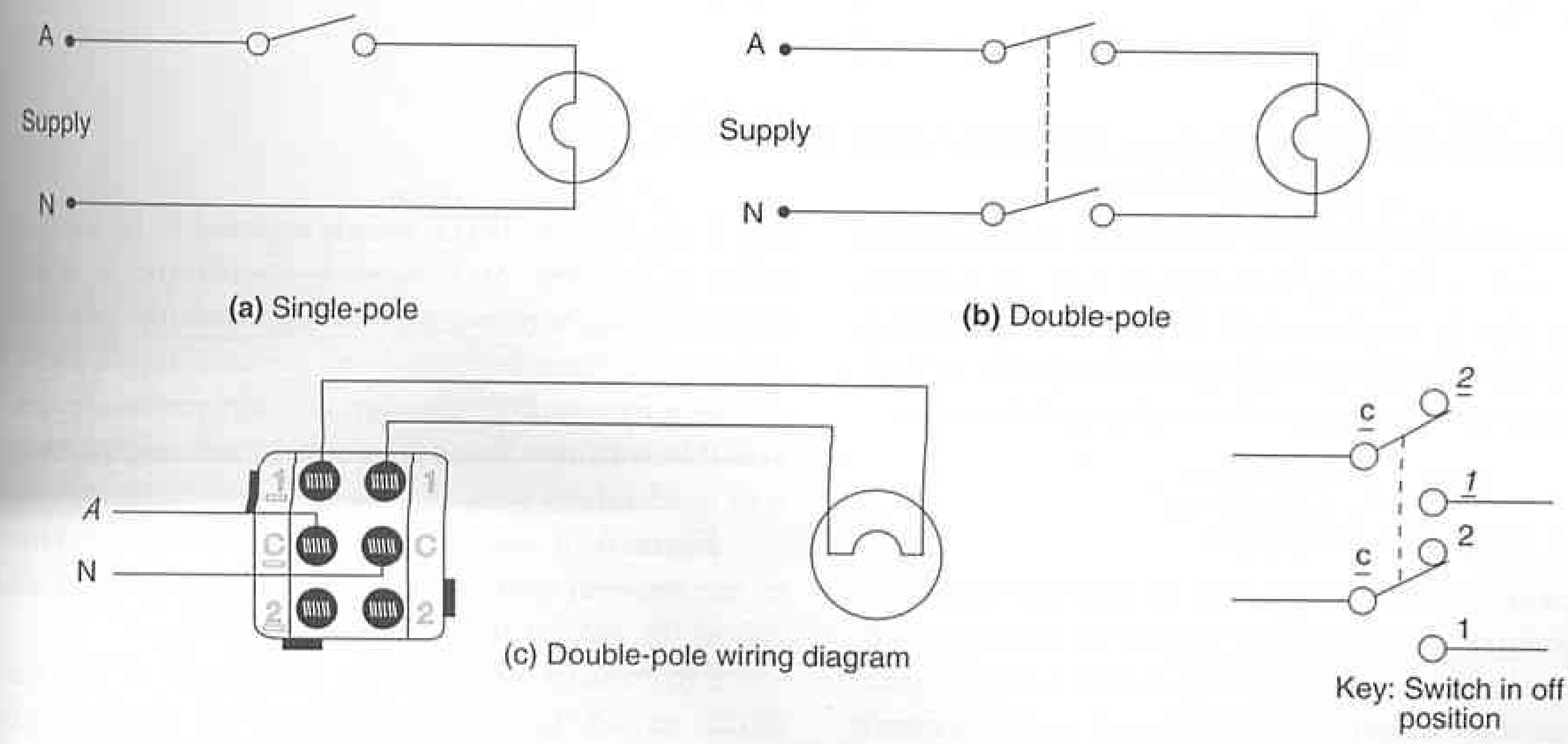


Fig. 6.6 *Single- and double-pole switching*

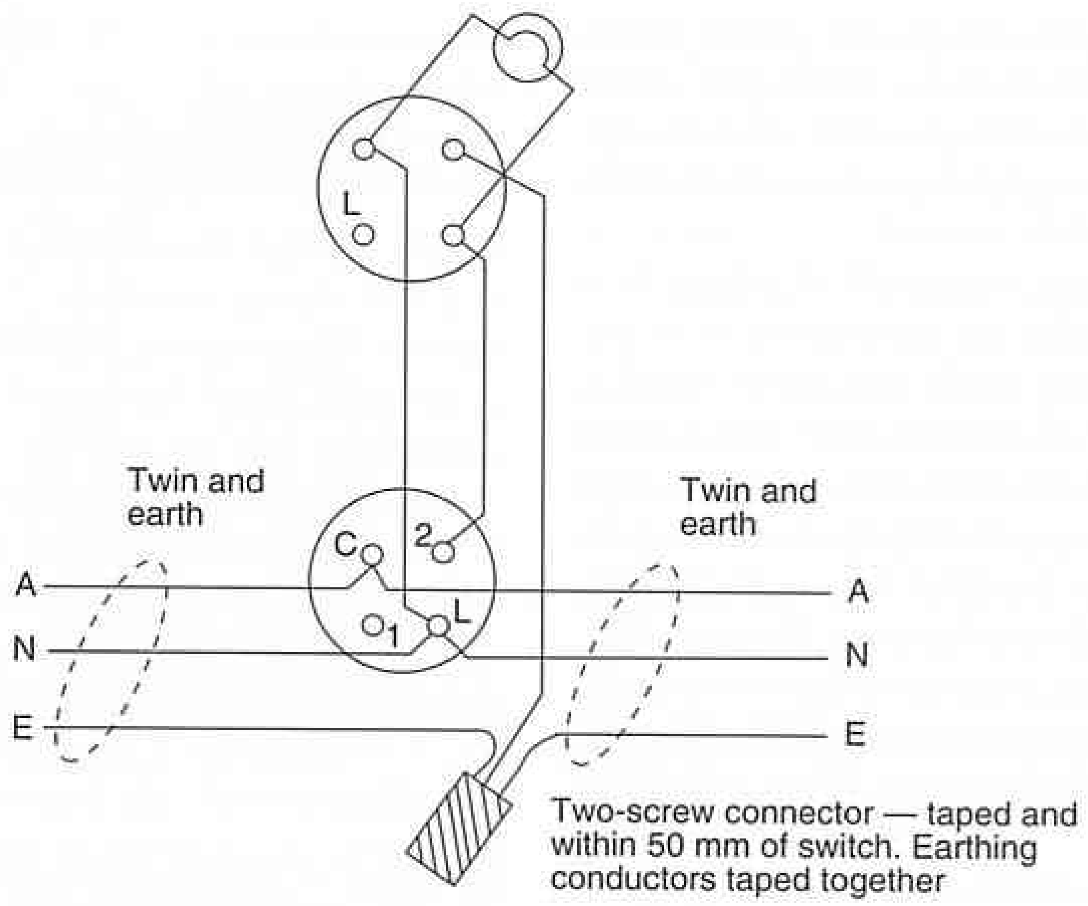


Fig. 6.8 *Looping at switch using twin and earth cable*

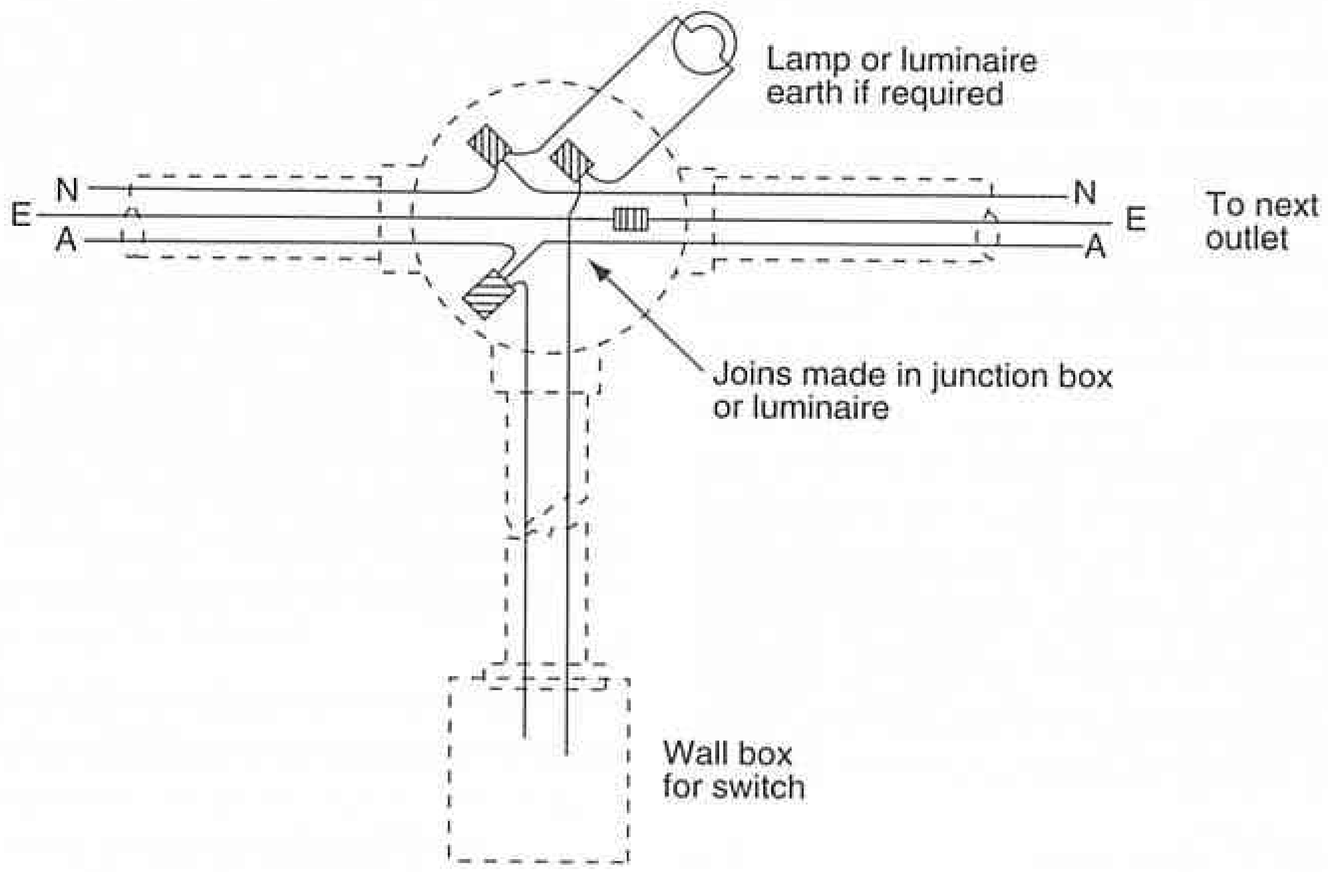


Fig. 6.9 *Looping-in at accessible junction box or luminaire in a conduit system buried in concrete*

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.

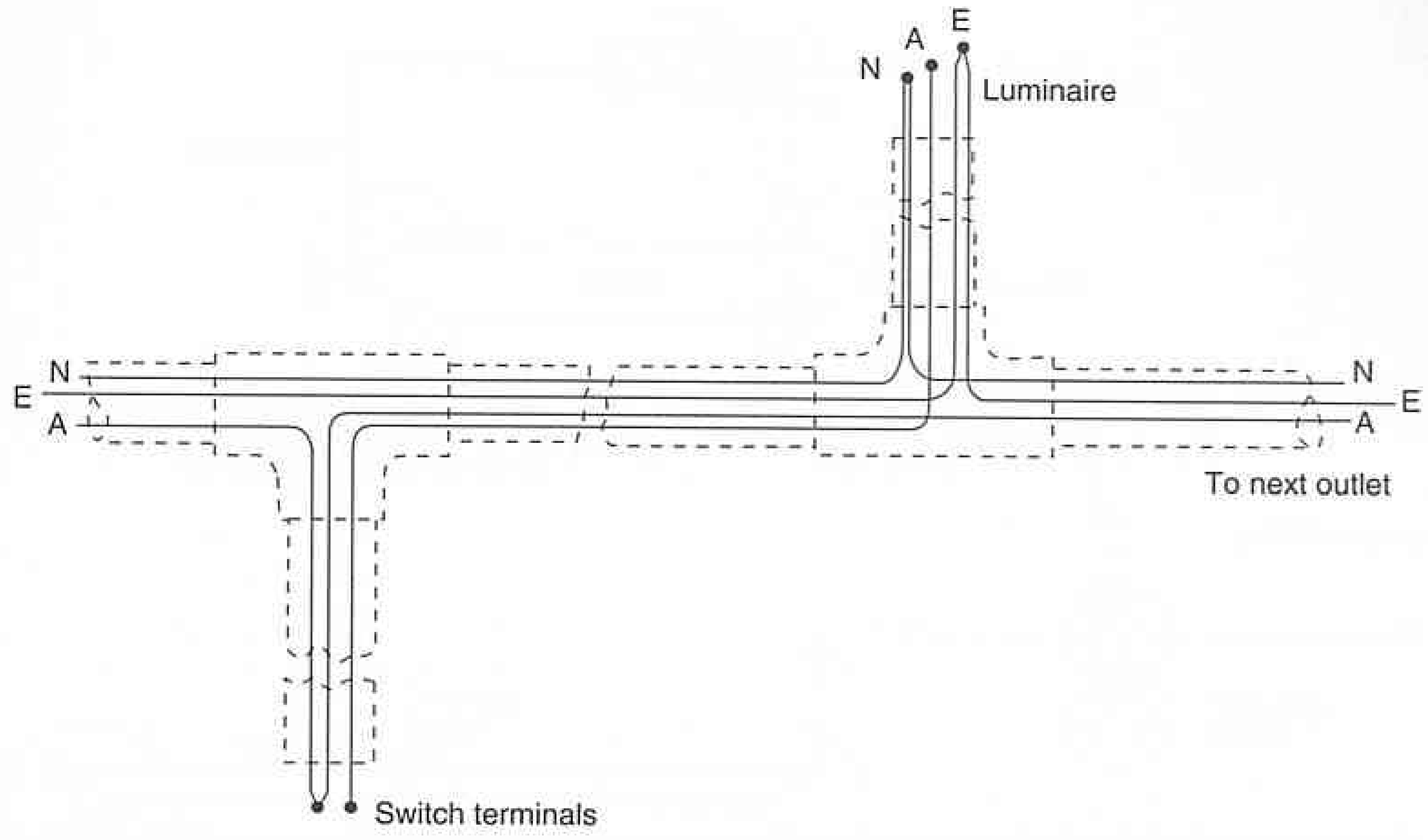


Fig. 6.10 *In this surface conduit system, actives are looped at the switch and neutrals or earths at the outlet or luminaire*

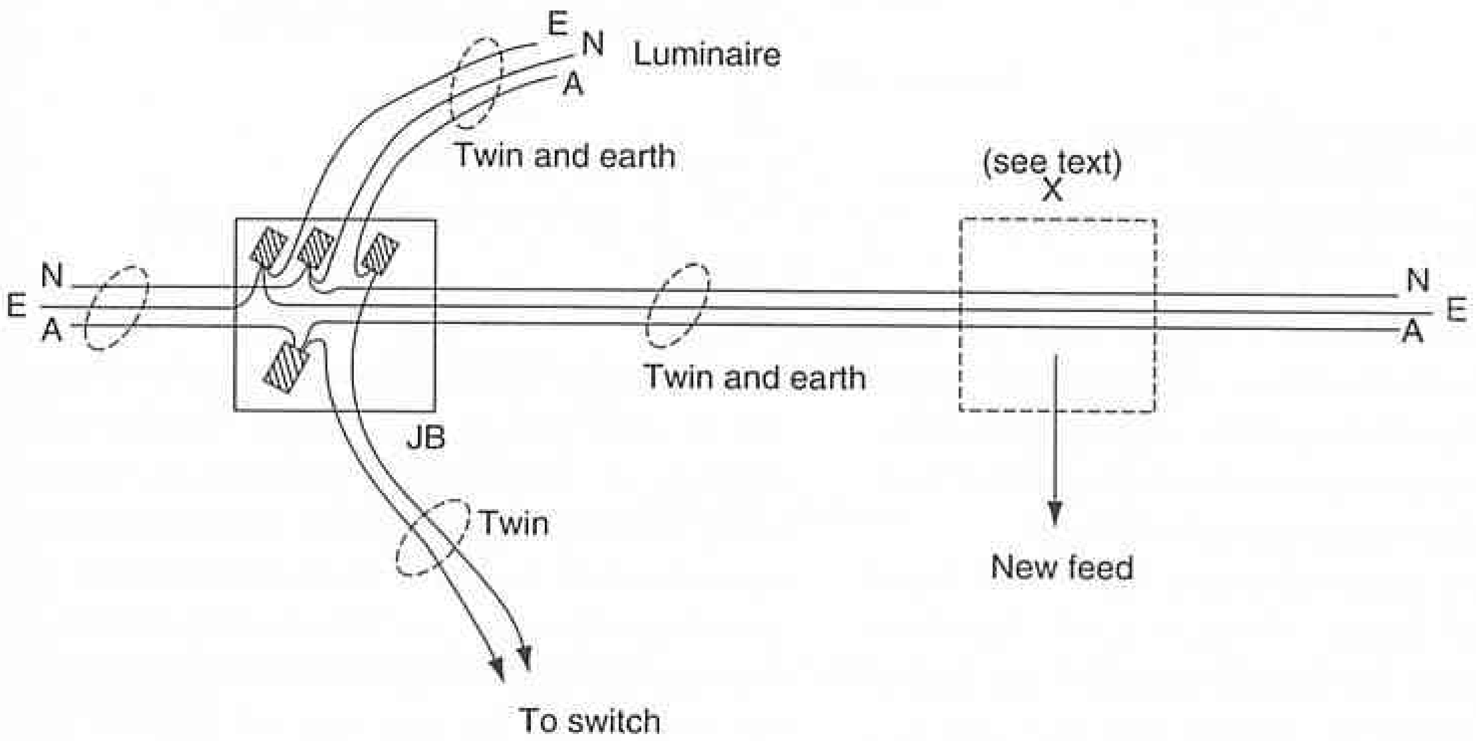


Fig. 6.11 *Use of a junction box as an alternative to 'looping-in'*

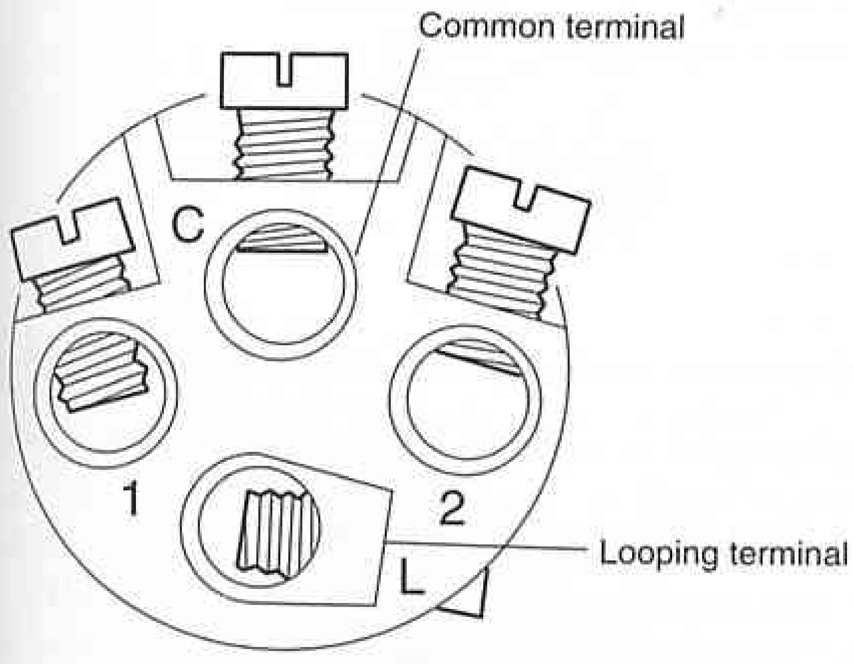


Fig. 6.12 *Terminal arrangement of a typical one-way/two-way switch*

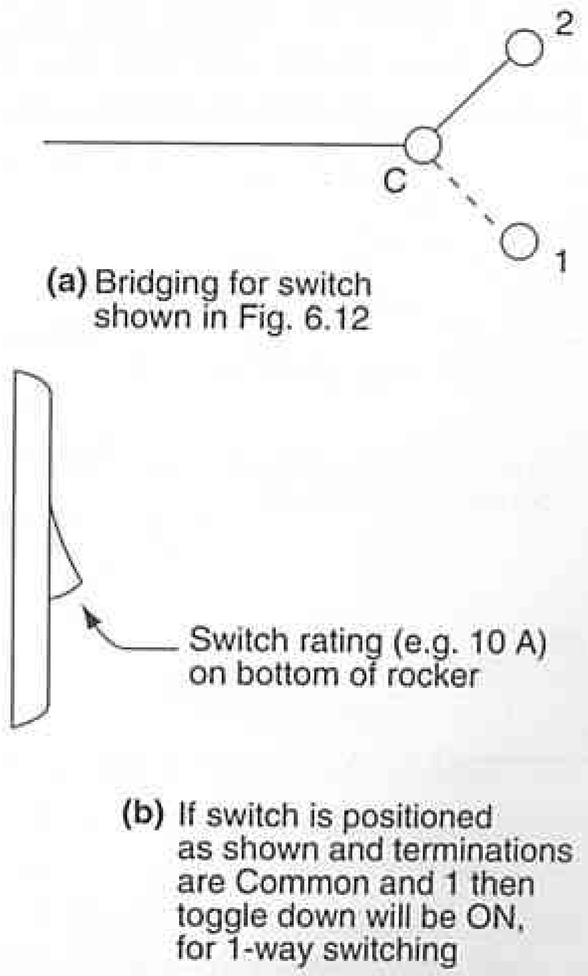


Fig. 6.13 *Switch operation and positioning*

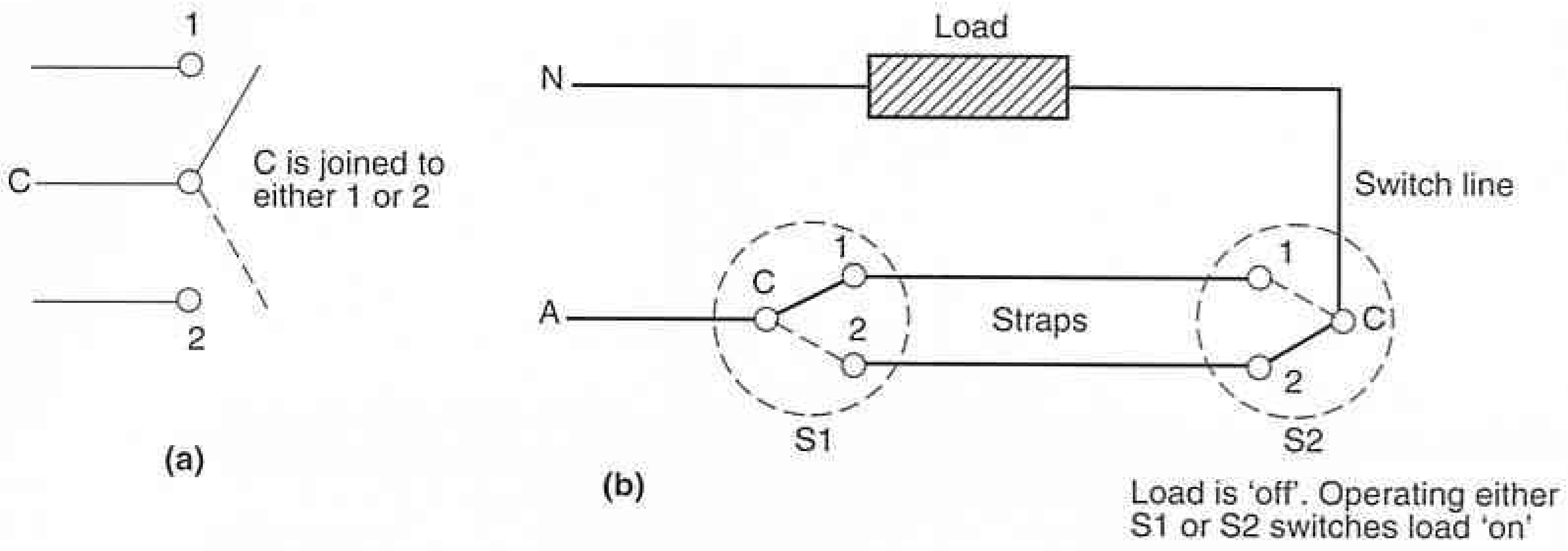


Fig. 6.14 *Two-way switching*

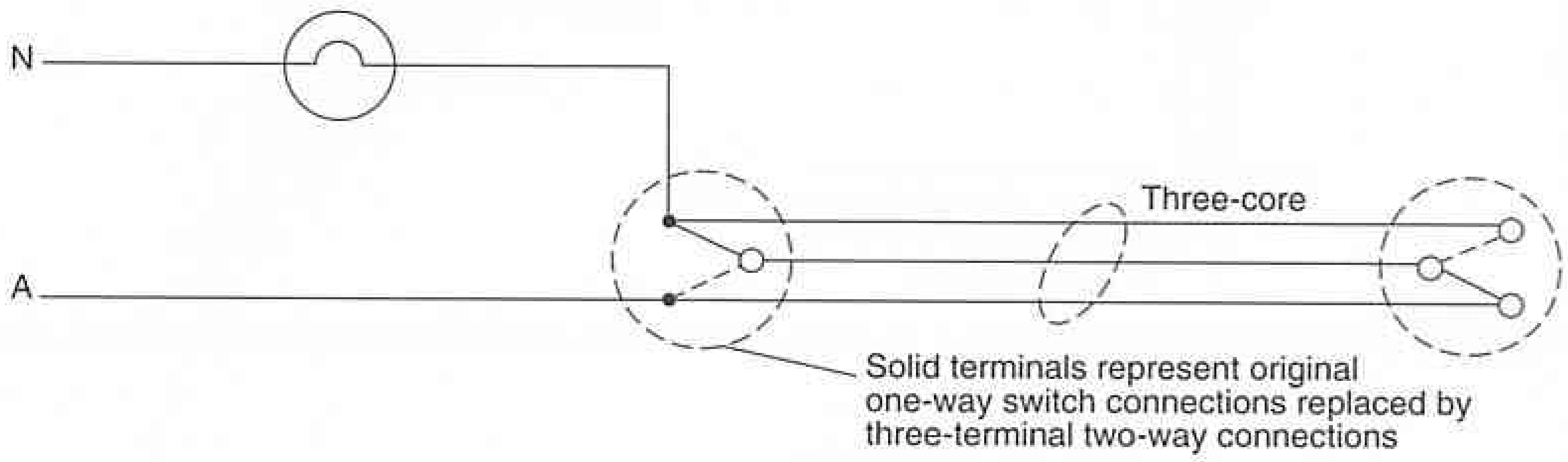


Fig. 6.15 *Changing from one-way to two-way control*

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

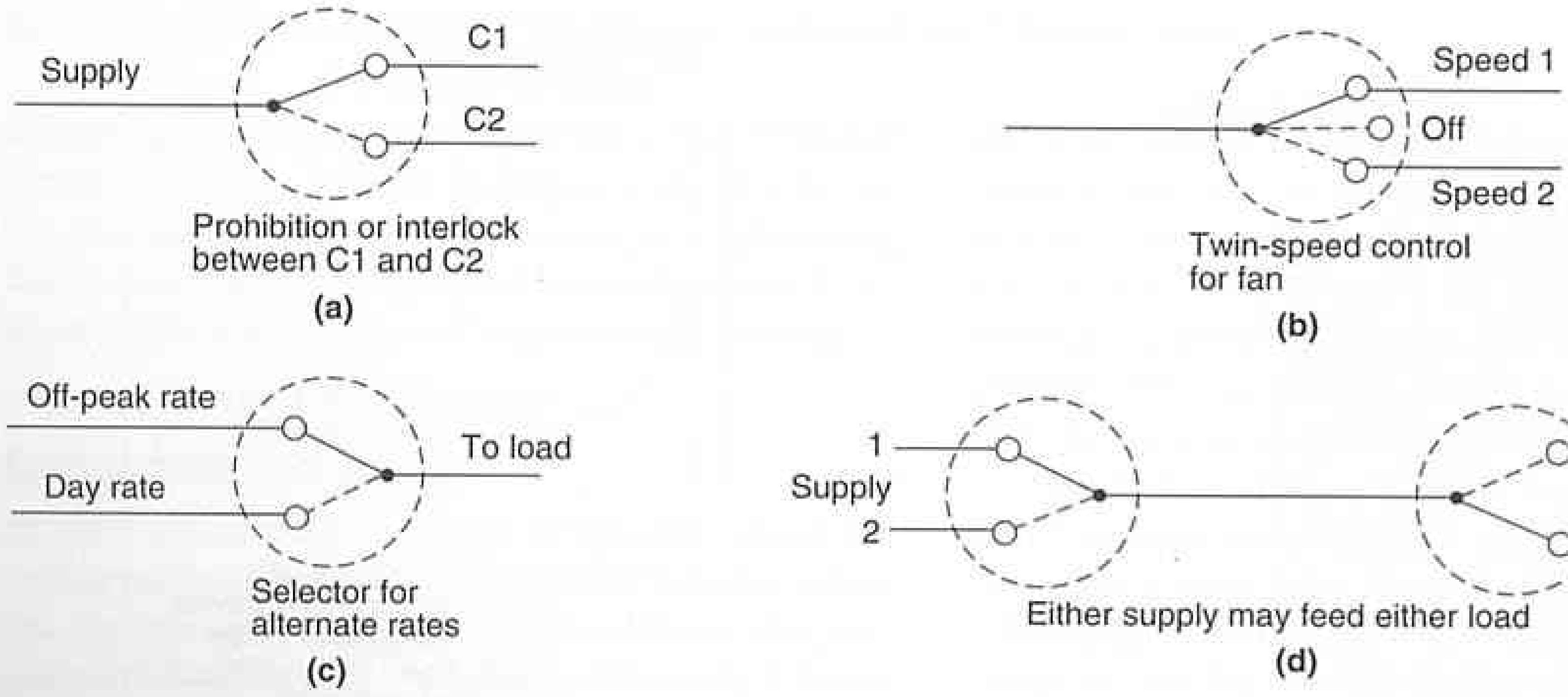


Fig. 6.16 *Some other applications of two-way switches*

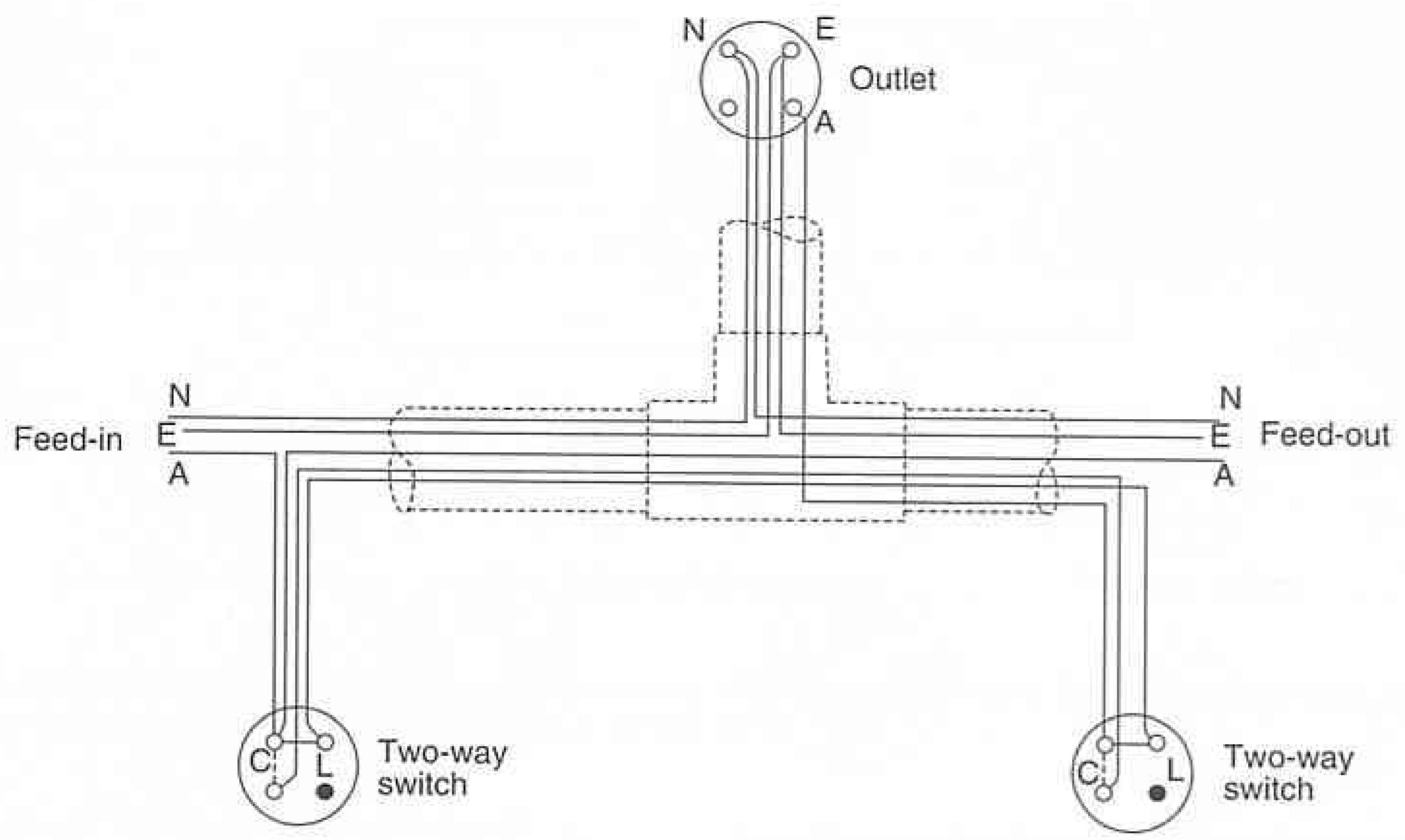


Fig. 6.17 *Connections for two-way switching using the 'looping-in' system with surface wiring in conduit*

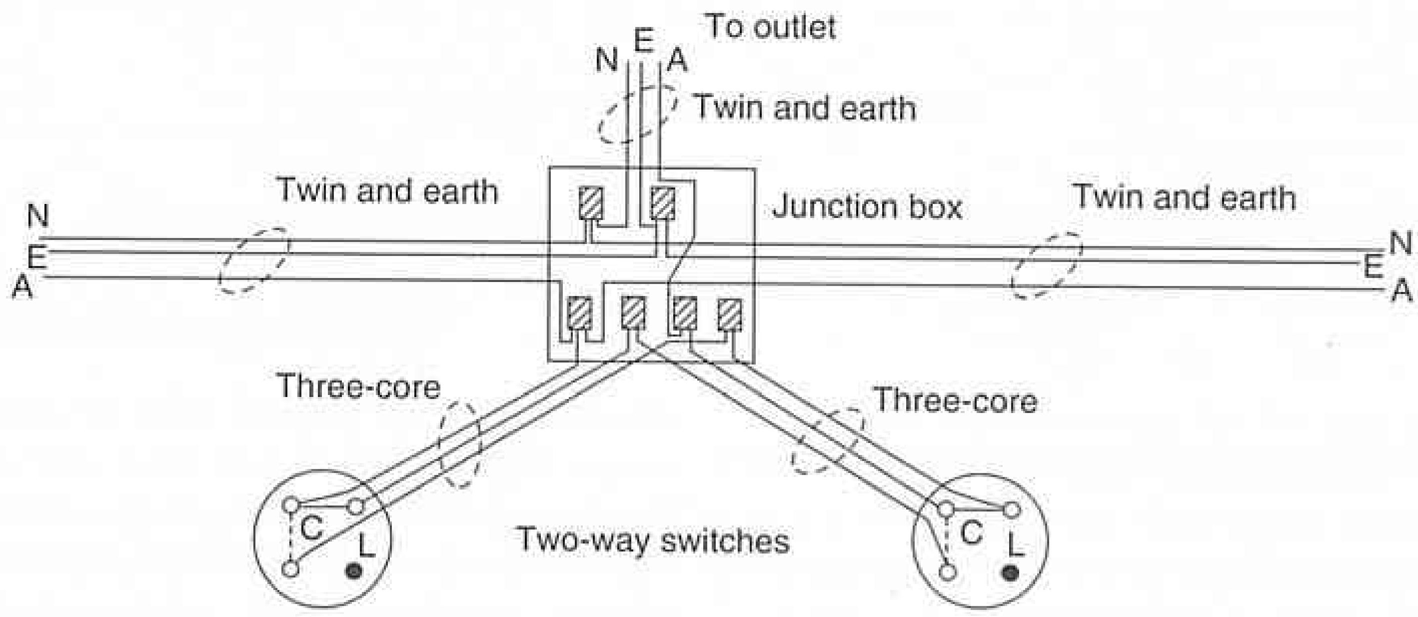


Fig. 6.18 *Two-way switching using twin and earth, and three-core cable and junction box. A two-core and single-core cable may be used instead of the three-core*

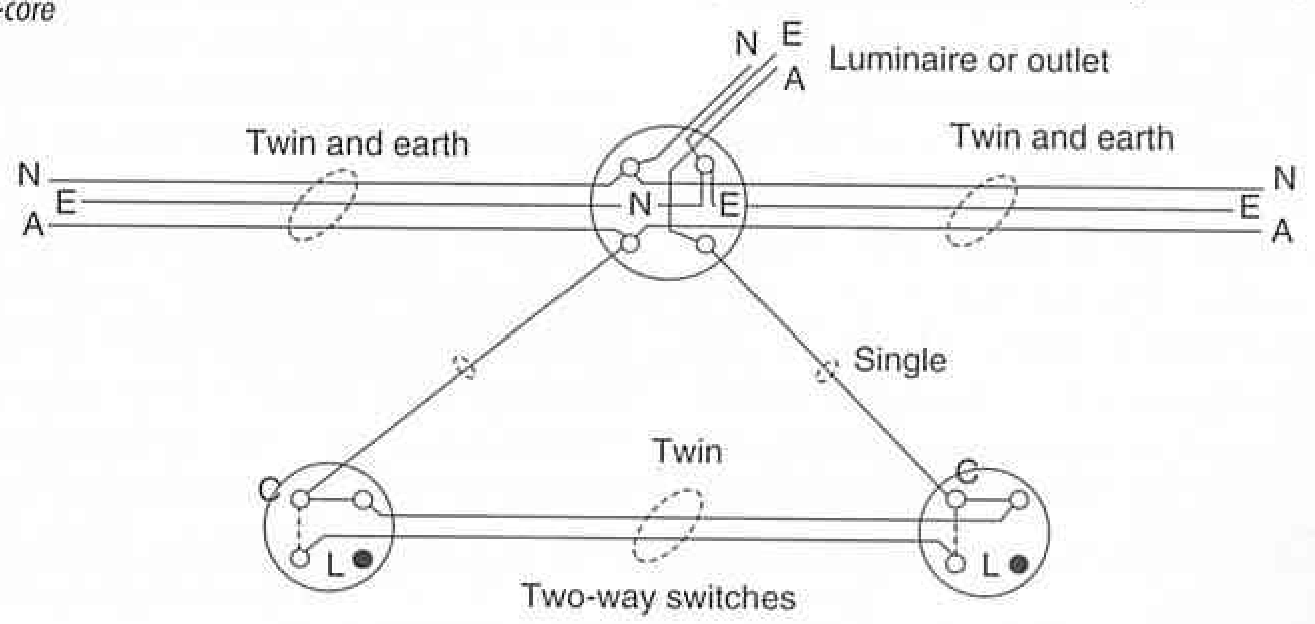


Fig. 6.19 *A method for two-way switching single-core, two-core, and twin and earth cables*

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.

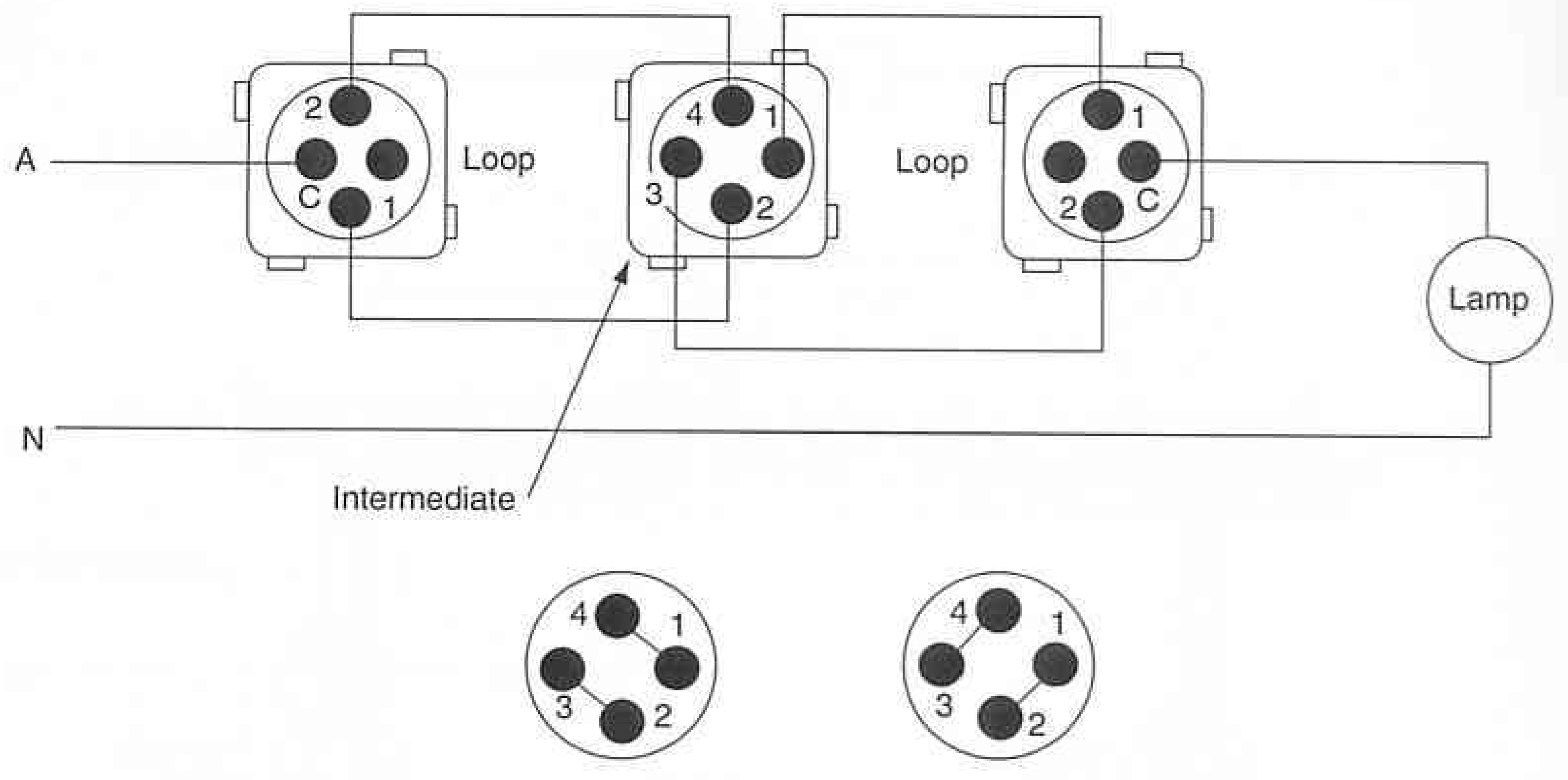


Fig. 6.20(a) *Rear terminal connections of a typical intermediate switch*

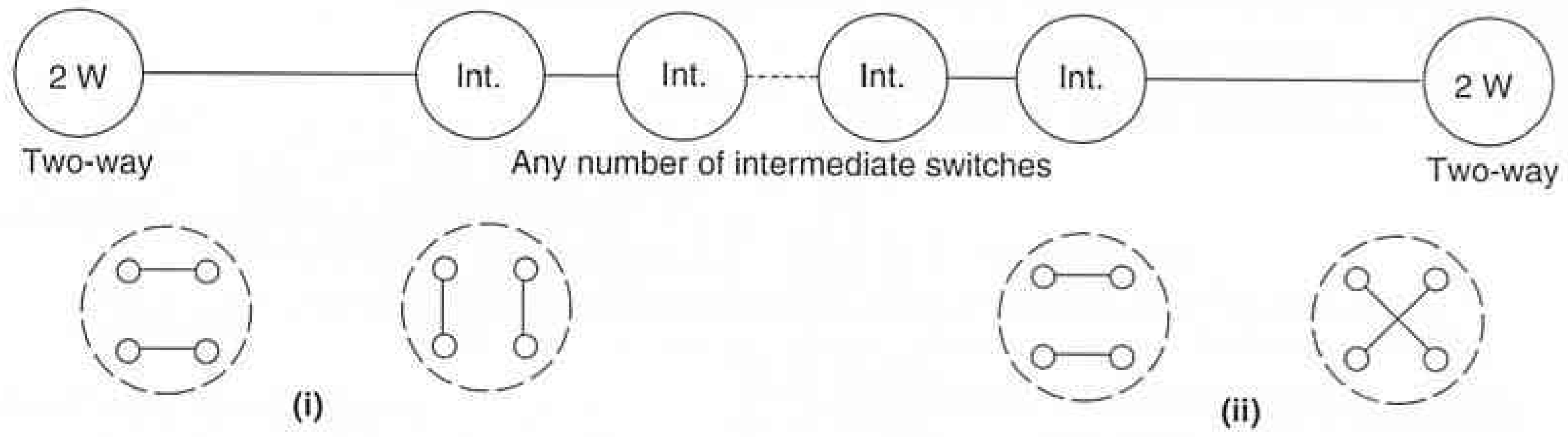


Fig. 6.20(b) *Two common methods of bridging for intermediate switches*

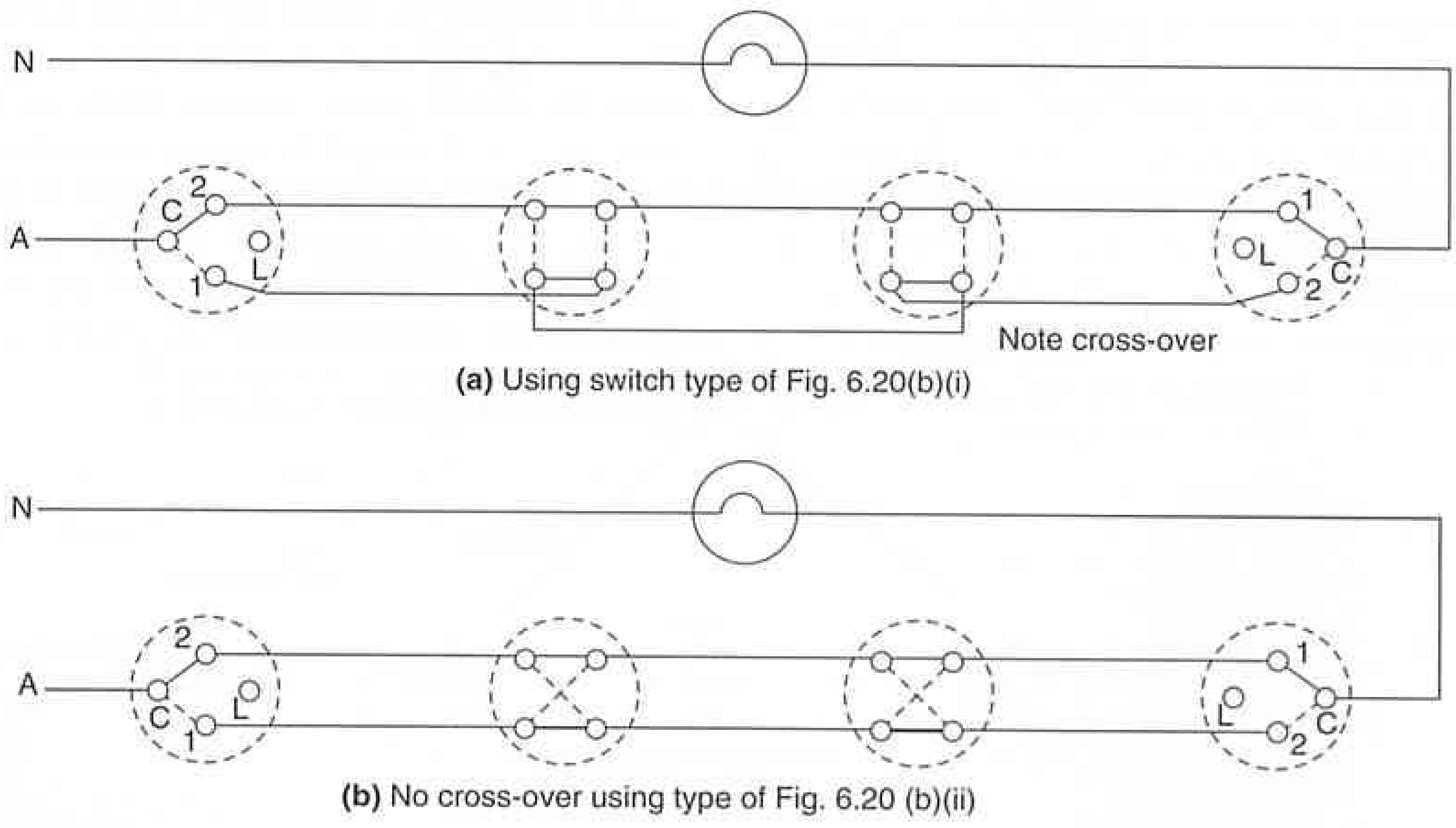


Fig. 6.21 *Connection of 'strap wires' between two-way switches and the intermediate switch depends on the internal bridging of the intermediate switch*

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

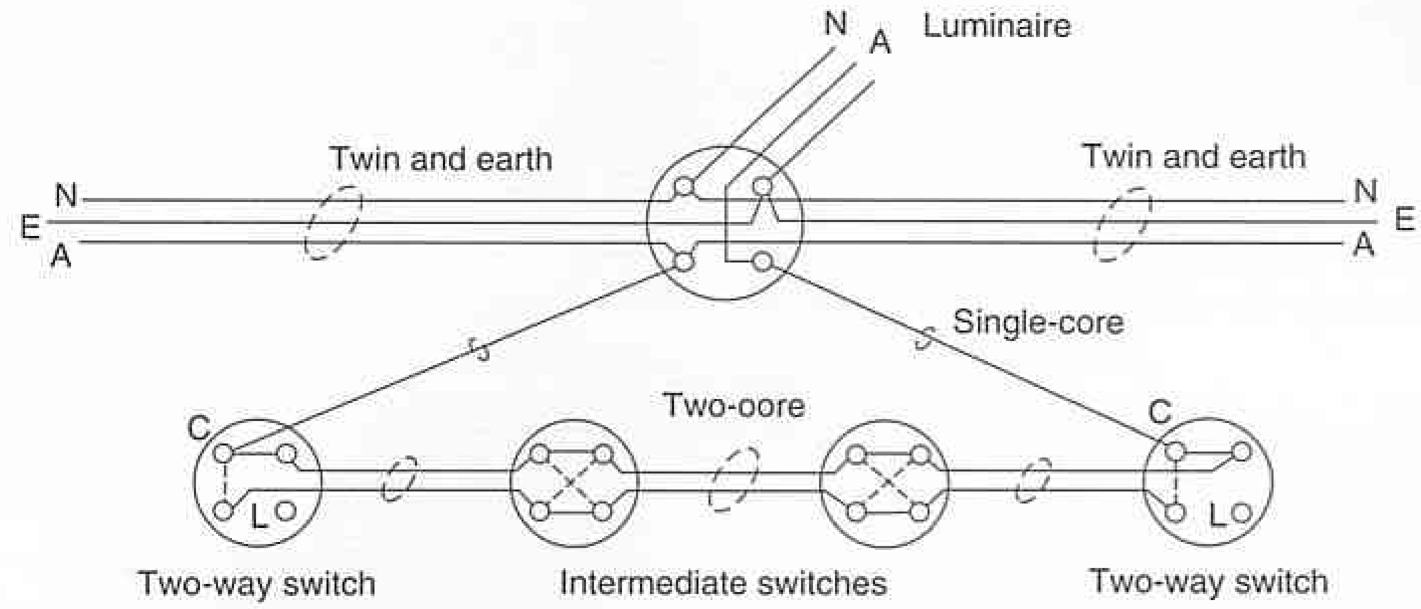
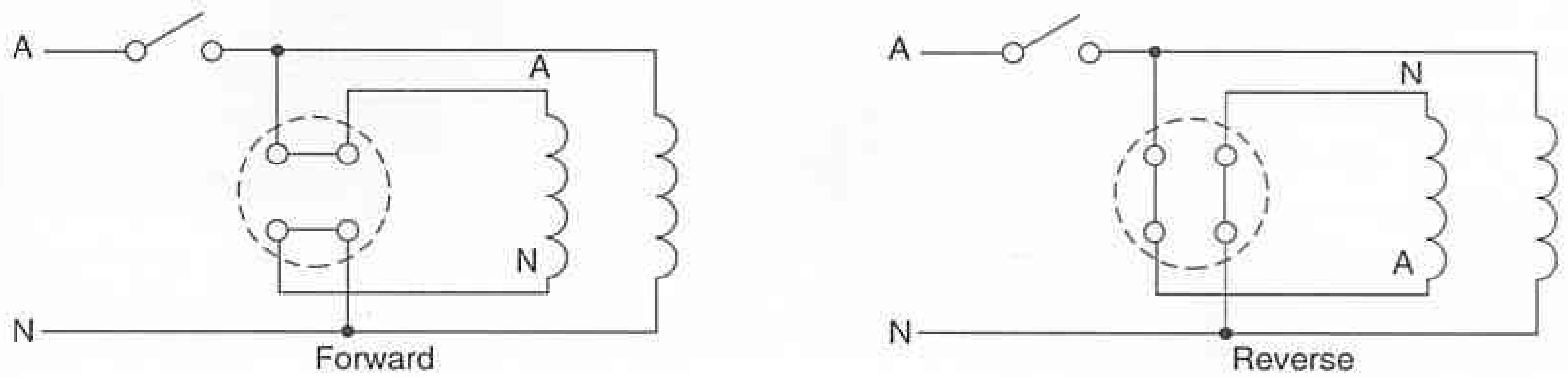


Fig. 6.22 *Multiposition control of a luminaire, using single-core, two-core, and twin and earth cable. Connection of 'strap wires' to intermediate switches depends on the internal bridging positions of switches used*



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.

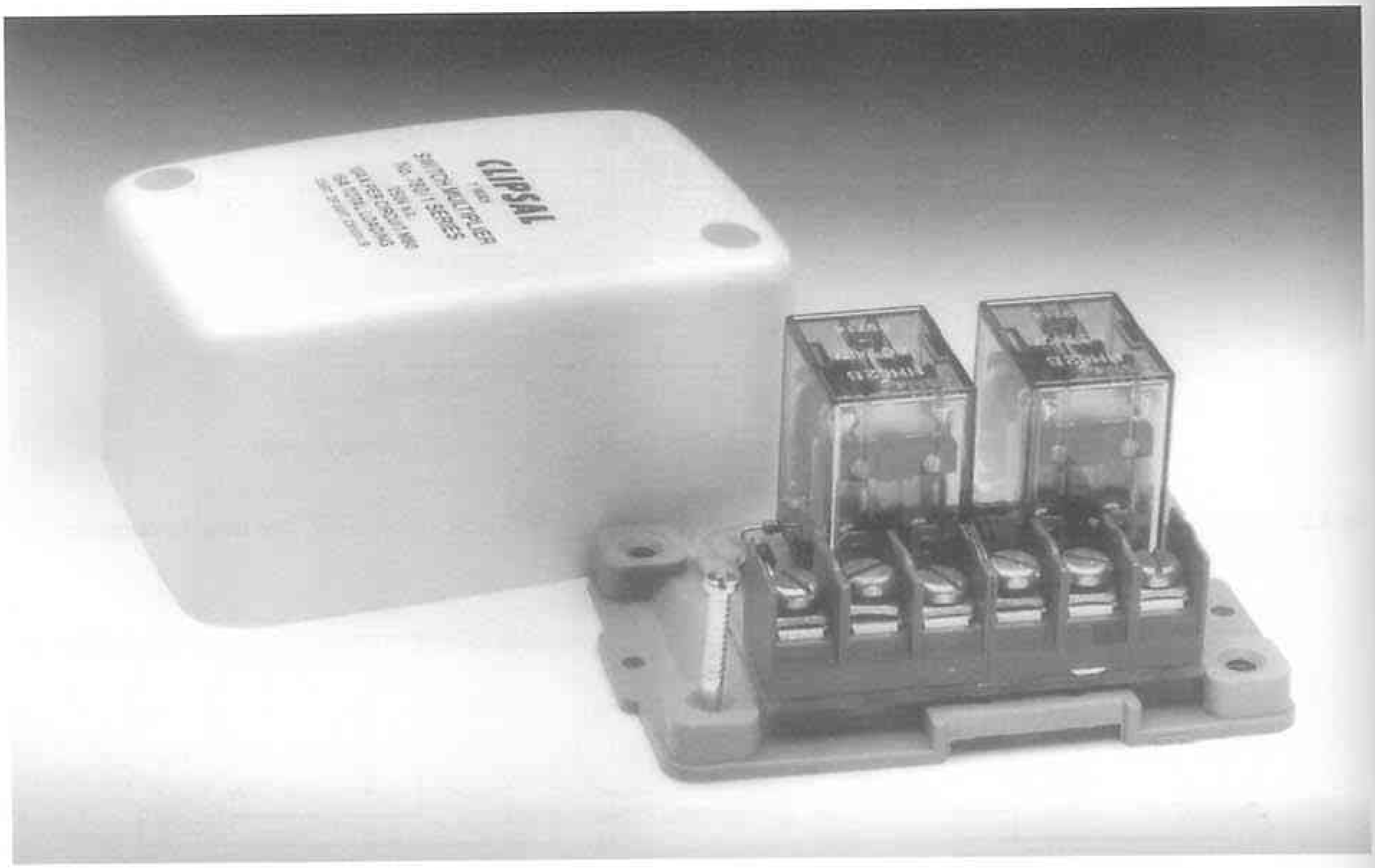
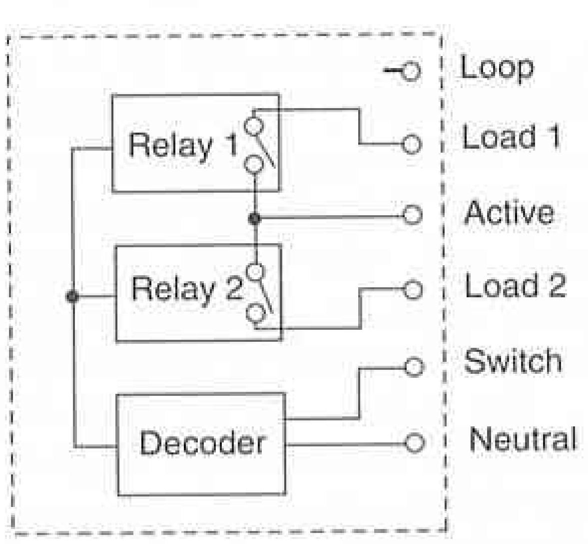


Fig. 6.24(a) *Switch multiplier* GERARD INDUSTRIES



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.

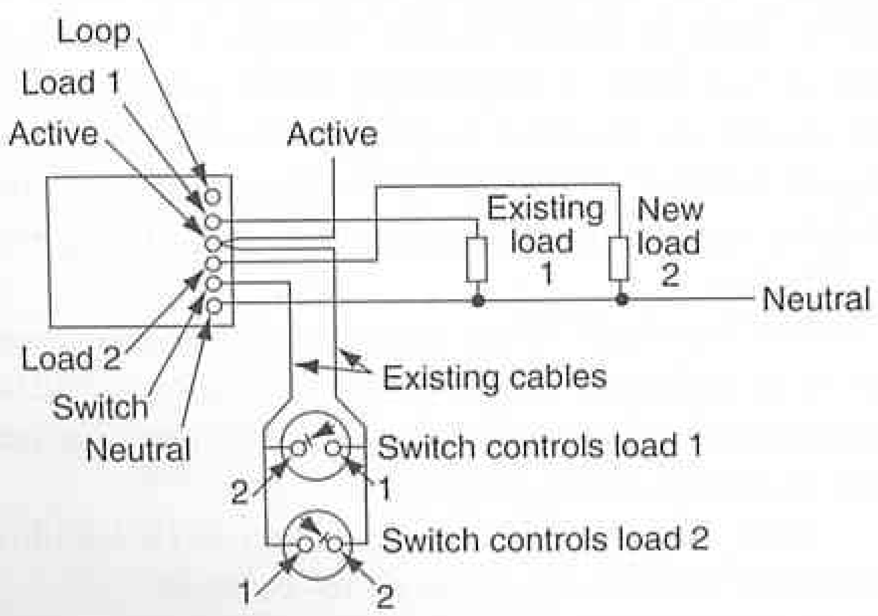


Fig. 6.24(b) *Connections and wiring diagram for switch multiplier* GERARD INDUSTRIES

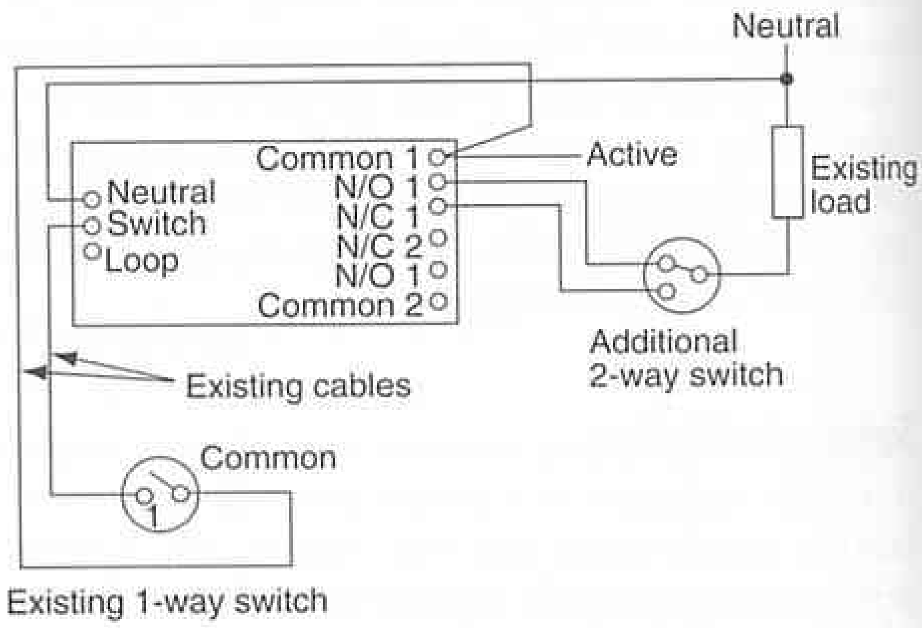


Fig. 6.25 *Conversion of existing one-way switch to two-way application using switch multiplier* GERARD INDUSTRIES

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.

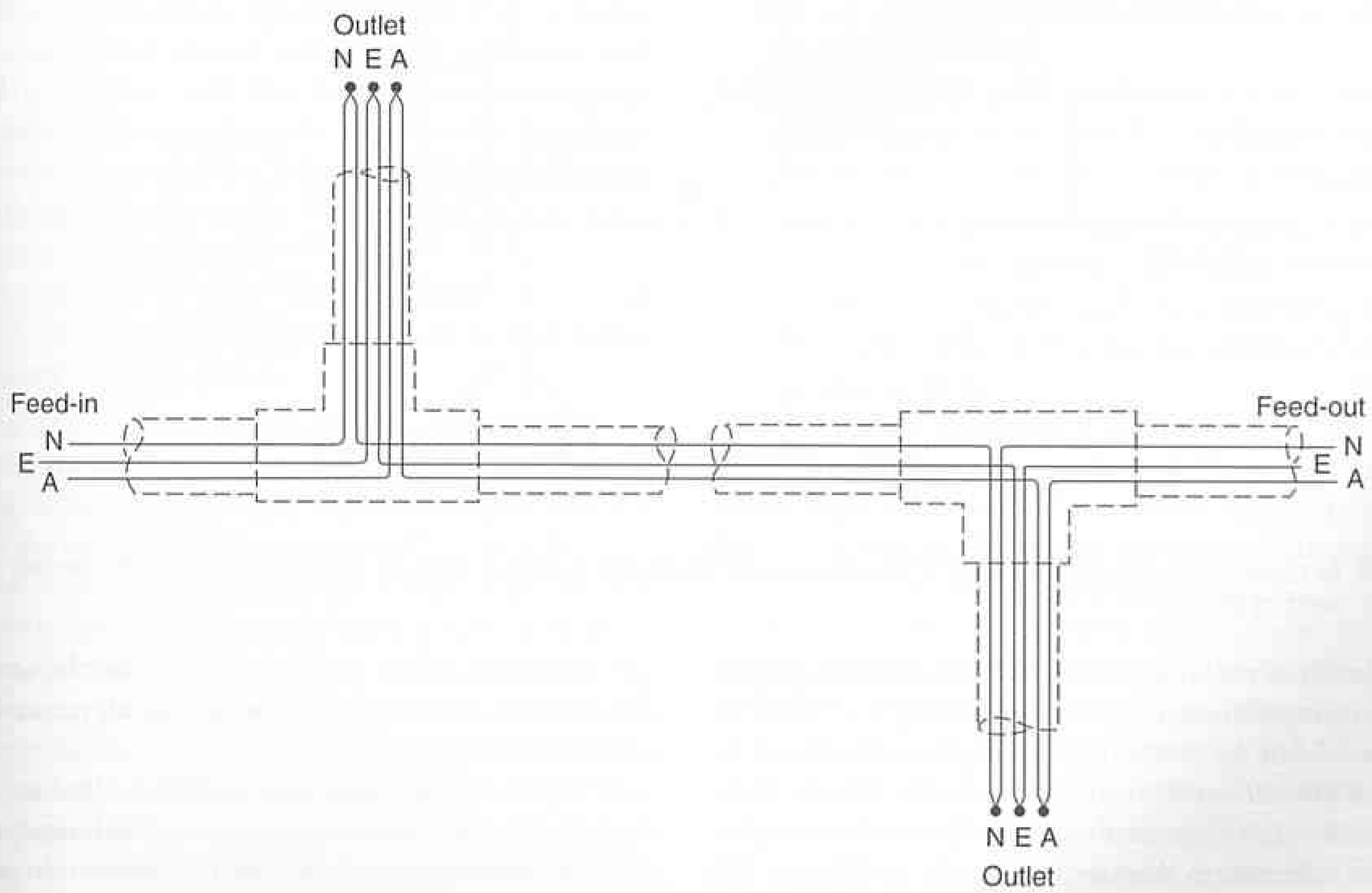


Fig. 6.26 *Wiring power outlets in a surface conduit system*

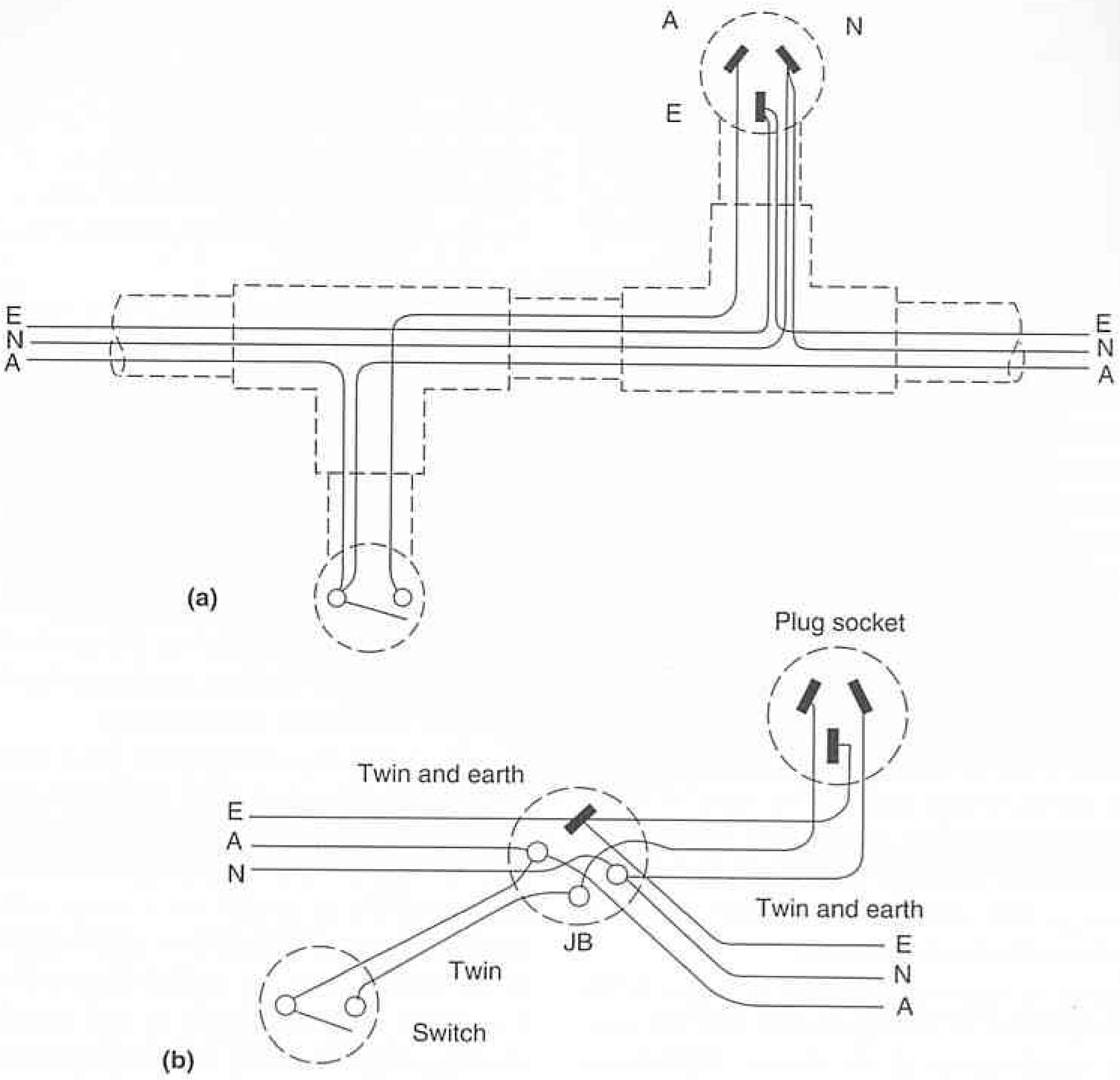


Fig. 6.27 *A power outlet may be controlled by a switch up to 1.5 m distant from the outlet, provided that the outlet is visible from the switch*

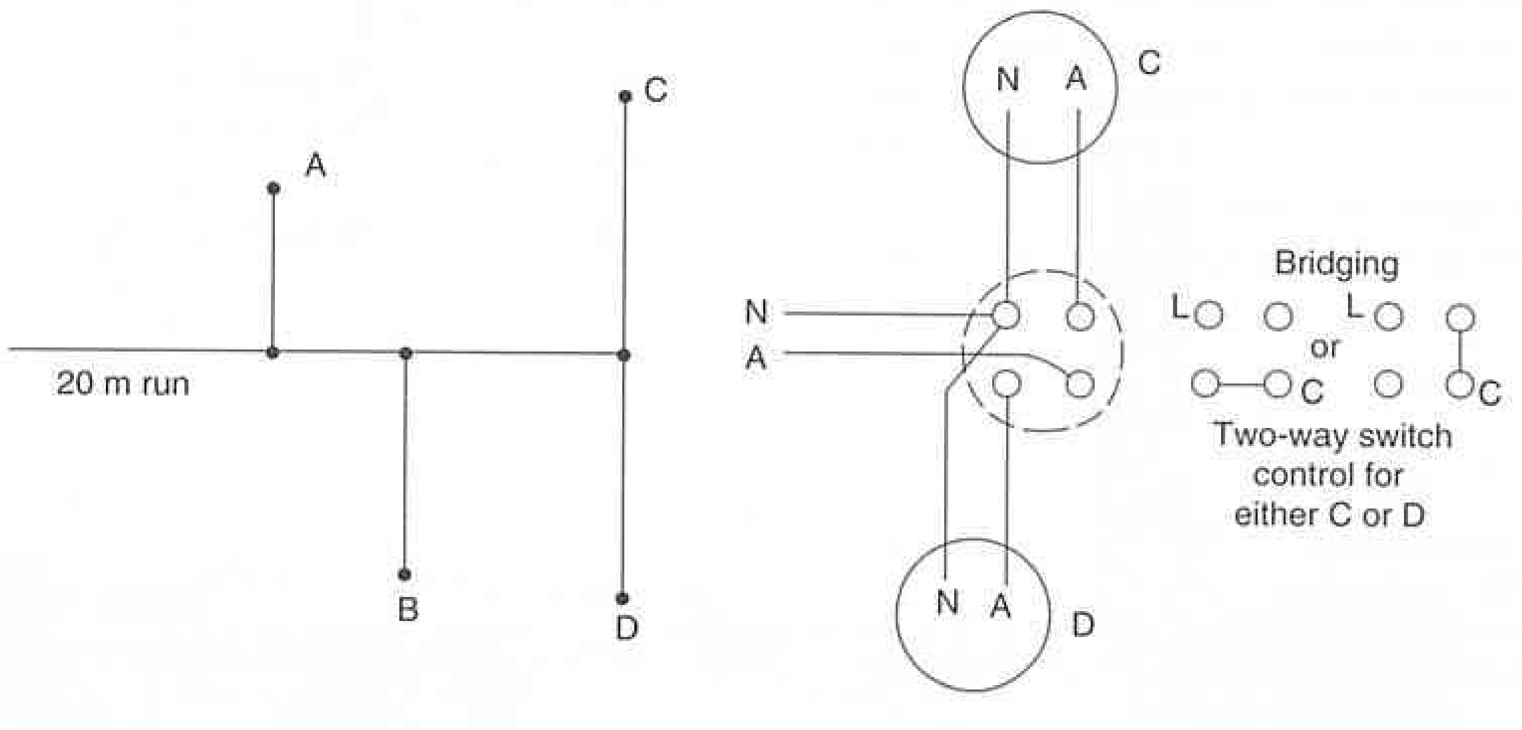


Fig. 6.28 *An additional power outlet installed at D has not increased the effective number of points on this circuit by virtue of the two-way switching provided*

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

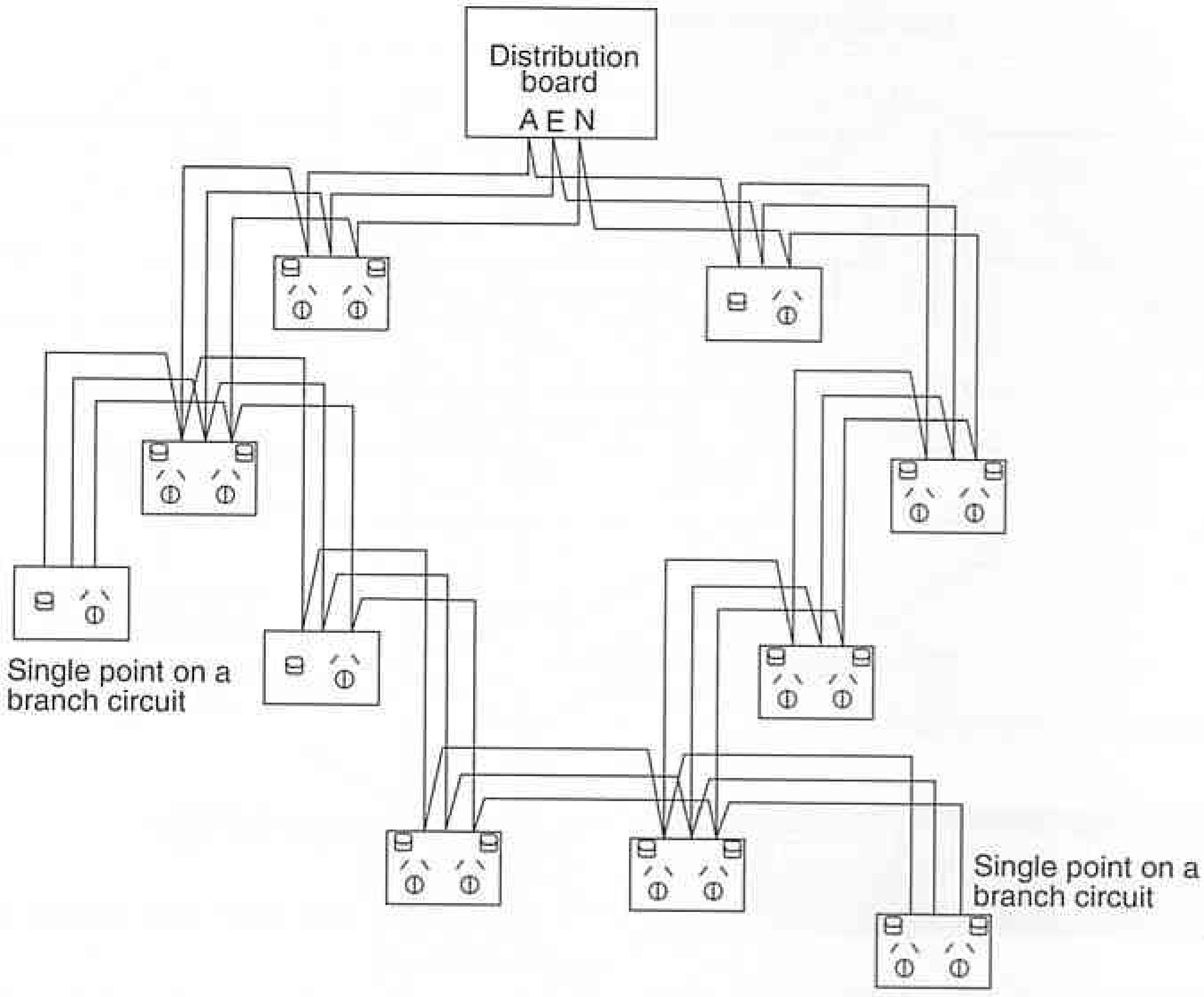


Fig. 6.29 *Ring circuit—a closed loop arrangement*

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).

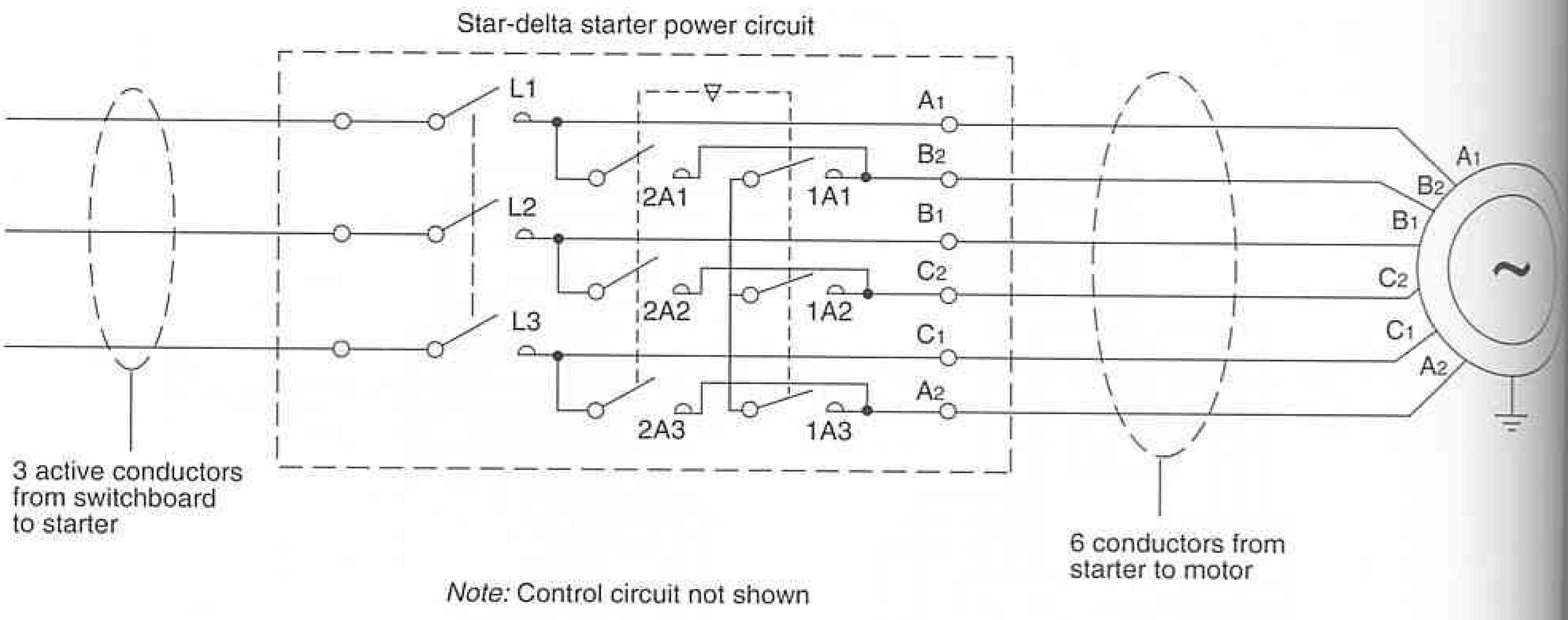


Fig. 6.30 *Star–delta starter power circuit wiring*

6.6 Building construction types, terms and materials

Before the commencement of any building job, plans and site plans are drawn up containing details of the type of building structure and the position on the site for the building. This affects the wiring method to be used and determines whether supply will be via overhead mains (as shown in Chapter 3, Fig. 3.11) or underground (as in Fig. 7.22 of Chapter 7). Strict standards apply to building materials and construction, and the terms used, with few exceptions, are standard ones. The electrician must be familiar with these for the correct interpretation of plans and specifications and for on-the-job discussion with the builder, consulting engineer or architect. Buildings must comply with the Building Act, building ordinances and the by-laws of any local government body where applicable.

Building construction will be looked at as it applies to:

- single domestic dwellings
- multiple domestic dwellings
- industrial and commercial premises
- drilling and notching of structural timbers.

Figures 6.31 to 6.33, 6.34(b) and 6.35 have been reproduced with permission from *Basic Training Manual 16–11* (Australian Government Publishing Service).

Single domestic dwellings

Types of construction and structural elements

Single domestic dwellings are usually one of six types of construction:

- brick (solid or cavity brick)
- brick veneer
- timber-framed and clad with timber or other external sheeting
- block or concrete masonry
- prefabricated
- steel-framed and clad with timber or other external sheeting.

Figure 6.31 shows wall and foundation details of a brick building, and Figure 6.32 shows construction in a timber-framed brick-veneer building. Note roofing and flooring timbers that provide fixing surfaces for wiring. A timber-framed building with weatherboard or aluminium external cladding is illustrated in Figure 6.33, and wall construction for concrete masonry can be seen in Figure 6.34(a). Concrete slab footings are illustrated in Figure 6.34(b).

A brief description of the function of the various parts of the building structure shown in Figure 6.32(a) follows. Items are listed in approximate order from the bottom left of the diagram, proceeding clockwise:

Reinforced-concrete strip footing supports the load of the whole building structure. It is usually reinforced with mild steel rods.

Brickwork in Figure 6.32(a) is a veneer enclosing the timber wall framing; sometimes steel is used for the wall and roof framing (see Fig. 6.36). The brickwork in a brick-veneer building normally carries no load.

Damp-proof course is a waterproof membrane that prevents rising damp. It is most commonly of polythene, sometimes of aluminium-cored bituminous material.

Bearer is a subfloor timber that provides support and fixing for the floor joists.

Bottom wall plate provides fixing for the studs of the wall frame and distributes the load that is bearing on the wall studs.

Isolated brick pier supports the floor bearers or any other superstructure such as verandahs or beams.

Galvanised ant caps provide a barrier against termites (white ants).

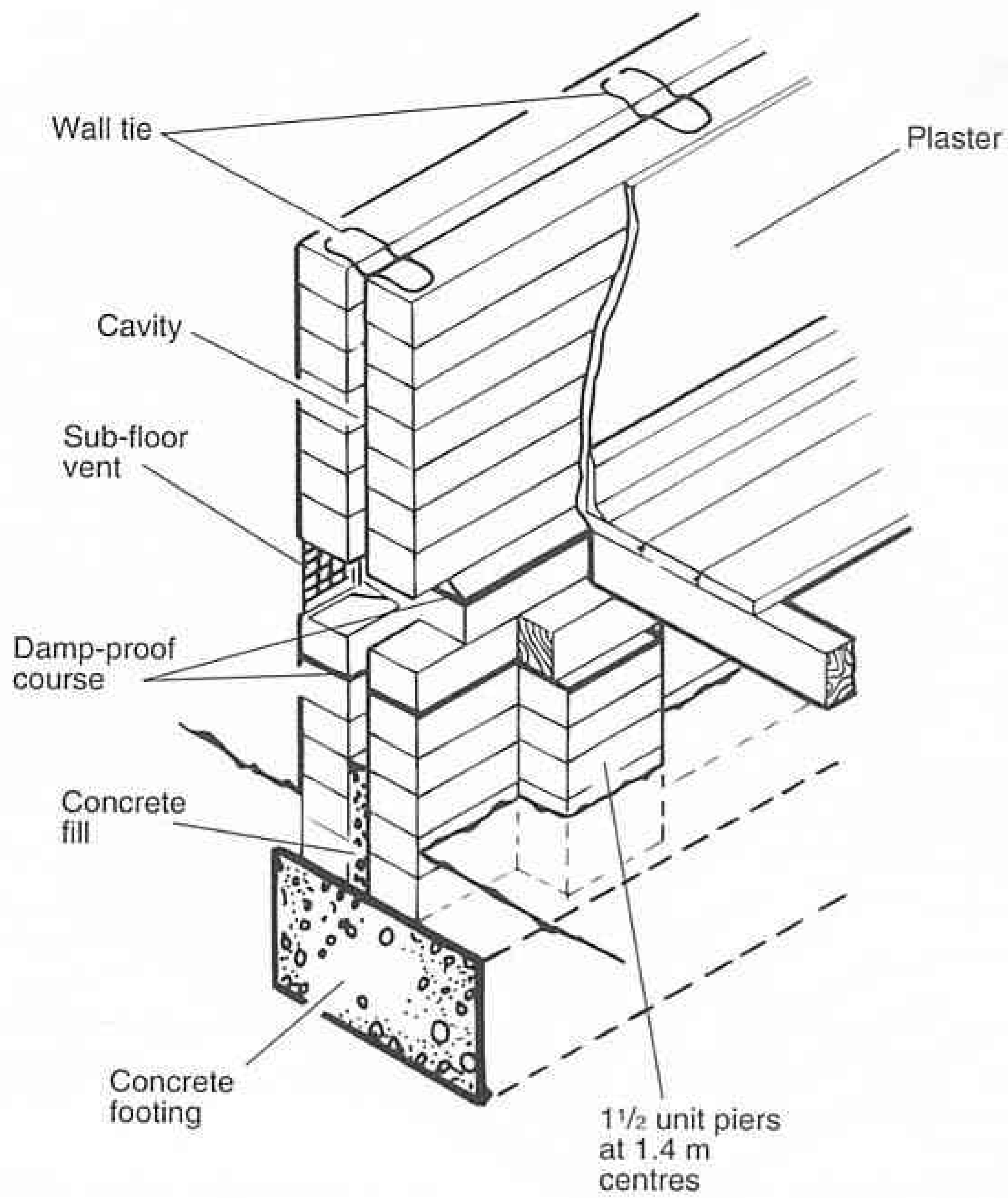


Fig. 6.31 *Solid brick construction* WORKCOVER AUTHORITY OF NSW

Floor joist is a timber member spanning between walls or other supports such as floor bearers. It is used for the support and fixing of flooring material such as timber or flooring-grade particle board.

Top wall plate is a continuous timber member on top of walls. It provides support and fixing for the roof structure and transfers the weight of the roof to the walls. It is required on top of all walls—timber, masonry or stone.

Window head is a load-bearing member that bridges the gap of a window opening and supports flooring timber above or roof structure, as the case may be.

Ceiling battens provide fixing for ceiling material. They may be packed up or trimmed to provide the means whereby a ceiling free of 'bumps and hollows' can be installed. They are often dispensed with, ceiling material such as gypsum plaster sheets being fixed directly to the ceiling joists, commonly with an adhesive.

Blocking prevents deep floor joists from twisting and provides rigidity for the floor frame. The same term is used to describe small timber blocks fitted between two adjacent studs close together, usually at a corner of the wall frame.

Purlins, fixed to the underside of rafters for their support, permit the most economic rafter size and prevent roof sag and collapse.

Struts and props (not shown in Figure 6.32(a)) are required to transfer the load on the purlins to the load-bearing walls and should be adequately supported directly over the studs in timber walls.

MS dogs are mild steel spikes used to tie ceiling joists to a hanging beam. They have been generally superseded by galvanised steel straps. Alternatively, timber battens may be used.

Hanging beam is a deep timber beam located perpendicular to the ceiling joists, to which the ceiling joists are fixed. It effectively reduces the span of the ceiling joists, enabling a more economical size of joist to be used. It must be supported at its ends over load-bearing walls.

Rafters give the roof its required slope and provide the structure on which the roof covering is fixed.

Ridge normally functions not so much as a load-bearing structural member but more as a means of setting out the pairs of rafters and ensuring that they meet at a consistent height to give a horizontal ridge line free of sags.

Trimmer is a cross-member fixed between uncut joints or studs when an opening has been formed in framework. In Figure 6.32(a) it extends the fixing for the ceiling between the last rafter and the top plate.

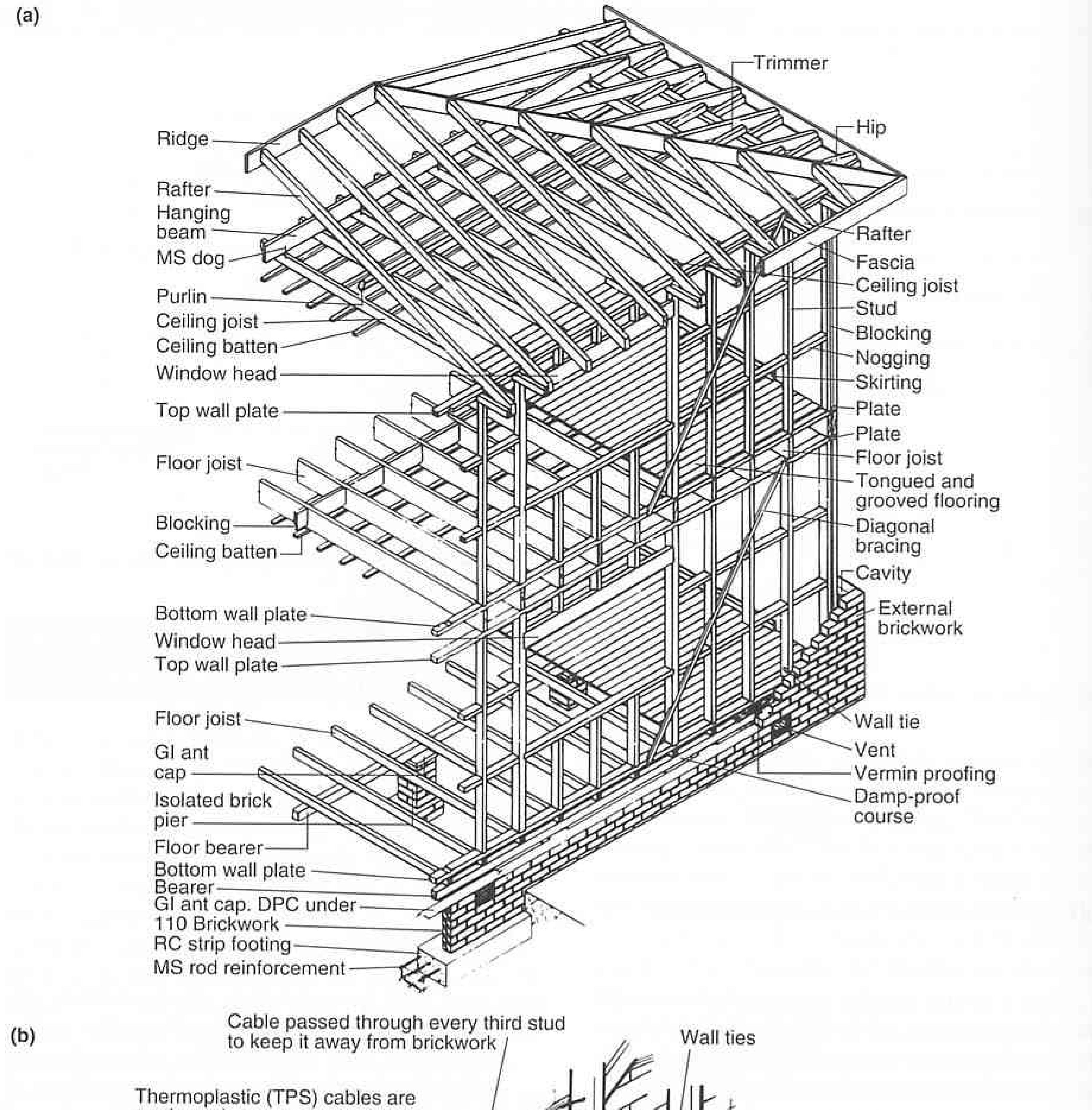


Fig. 6.32 **(a)** *Timber construction: brick-veneer, hip-tile roof, two-storey construction;* **(b)** *Some mothods of wiring in brick-veneer construction* WORKCOVER AUTHORITY OF NSW

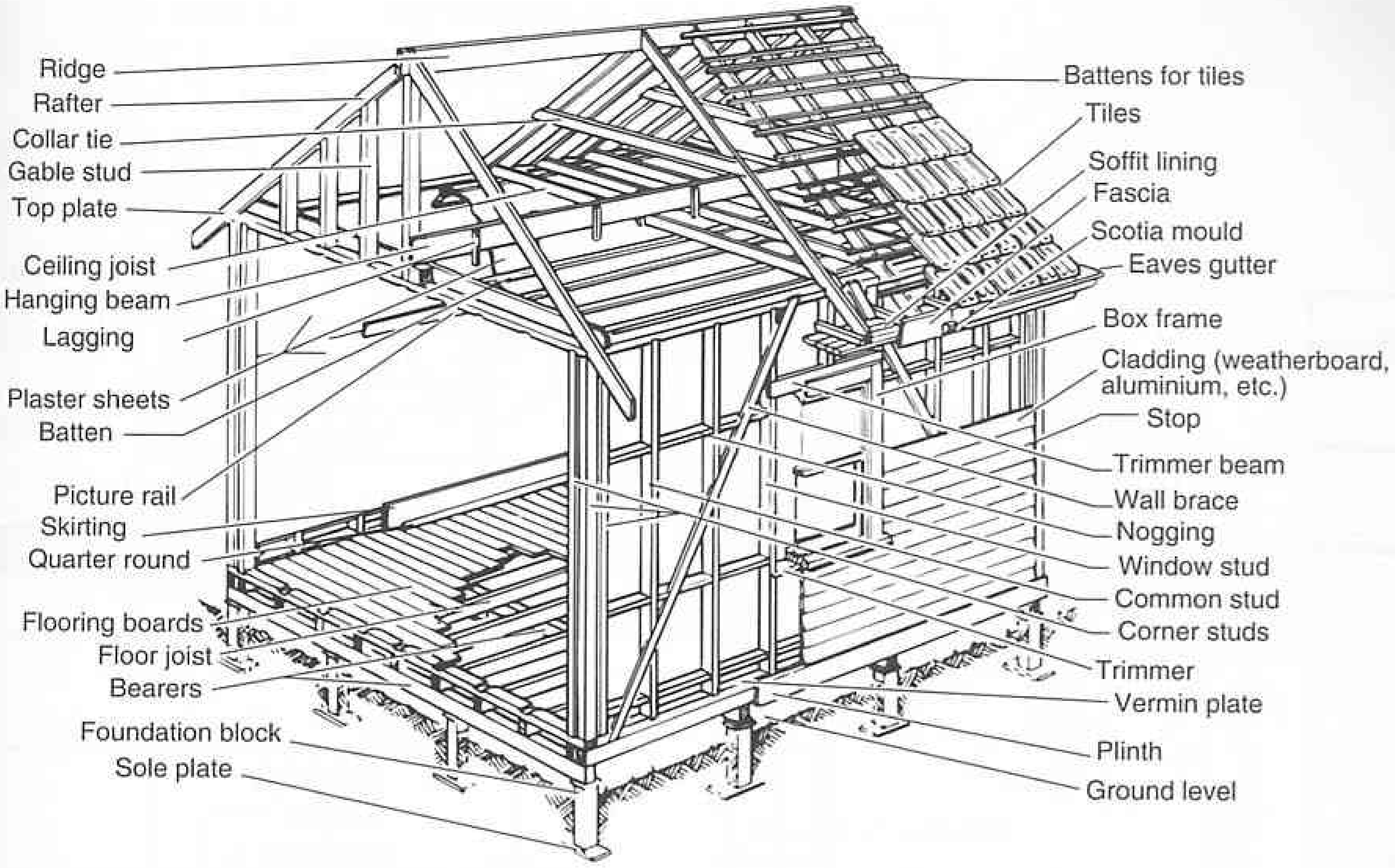


Fig. 6.33 *Timber construction: external cladding, gable-tiled roof* WORKCOVER AUTHORITY OF NSW

Hip rafter functions similarly to the ridge beam in that it locates and supports the rafter pairs as they make the transition from one roof plane to another.

Fascia is a structural board fixed to the ends of rafters to restrain and tie the rafter ends and to enclose the eaves in conjunction with the soffit lining. It also acts as a fixing for guttering.

Soffit lining (see Fig. 6.33) is material, usually fibrous cement, used to box in the eaves for appearance and for vermin- and bird-proofing.

Studs are the vertical load-bearing members in the wall frame. They support the weight of the floor and/or the roof above and provide a fixing for wallboards.

Noggings are installed between studs, most commonly staggered vertically to permit end nailing. They prevent studs from spreading under load, stiffen the frame, and provide additional fixing and support for the horizontal edges of wallboards.

Skirting provides a finish to wall cladding and flooring ends.

Diagonal bracing prevents horizontal movement of wall framing and keeps it plumb. Galvanised steel strip is more commonly used than timber.

Cavity provides the means for any water penetrating the external brick wall to drain clear of the inside wall. It also provides ventilation through to the roof.

Wall ties are galvanised steel straps or, in older buildings, wire devices used at intervals between two walls to restrain the external wall from falling over. They give added rigidity to the building frame and reduce the danger of uplift of frame and roof in high winds.

Vents provide cross-ventilation under the floor and so reduce the incidence of dampness and dry rot in flooring timbers.

Vermin-proofing is wire mesh installed across the gap between the brickwork and the bottom plate to which it is fixed. It prevents the entry of vermin such as rats and mice to the building.

In Figure 6.35 a trussed roof is illustrated, which, as can be seen, consists of a series of prefabricated structural frames used to support the roof load and transfer it to the load-bearing wall frames. Trusses are light and easy to handle and have a very good span-to-weight ratio. The parts of a truss and their functions are as follows:

Top chord is two pieces of timber that meet at the apex of the truss and effectively become the rafters for the roof.

Bottom chord is normally one horizontal timber member that may be used as a ceiling joist. However, the trusses may be exposed to view and the ceiling fixed over the top chord, if desired.

Web members take the compression and tension loads between the top and bottom chords and contribute to the strength of the truss.

Integral nail plates are galvanised steel plates stamped out to produce 'gangs of nails'. They are positioned on each side of the joint and pressed into the timber to form an efficient low-cost joint.

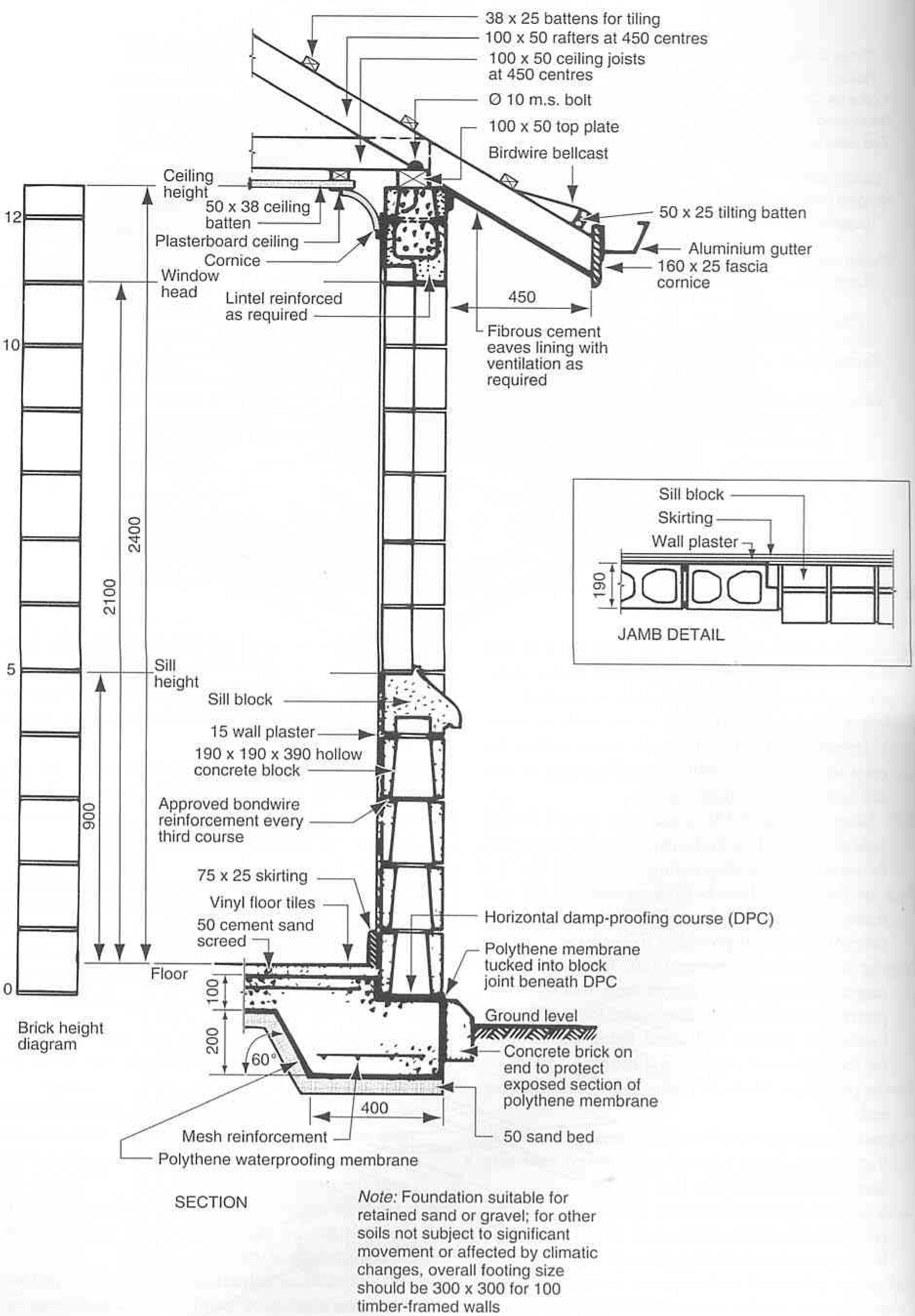


Fig. 6.34(a) *Wall construction: concrete block and timber framed* TAFE COMMISSION, NSW

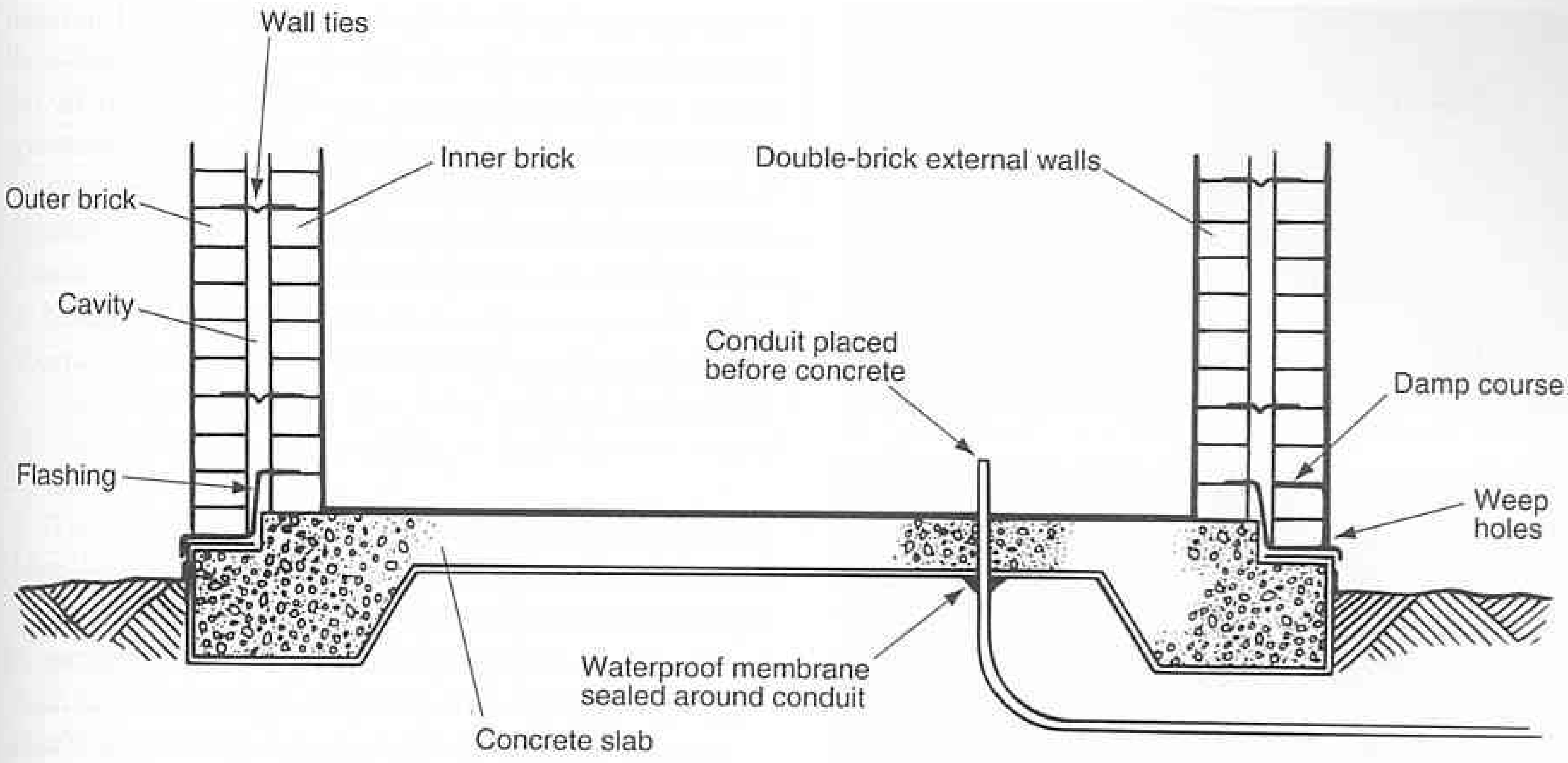


Fig. 6.34(b) *Concrete slab footings* WORKCOVER AUTHORITY OF NSW

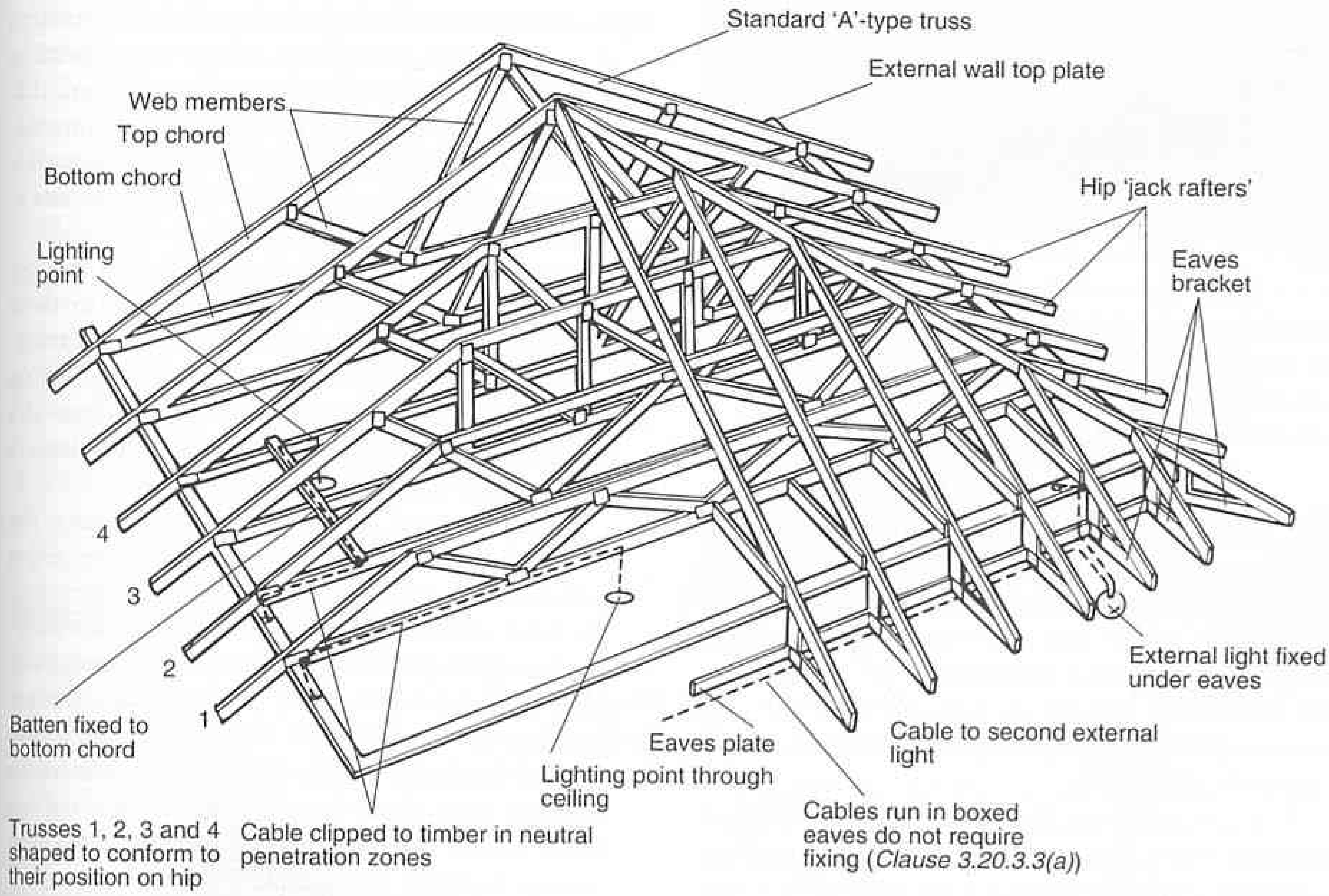
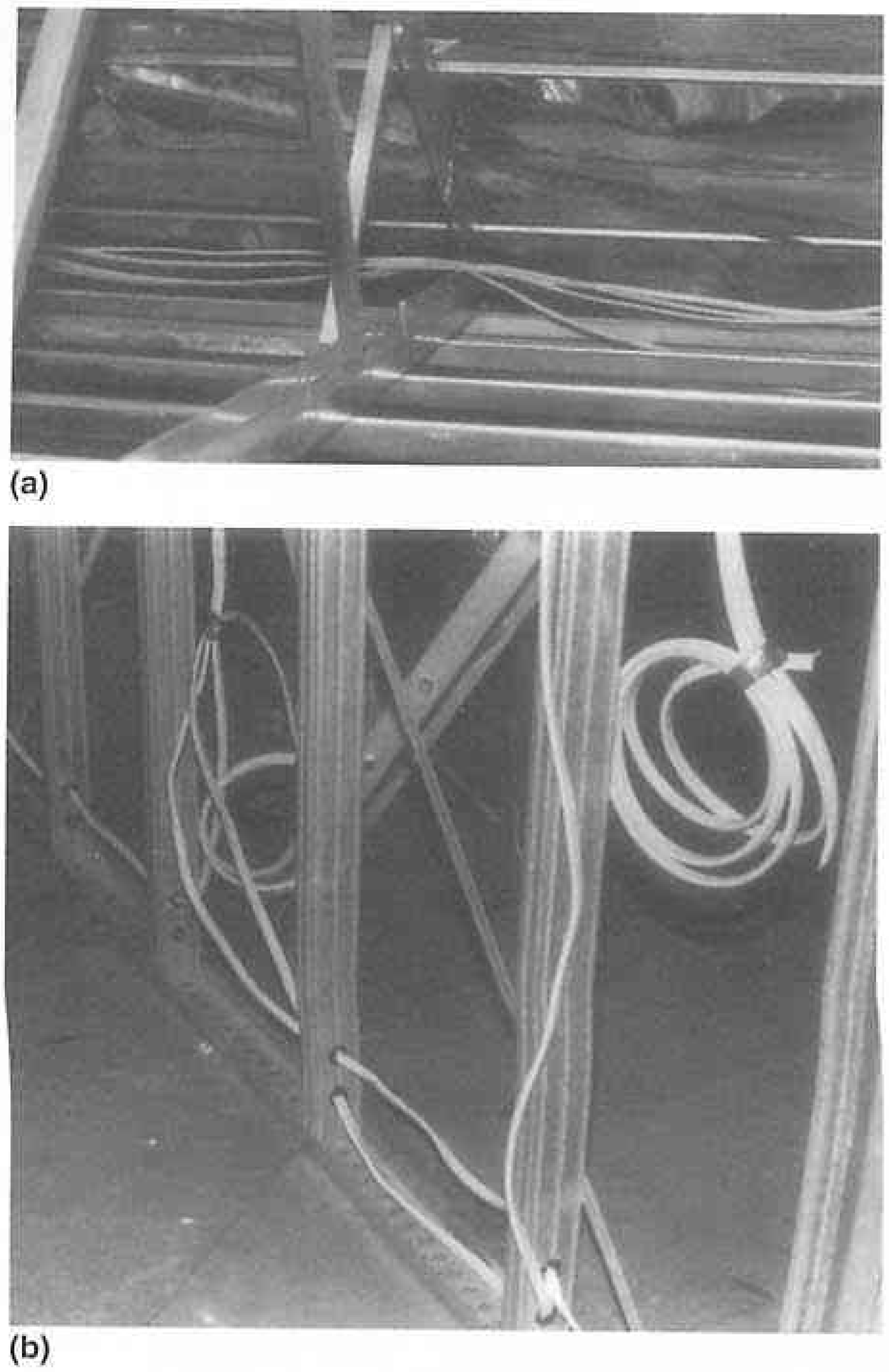


Fig. 6.35 *Constructional details of a roof using gang-nailed timber trusses* WORKCOVER AUTHORITY OF NSW

Prefabricated designs of buildings also are available. These vary with the manufacturer, but they use standard materials and many incorporate full provision for the electrical services within the prefabricated modules. The building terminology is the same as for other types of construction. In common with the alternative construction methods, prefabricated structures may be built on a concrete slab.

Another type of building structure is assembled from steel structural members. The entire wall-frame system, and if desired the roof framing (see Fig. 6.36(a)), are made from galvanised steel and supplied in kit form.



(a)

(b)

Fig. 6.36 *Wiring* **(a)** *in the ceiling and* **(b)** *in the internal wall of a prefabricated steel-framed building. Where cables pass through the steel frame, preformed smooth holes or bushes must be provided to prevent cable damage*

Plastic grommets are provided in studs for electrical and plumbing services (see Fig. 6.36(b)).

The electrician must know the structural details of a building to ensure that all wiring is hidden, except where this is a practical impossibility, for example in a solid feature wall exposed on both sides. In this case, alternative positions for equipment or accessories should be seriously considered.

It is also important that the wiring be installed in such a way that it does not interfere with other services, for example conduits crossing a space reserved for a ventilating duct. Care must also be exercised to see that any part of the structural design is not changed or made prone to damage, such as piercing a damp-proof barrier or a vermin-proof wire mesh, or running cables operating at a high temperature in contact with combustible material.

Where cables are run in the cavity of a brick or brick veneer wall in a position exposed to inclement weather (facing south in Australia and New Zealand), it is a good idea to arrange cabling so that it does not touch the brickwork of the outside wall, as this can often cause moisture to be carried across to the inside wall frame. An alternative is to provide a drip loop in the cable immediately before the cable enters the accessory.

AS 3000—1991 permits cables to be supported on wall ties, but in Victoria cables must be taken through every third stud to keep the cable away from the outside wall. This is considered to be a preferred method of installation where wall ties are to be used to support TPS cables.

Building operations

For all the above structural types the sequence of building operations in general follows a common course:

1. The site is cleared, levels are determined, and topsoil is removed where necessary to expose the solid foundations required for the support of footings. Provision for underground wiring may need to be made before footings or slabs are placed, as described in 2 below (refer to Fig. 6.34(b)).
2. Foundations and footings are then laid. The building is supported by the footings, which vary depending on the type and construction of the structure that they support. Figure 6.31 shows a continuous-poured concrete footing for brick wall support with attached piers for the support of the floor bearers at the brick walls.

   Suitably spaced isolated stumps or piers are used for bearer support between walls, similar to those shown in Figure 6.32. This illustration shows brick-veneer construction where a reinforced strip footing supports the outside brick wall and also provides support for brick piers on which the floor bearers rest.

   In both brick and brick-veneer structures, the cavity between walls and the area above the ceiling provide space and concealment for TPS cable runs, the brick-veneer cavity being much more accessible. Bearer and floor joists provide fixing for underfloor cable runs and may be used, provided that cables are installed to comply with *Clause 3.20.3.2* 'Cables likely to be disturbed' (see Fig. 6.32(b)). Underfloor wiring is more labour-intensive, due to more tedious fixing and the necessity to avoid possible mechanical damage to cables, for example if the space is used as a storage area.

   For slab-on-ground construction, shown in Figures 6.34(a) and (b), the slab doubles both as the footing to support the building and as the floor of the building, this being the most popular type. Independent slab construction may be used as a suspended reinforced slab for an upper-storey floor or a bathroom floor. Sometimes a ground-floor slab is poured between walls for slab-on-ground construction.

In most jobs for single residences, in order to save labour and material costs the wiring is kept out of the slab. If this is not practicable, the wiring system within the slab must be one that provides mechanical protection, for example wiring in conduit (see Chapter 9). MIMS underfloor heating cable is sometimes installed in the slab, as described in Chapter 21, Volume 2.

Note that in Figure 6.34(b) an elbow shown in the original diagram has been replaced by a large-radius bend in the conduit, to facilitate drawing of cables.

3. The interior floor and the building frame support in the form of bearers and floor joists are installed, and the building frame is erected. Floors of timber or particle-board sheeting are then laid. If there is any underfloor wiring, the most convenient time for this is before the laying of the floor.

   Upper-storey floors, having no stump or pier support, are supported by larger joists (sizes are determined by building codes), unless they are of the concrete suspended-slab type, which is rare in single residences.
4. The roof is installed. At this stage, with ceiling joists and battens (if used) in place, it is sometimes convenient to install the wiring well before the ceilings or inside wall claddings are fixed. However, some electricians prefer to install wiring after the ceilings have been fixed but before interior wall claddings have been installed, the ceiling surfaces being used as supports for TPS cables (see Fig. 8.8(a), Chapter 8). It is not uncommon for little or no wiring to be installed until 'lockup' stage of the building has been reached, especially in domestic dwellings.
5. Ceilings and interior wall claddings are fixed.

Multiple domestic dwellings

Terms are the same as for single units, except that multi-storeyed buildings may be of concrete slab construction where the slab, between floor levels, provides the ceiling of the unit below and the floor of the one above.

Industrial and commercial premises

Again, the building terminology used is standard for industrial and commercial buildings. Many concrete-slab-type buildings may have suspended ceilings in which the electrical and other services are installed, and it is also usual to provide vertical ducts for the various services. The electrical duct may house rising mains for supply to the different floors and other circuits, such as large submains to the plant room or the lift motor room.

Drilling and notching of structural timbers

Installation of the wiring in any timber wall or floor framing must not cause any structural damage or weaken the structure; for example, a drilled hole through a load-bearing member may not be acceptable to the builder or architect. AS 1684: *Timber Framing Code* and some other state codes restrict the drilling and notching of structural framing and flooring in residential, light commercial and industrial buildings, to ensure that a satisfactory degree of strength and durability is maintained in the structure. Some of the requirements of AS 1684 follow.

Housing, drilling or notching of studs

AS 1684, *Clause 4.3.3.1*, permits the housing or notching of the narrow face of studs to accept bracing and specifies maximum depths in a series of tables published in the standard. Housing or notching of the wider face to accept noggings and the like is limited to 10 mm maximum depth. This corresponds to the Queensland code (10 mm maximum for any purpose), which also specifies a depth of 20 mm maximum on the narrow face, again for any purpose.

However, the electrician will be more concerned with the drilling of studs through the wide face, and AS 1684 specifies that the width of the hole must not exceed one-quarter of the width of the face, as shown in Figure 6.37, and that the holes made in the same or adjacent faces of the stud must be spaced not less than twelve times the width of the stud apart. For example, if the stud size is 100 mm × 40 mm, the maximum hole size is 25 mm and holes must be a minimum of 480 mm apart.

There is no restriction in the standard for the drilling of top and bottom plates. However, local standards should be checked; for example, the Queensland code restricts hole diameter to 25 mm maximum, located anywhere (see Fig. 6.37).

Drilling and notching of floor framing

Restrictions on the drilling and notching of flooring timbers will less often concern the electrician. The restrictions are described in some detail in AS 1684 and will not be dealt with in depth here. If the electrician should be required to drill or notch flooring timbers, the builder or architect may need to be consulted. Alternatively, the Australian Standard, or the code applicable in the area in which the work is being done, must be studied. Figure 6.37 shows some restrictions on the drilling and positioning of holes in a flooring joist or bearer, where holes do not exceed one-eighth of member depth or 25 mm.

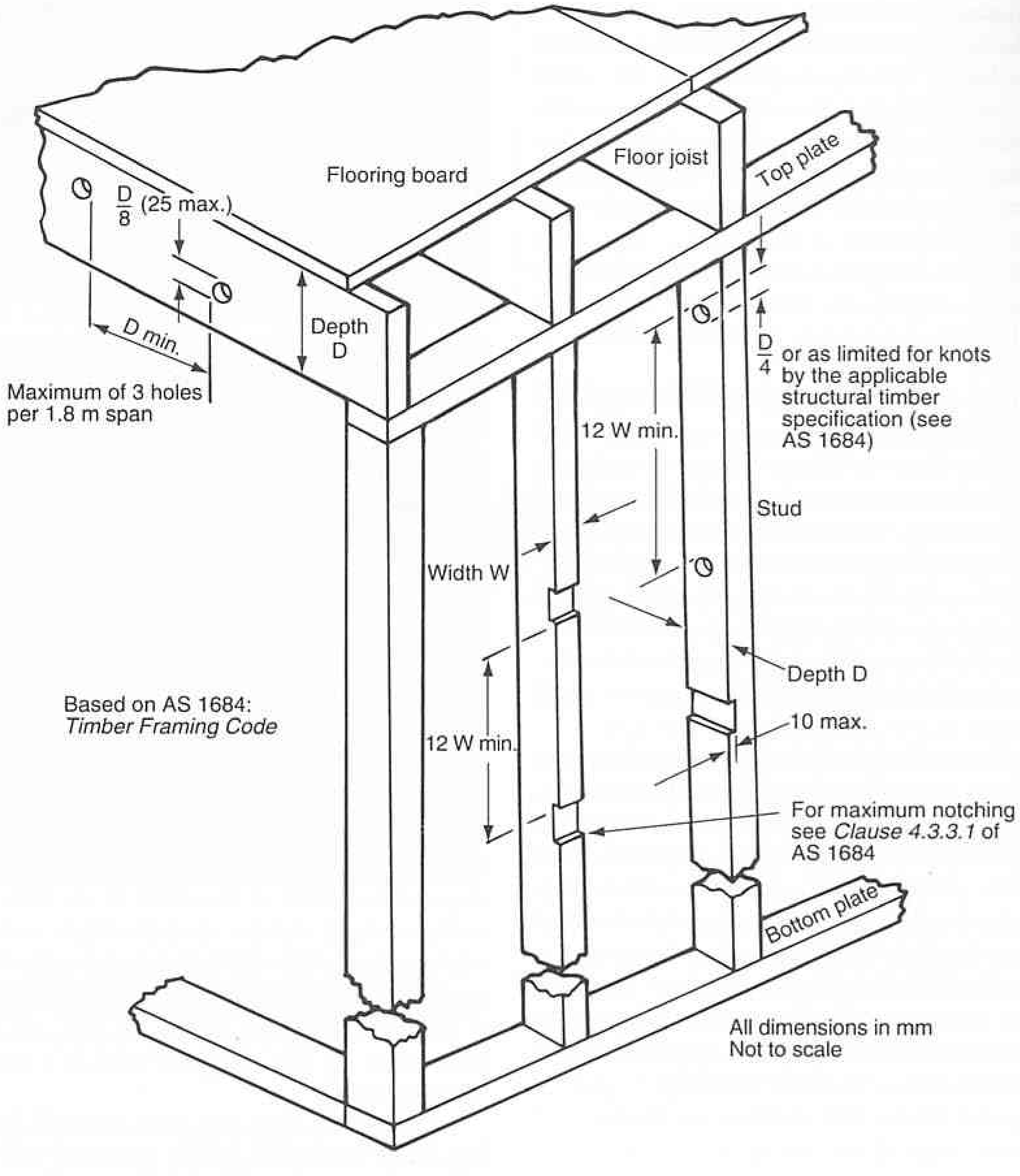


Fig. 6.37 *Notching and drilling studs, and drilling flooring joists and bearers*

6.7 Plans and standard symbols

Before the commencement of any electrical installation work, some form of wiring layout plan and a list of required materials must be prepared.

In the introduction to this chapter, it is suggested that for a simple installation such as an additional light point or general-purpose outlet (GPO) both the wiring layout and the associated job materials will probably be retained in the memory of the practising electrician. An experienced electrical contractor with a truck or van well stocked with a comprehensive range of materials will often go to a small job and be able to complete it with the materials at hand. However, on larger installations it will be necessary to have detailed materials lists, specifications and appliance schedules prepared, and on complex installations these may be issued to the contractor by the builder or developer.

The preparation of plans, schedules and specifications is the duty of the architect or design engineer, who must express through these drawings, schedules and specifications exactly what is required of the various tradespersons involved in the job. These documents also provide the basis for the contractual requirements to be fulfilled in the construction, and are the basis for estimates. They include scale drawings and written descriptions that state precisely what is required by the owner, architect or supervising engineer.

On large projects there will be many engineering consultants for specialties such as lighting, heating, ventilating, air conditioning, lifts and communications cabling. All of these specialist consultants will produce plans and specifications for their own specialty, which will be incorporated into the overall specifications. It is also usual for separate contracts to be let to specialist firms for installations and services, such as lifts or air conditioners, but the electrical contractor is usually involved in the provision of supply feeds for them. The electrician must consult and work in with these other contractors when planning the wiring layout.

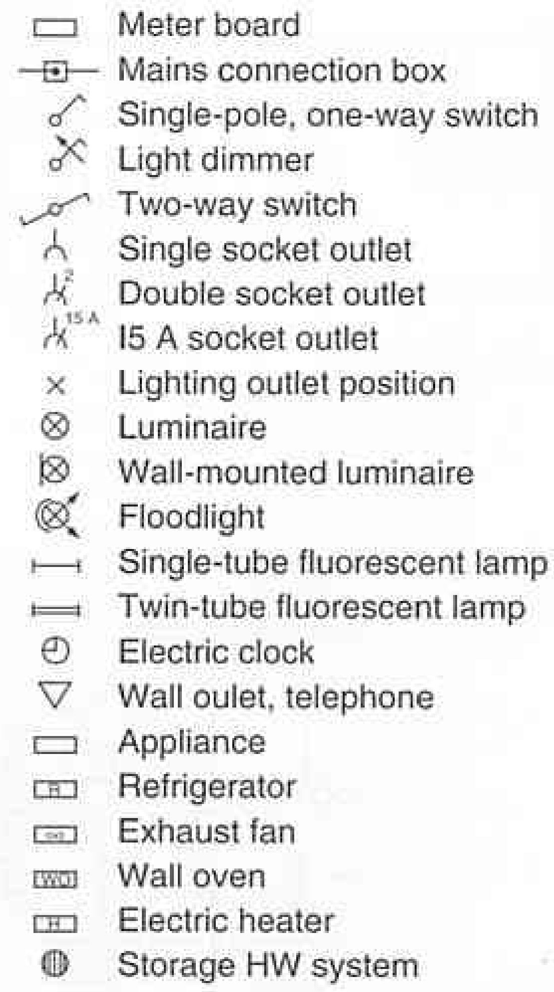
The electrical plan is the architect's or engineer's floor plan, with outlets, luminaires and control devices marked in at their required locations using standard symbols. These appear on the general plan for small jobs; but as the size of the job or its complexity increases, it is customary to draw a special plan for each trade. This separate electrical plan utilises the architect's floor plan, but only the structural details or items of equipment that are relevant to the electrical installation are shown. The positions of all electrical outlets and appliance positions are indicated on the plan using standard symbols, and the plan usually includes the routes for main cables such as feeders and rising mains, together with the locations of the switchroom, switchboards, distribution boards, control centres and the like.

There will be at least one separate plan for each floor of a large building; and, if warranted, there are further part plans or subdivisions of the whole plan. Note that, although major cable routes are usually indicated, the layout of subcircuit wiring for power, light, appliances on separate circuits and the submains' feed is usually the responsibility of the electrician on the job.

The electrical trade student or electrical tradesperson will have studied and practised electrical layout drawings and circuit diagrams in the electrical trades course. This subject is well covered at trade level in Chapters 17 and 18 of *Electrical Principles for Electrical Trades* (4th edn, 1995) by RJ Jennison. This book is part of the McGraw-Hill Australian Series in Electrical Technology, and cross-reference should be made to Jennison's text when studying this chapter. Another useful reference is a Standards Australia publication, HB3: *Electrical and Electronic Drawing Practice for Students* (1996).

On jobs such as a small factory or domestic residence, there might be only a floor plan and a list or schedule of appliances and luminaires. It would be left to the electrician to devise a working procedure and layout plan, including switchboard positions, number of circuits, subcircuit wiring and mounting methods for appliances. In addition, consideration would have to be given to cable sizes and types of protection to comply with AS 3000, the local service rules and any other codes. The routes to be taken for the consumer's mains and any submains would also have to be selected by the electrician on the job.

Standard symbols used on electrical plans are those of AS 1102, *Part 8*, 'Location symbols, power supply systems and electrical services for buildings and sites'. The Australian Standard symbols conform to those internationally agreed on by the International Electrotechnical Commission (IEC), with only a few exceptions, in which case alternative symbols are shown. Some symbols are shown in Figure 6.38, but the serious student should obtain a copy of the above-mentioned standard. Note that the symbols illustrated are for use on location plans and diagrams, not on circuit diagrams.



For a complete list of standard symbols used in electrical plans the reader should refer to AS 1102.8—1986: *Symbols for Location Diagrams.*

Fig. 6.38 *Legend for Figs 6.39, 6.40, 6.43(a) and 6.46*

Symbols are shown employed as location symbols in the domestic installation of Figure 6.39, and in the electrical plan of light and power for a small canteen in Figure 6.40. Note that the latter drawing is intended to be read in conjunction with a separate specification and that reference must also be made to related drawings.

The wiring layout, and hence the material required on a project, will be affected by the building structural scheme and, as mentioned earlier, by other services. Related electrical drawings may show, for example, the details for the connection and installation of some appliances. The electrician must be alert to the possibility that specified installation or fixing requirements, some of a non-standard nature, could necessitate the purchase of extra materials or possibly special materials. This would usually involve increased labour costs.

Figure 6.41 shows fan suspension details or a carpentry workshop, and it is easily seen from this drawing that the electrical contractor would be required to provide extra materials and would need to allow for increased labour costs for installation of the fans.

Related drawings must always be consulted when

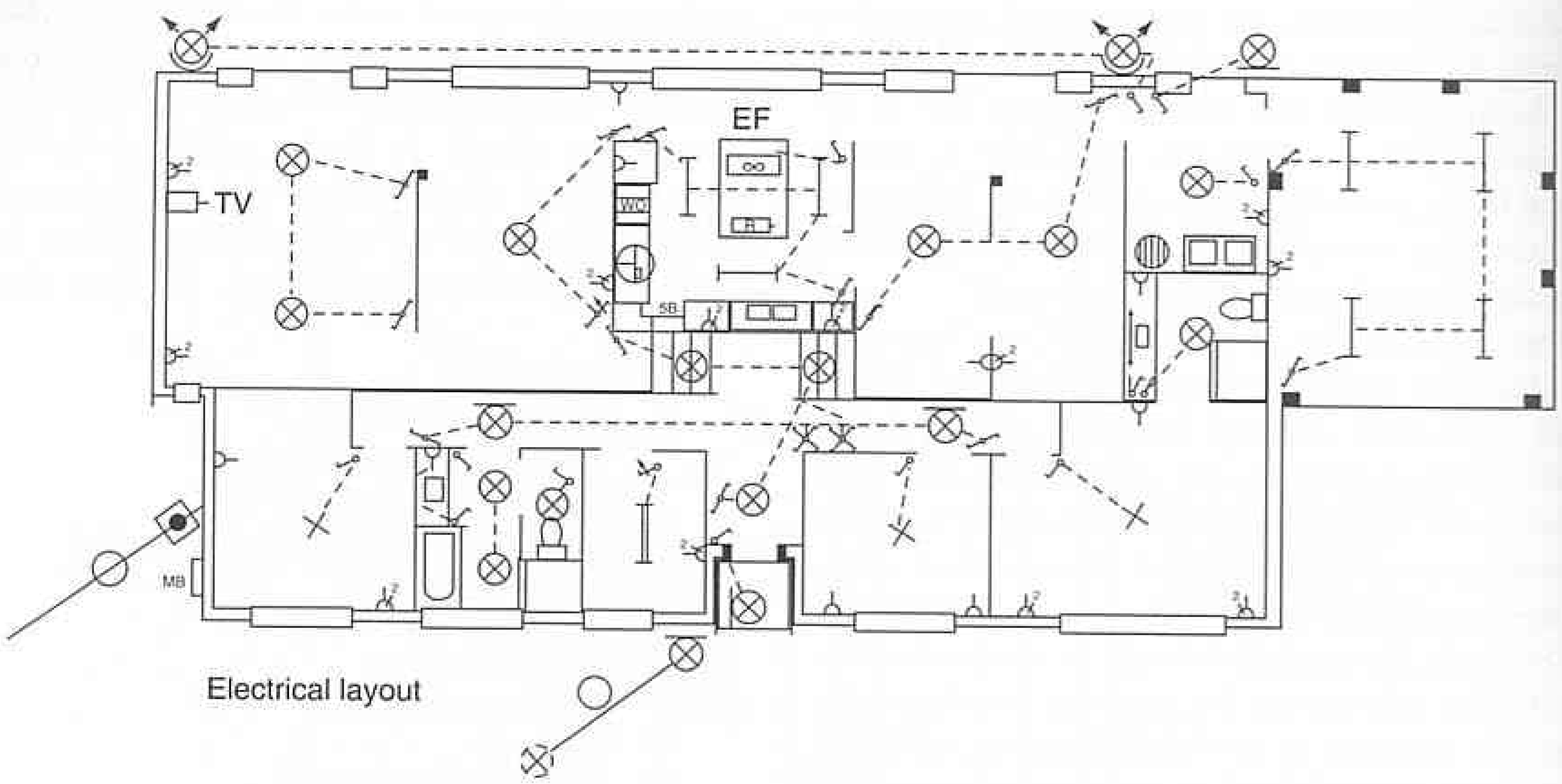


Fig. 6.39 *Floor plan showing the location of lighting and power outlets in a domestic installation*

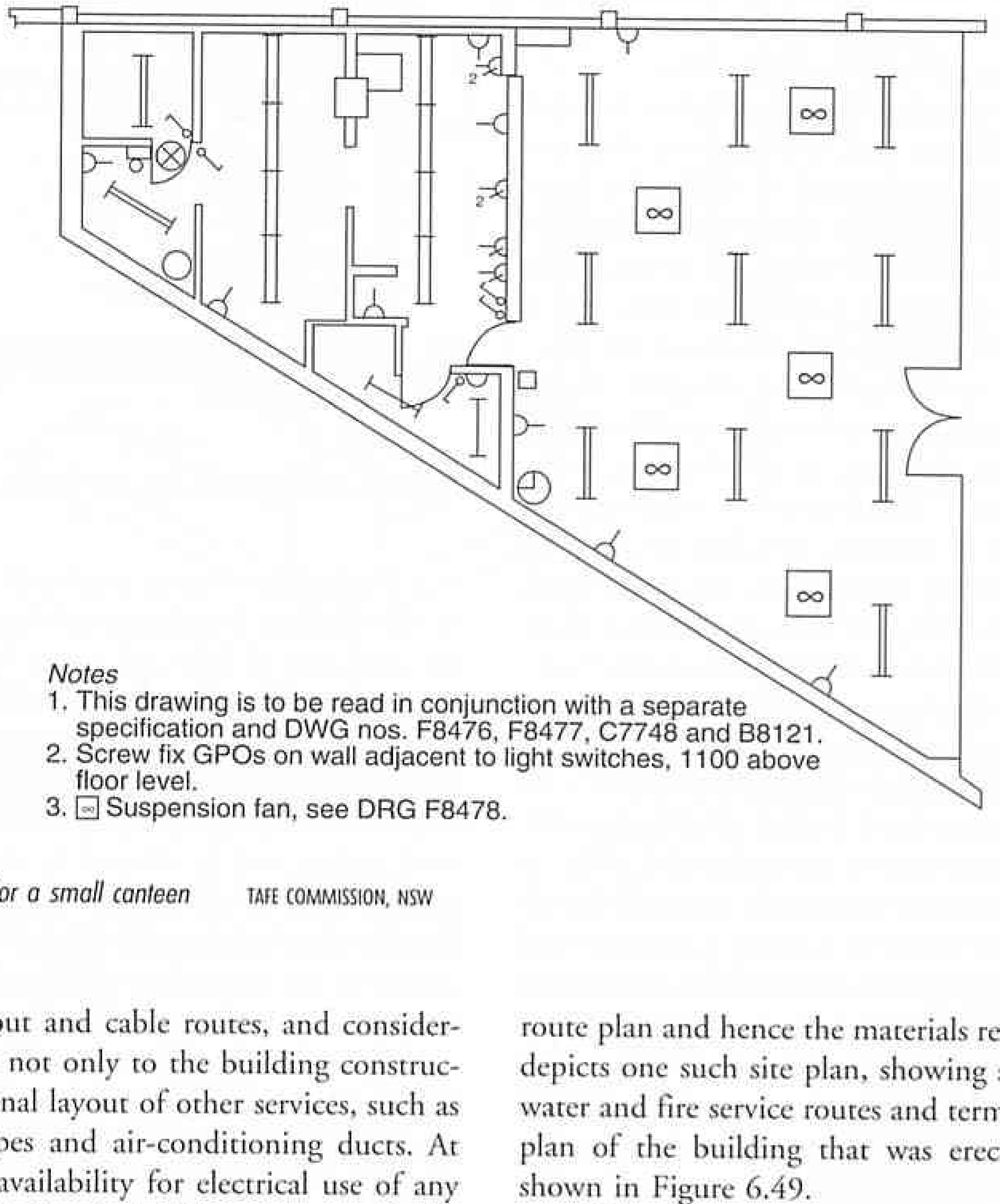


Fig. 6.40 *Electrical plan for a small canteen* TAFE COMMISSION, NSW

deciding wiring layout and cable routes, and consideration must be given not only to the building construction but to the internal layout of other services, such as plumbing, waste pipes and air-conditioning ducts. At the same time, the availability for electrical use of any ducts or wells provided in the building structure should be checked.

The site plan must also be consulted when considering the route of the supply service line, especially if it is an underground feed, as the layout of other services such as sewer, drains and water supply may affect the route plan and hence the materials required. Figure 6.42 depicts one such site plan, showing sewer, water, storm water and fire service routes and terminations. The floor plan of the building that was erected on this site is shown in Figure 6.49.

If the site is not level, the ground contours will be shown on the site plan, and in this case it becomes necessary to check slope and other irregularities with regard to their effect on the cable route or installation method. This applies especially where ground clearance under aerial cables is a consideration.

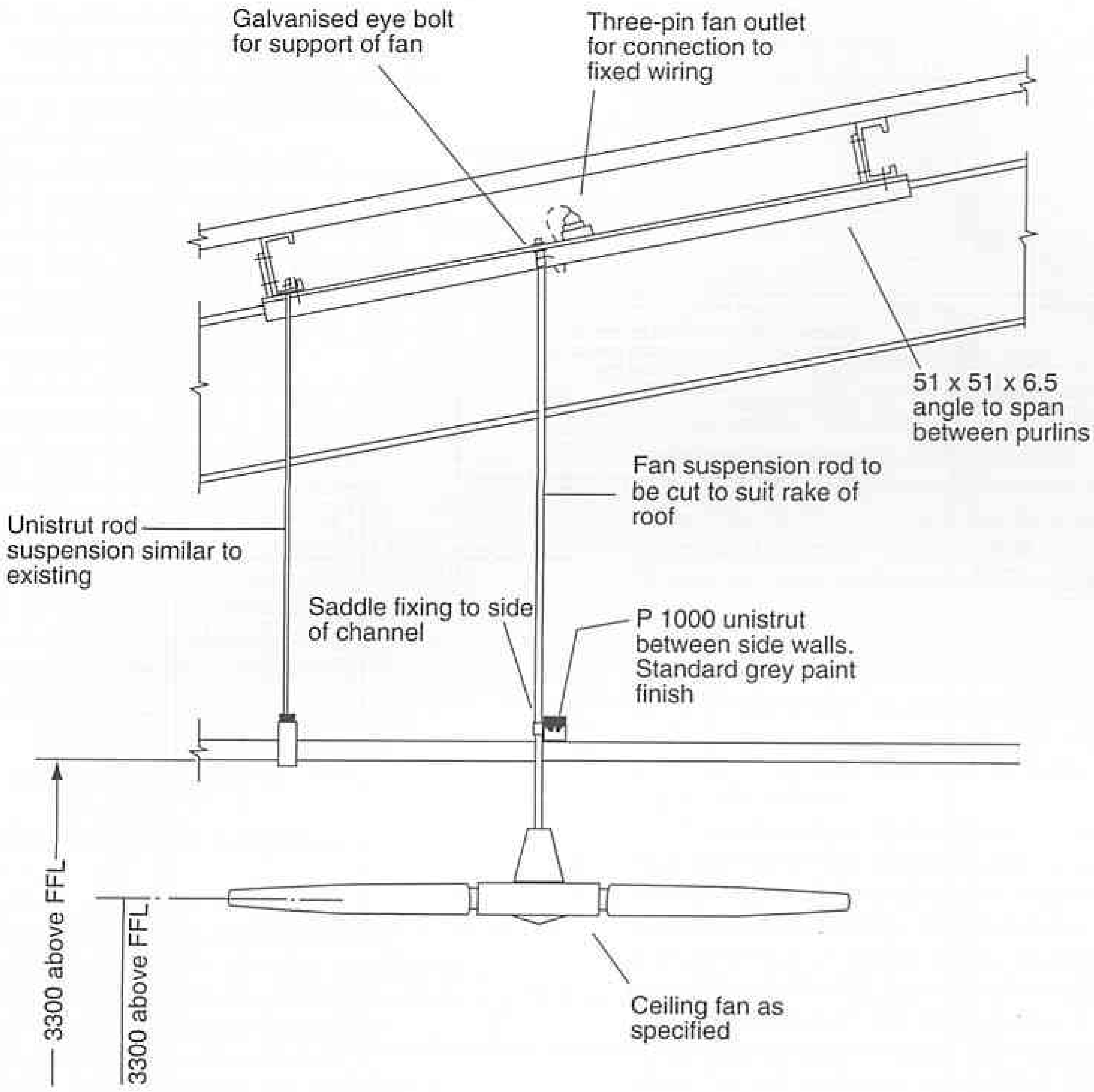


Fig. 6.41 *Fan suspension details* TAFE COMMISSION, NSW

6.8 Electrical specifications and schedules

Specifications

An electrical specification must fully inform the reader in specific terms of all the details of the installation as required by the owner, architect or consulting engineer. Its clauses should include information on the types of wiring and wiring methods to be employed, luminaires, types of accessories, number of circuits and the type of circuit protection needed. In addition, reference may be made to specific codes, rules and regulations to be observed and to the supply and distribution system for the job, including switchboard positions and sites.

The specification must contain full and detailed coverage on all aspects of the work. In addition, it must cover the conditions of contract and other legal provisions not directly connected with the wiring work. This coverage is necessary because the specification, together with supplementary plans and schedules, furnishes installation details and is the basis for estimates and tenders, which are legally binding.

The main objective of sections 6.8–6.10 of this chapter lies in the preparation of a materials list for a small job. However, it is thought that an electrical student should possess some background knowledge of the scope and extent of specifications that basically apply to all work. This is despite the fact that in the case of simpler jobs provisions are curtailed or omitted and in many cases simply implied, as will be seen later.

For the foregoing reasons, typical 'model clauses' are shown below, being those recommended by the Electricity Supply Association of Australia. This is not a specification but a list of clauses indicating the **scope** for inclusions within a specification.

Model clauses for electrical specifications

Introduction

Technical clauses for inclusion in the electrical installation specification for any type of premises are set out hereunder, together with relevant notes for guidance.

The specification writer should insert clauses indicating the applicable conditions of contract. These should include terms of payment, indemnity, liquidated damages, maintenance

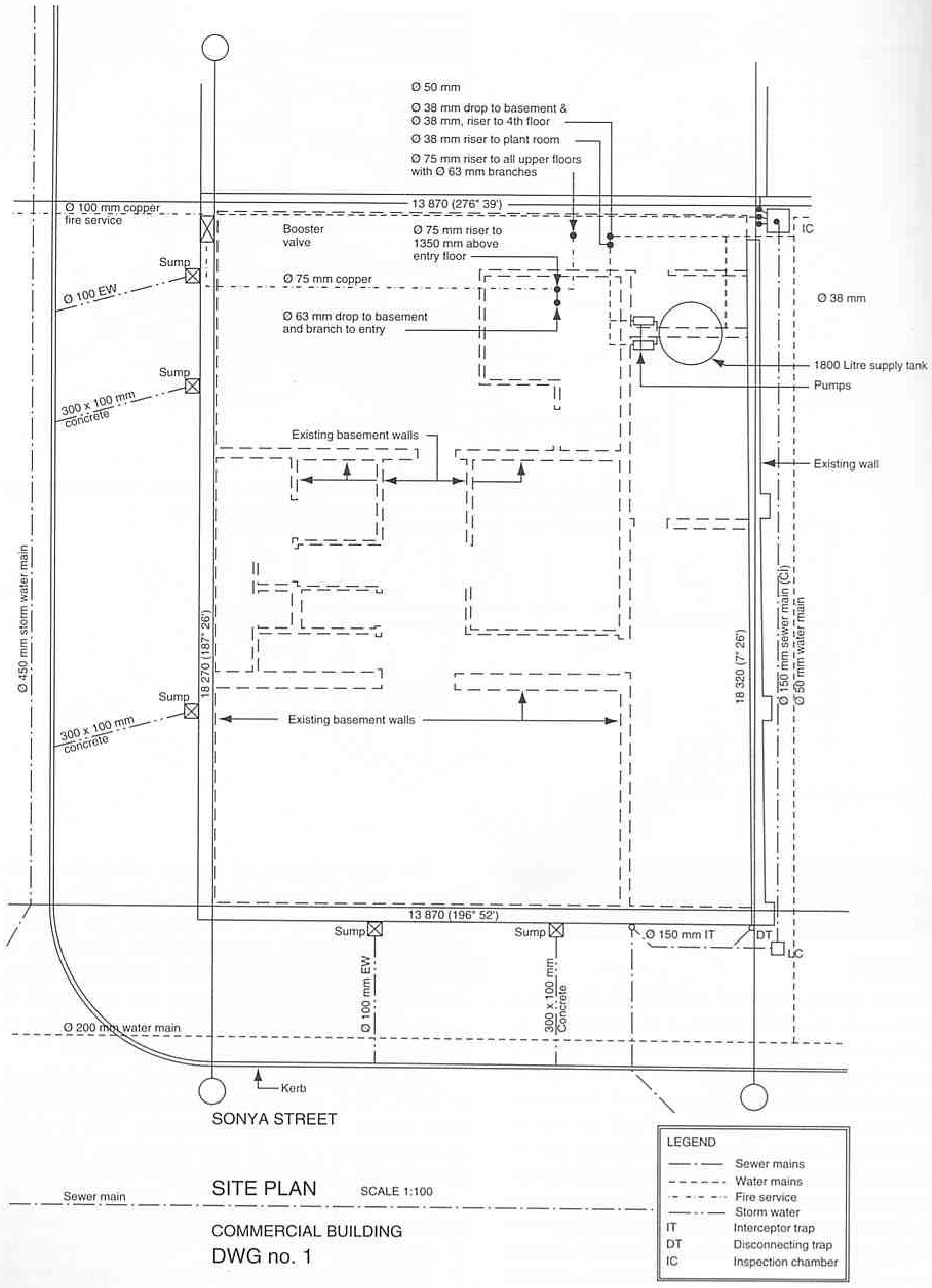


Fig. 6.42 *Typical site plan* TAFE COMMISSION, NSW

period, etc. Clauses relating to alterations and additions, making good damage, extending of guarantees, commencing and completion dates, should also be included in the general clauses preceding the technical section.

Drawings should be provided with the specification and either a schedule or schedules shown on the drawings or appended to the specification listing the types of lighting fittings and other appliances or apparatus to be supplied by the contractor or indicating how else they are to be provided for the installation.

It is essential that the listing of appliances be accurate and complete with full details of any control equipment supplied with the respective appliances, together with the total electrical loading or kW rating of each appliance. The addition of appliances, particularly those of high electrical loading, during the course of the contract could lead to mains cables, submains cables and switchboards becoming inadequate and requiring costly alterations before the initial installation has been completed.

Specification for electrical installation

1. Scope

The work to be carried out under this specification shall (except as otherwise herein specified) include the supply, complete installation, testing and with the appended *, drawing(s) no(s), + and the ++ of all materials, fittings and apparatus required by the terms of this specification to be performed by the contractor at the premises known as ** and herein referred to as 'the site'.

* Insert 'schedules' if appended to specification.
\+ Insert drawing(s) number(s).
++ Insert title of contract conditions and whether attached or address where it can be viewed.
** Insert name and address of premises.

2. Description and extent of work

The work to be performed under this contract shall include the complete electrical installation in the premises shown on the drawing(s) from * as referred to in Clause 7 (System of supply).

It shall be the responsibility of the firm or persons submitting a tender for the work to visit the site with the object of obtaining a full understanding of the requirements of the work covered by this specification.

* The energy distributor should be consulted during the early planning stages as to the availability and type of electricity supply desired and/or able to be made available for the premises and the following applicable wording inserted:

(a) The point of attachment of the overhead service for premises.
(b) The point of entry and termination of the underground service for the premises.
(c) The location of the substation for the premises. (See also section relating to electrical substations.)

3. Regulations

The whole of the work performed by the contractor, the materials used and the complete installation shall strictly comply with the *SAA Wiring Rules* or, in Victoria, the State Electricity Commission of Victoria Wiring Regulations, as applicable and the requirements of the supply authority and any other authority having jurisdiction over this particular installation.

4. General

Details as to the position of the main switchboard, distribution boards, etc. (if any) and particulars of lighting outlets, power outlets (which term shall include general-purpose outlets and the termination of wiring for attachment to fixed consuming devices, etc.) and switching points to be installed, together with details of lighting fittings and other appliances are set out in the annexed drawing(s)*.

The position of the respective parts of the installation shall be generally in accordance with the positions shown on the drawing(s), but if sufficient information is not provided, the exact location of any such parts shall be marked at the site by the architect.

Notwithstanding the foregoing, the contractor shall not rely on the drawing(s) for the exact determination of the positions of outlets for the connection of appliances. Particularly for large appliances such as electric ranges, motors, etc., the contractor shall verify the dimensions of the respective appliances and the positions at which their terminal boxes, controls, etc. will be located when the said appliances are installed. The locations of the respective outlets shall be finally determined so as to ensure short, neat and satisfactory connections from the outlets to the terminal boxes, controls, etc.

* Insert 'and schedules' if appended.

5. Supply of fittings and apparatus supplied by contractors

The contractor shall supply and deliver, as well as install (if so required) all lighting fittings and apparatus listed in the schedules.

The said lighting fittings, apparatus, etc. shall be generally in accordance with the respective descriptions set out in the schedule and shall be to the approval of the architect.

All lighting fittings and apparatus required to be supplied and installed by the contractor shall, as part of the finished installation, be handed over in good condition. The contractor shall be responsible for the replacement at his own cost of any lighting equipment which by reasons of work or blemish (whether caused by the contractor or incurred by other means) is rejected by the architect.

6. Fittings, appliances, apparatus, etc. supplied by others

The contractor is **NOT required** under the contract to supply lighting fittings, appliances, apparatus, etc. which are listed in the schedules as being supplied by others, but shall install them (unless otherwise specified herein).

The contractor shall, however, supply such fittings, accessories, etc. which are not normally sold as component parts of such articles. The contractor shall be responsible for the cleaning, to the satisfaction of the architect, of all lighting fittings, lamps, etc. before erection.

The contractor shall (unless otherwise specified herein) supply all other fittings, accessories, plugs, bolts, screws, small ironwork fixing devices, brackets, etc. and material for the full and proper performance of the work and shall carry out the installation and erection of wiring, main switchboard, distribution boards (if any), lighting fittings, lamps and other electrical appliances, whether supplied by others or himself, and complete the whole of the electrical installation in accordance with this specification to the satisfaction of the architect.

Note:

(a) Where certain appliances, etc. will be supplied by the contractor or by others, but installed in position or built in by others, separate clauses should be included to indicate that the contractor will still be required to carry out the electrical installation work.

(b) Where certain sections of the installation such as mechanical plant, air-conditioning plant, lifts, etc. will be installed by others with their associated electrical installation work, separate clauses should indicate the work, if any, to be carried out by the contractor. This should include the supply, installation and connection of submains cables to a plant or lift control board being supplied and erected in position by others.

7. System of supply

The system of supply to the premises will be *.

The premises will be supplied by means of an + terminating at a point on **, the approximate position of which is shown on the drawing(s); the exact position shall be determined on site.

Metering of supply will be carried out at ++ and shall be so arranged to provide for the following tariff(s): *+.

The whole of the electrical installation shall be carried out in accordance with the regulations with respect to the **+ system of earthing.

* The energy distributor will indicate the system of supply, e.g. 240/415 volts, three-phase, four-wire, 50 Hz ac.

\+ Dependent upon underground or overhead supply.

** This should be completed to suit the energy distributor made available, e.g.

(a) 'On the wall of the main switchboard room' for an underground supply; or

(b) 'On the building' for an overhead supply; or

(c) Suitable wording given by the energy distributor if a substation is required.

++ Indicating metering location, e.g. main switchboard.

*+ The energy distributor will indicate the tariff(s) applicable.

**+ The energy distributor will indicate the system of earthing which is applicable, i.e.:

(a) multiple earthed neutral system; or

(b) direct earthing system; or

(c) voltage-operated earth-leakage circuit breaker system.

8. System of wiring

(a) General

The system of wiring to be installed in this installation shall, in general, include any of the systems approved of by the wiring regulations of *SAA Wiring Rules*, as applicable, and the requirements of the energy distributor.

All wiring shall be concealed wherever practicable.

Note: For large industrial or commercial installations, this clause would be expanded so that tenderers are required to offer their proposed systems of wiring for various designated locations or areas or are required to comply with various systems nominated by the specification writer for particular locations.

(b) Number of outlets on final subcircuit

The number of general-purpose outlets or lighting points installed on each final subcircuit shall be as set out in the attached schedule.

General-purpose outlets in the kitchen of domestic premises shall be divided between at least two final subcircuits.

(c) Mains and submains cables

The contractor shall supply and install all mains and submains cables required for the installation.

Unless otherwise specified herein the size of mains and submains cables for commercial or industrial installations shall be calculated to provide for the total electrical loading of the installation specified herein and shown on the drawing(s), plus provisions of 25 per cent for additional future electrical loading.

Note: Should the installation be one stage only of known future stages, this clause should be amended so that the sizes of the mains and/or submains cables include provision for the future expansion, plus provision for a further 25 per cent.

9. Accessories, approval of materials

The contractor shall as required by the architect submit for approval samples of the accessories, fittings, materials, etc. which he proposes to use and such samples may be retained by the architect until the work is taken over. The accessories, fittings, materials, etc. supplied and used shall correspond with the samples approved, but the approval of the architect shall not relieve the contractor of his obligations to supply accessories, fittings, materials, etc. of the best quality, type and performance for their particular function in the installation.

10. Main switchboard and distribution boards

The contractor shall be responsible for the manufacture, supply, delivery and erection of the main switchboard and distribution boards (if any) for the installation, including all fastenings and work of erection incidental thereto, to the approval of the architect.

Unless a switchroom or enclosure is provided, open-panel switchboards shall not be installed in open areas of commercial or industrial premises. All such switchboards shall be completely enclosed within approved sheet steel cabinets fitted with a hinged door or doors operated by locking-type lever handles.

For all commercial and industrial installations, the tenderer shall submit for approval dimensioned sketches and full details of the proposed layouts of the main switchboard and distribution boards (if any), showing the make and type of apparatus he proposes to install. The details shall include the proposed method of legible and permanent labelling being provided for main switch(es), voltages, fuses, apparatus, etc.

Typed legends, enclosed in approved transparent envelopes, listing each fuse (or circuit breaker) number and the outlets controlled therefrom, together with their locations in the premises, shall be supplied by the contractor. The legends shall be mounted in approved locations adjacent to the respective switchboards. The contractor shall ensure by carrying out appropriate tests that each fuse protects the corresponding outlets or points as listed.

Note: For larger industrial or commercial installations the costs of switchboards could vary considerably depending on the design, type and quality of the apparatus being offered. This, in turn, could affect the degree of electrical protection provided to the installation. For such installations, it would be desirable to:

(a) engage an electrical consultant to design the switchboards and write the necessary clause;
(b) engage an electrical consultant to design the switchboards and call separate tenders for their supply, this being covered by a prime cost item of the electrical installation specification; or
(c) allow a provisional sum in the electrical installation specification for the switchboards and negotiate the design, etc. later. This would enable all tenders to be on a common basis for the switchboards.

Compare the requirements of the foregoing model clauses for electrical specifications with those included in a general specification for a domestic residence supplied as a standard printed form, where the owner or builder fills in details in the spaces provided on the form. We quote:

'electrician . . . to provide . . . power outlets and . . . light outlets with control switches where required by owner. Connect to main supply in accordance with energy distributors' regulations . . .'.

Note here that appliances such as an electric range or hot-water system are not mentioned, and the whole operation is left to the electrician on the job in consultation with the builder and owner. The words 'in accordance with energy distributors' regulations' ensure that the local service rules and AS 3000 are observed. Also note that all service rules include a clause stating that the installation must comply with AS 3000.

Brief specifications may often be included with the layout plan for the electrical work (see Figs 6.43(a) and (b)). Observe that, although there is no separate specification, reference is made to the necessity of consulting other related drawings.

Installed appliances such as electric ranges, motors, air conditioners and hot-water systems are manufactured to comply with the appropriate Australian Standard specification, and the manufacturer is responsible for their compliance and performance. Their installation requirements, however, are included in the electrical specification. Separate specifications for equipment such as lifts, air-conditioning plant and any large plant and machinery are provided.

Main switchboards and sometimes distribution boards and control panels are other items in the installation that are often the subject of separate specifications. On small installations they may be bought in as a unit, and the only material required is that needed for connecting up. Some domestic and other small switchboards are assembled and wired by the contractor at the contractor's workshop, or even on the job, and in this case switchboard materials must be included in any materials list.

Large switchboards invariably require separate specifications and drawings (see Chapter 17, Volume 2). Figure 6.44 is a line diagram for additions to a distribution board.

Schedules

In all but the smallest jobs, the locations of outlets and appliances are marked on the plan, and the type of appliance is identified by the appropriate standard symbol and further identified by a location number. In addition, an electrical schedule is provided on most large jobs. This schedule supplements the specification with information applicable to individual outlets and appliances that, if included in the specification, would make it too cumbersome and hard to interpret.

To assist in the interpretation of the schedule, it is prepared as a tabulated list with column headings that vary with the type of installation. It usually contains information pertinent to plan identification number, power rating of outlets or appliances, types and makes of appliances or luminaires, mounting provisions, mounting heights and whether the electrician is responsible for the full installation or for the wiring only.

To assist in estimating, it is also usual to indicate the source of supply of appliances (proprietor or contractor), and if the appliance is a post-construction (PC) item, the amount to be allowed in the estimate is shown. Circuit arrangements or any special provisions necessary are also often added in a remarks column: for example, 'make circuit provisions for a kitchen ventilation fan, to be installed later' or 'provide a separate circuit for this appliance' or 'power outlets nos 4 to 15 inclusive are to

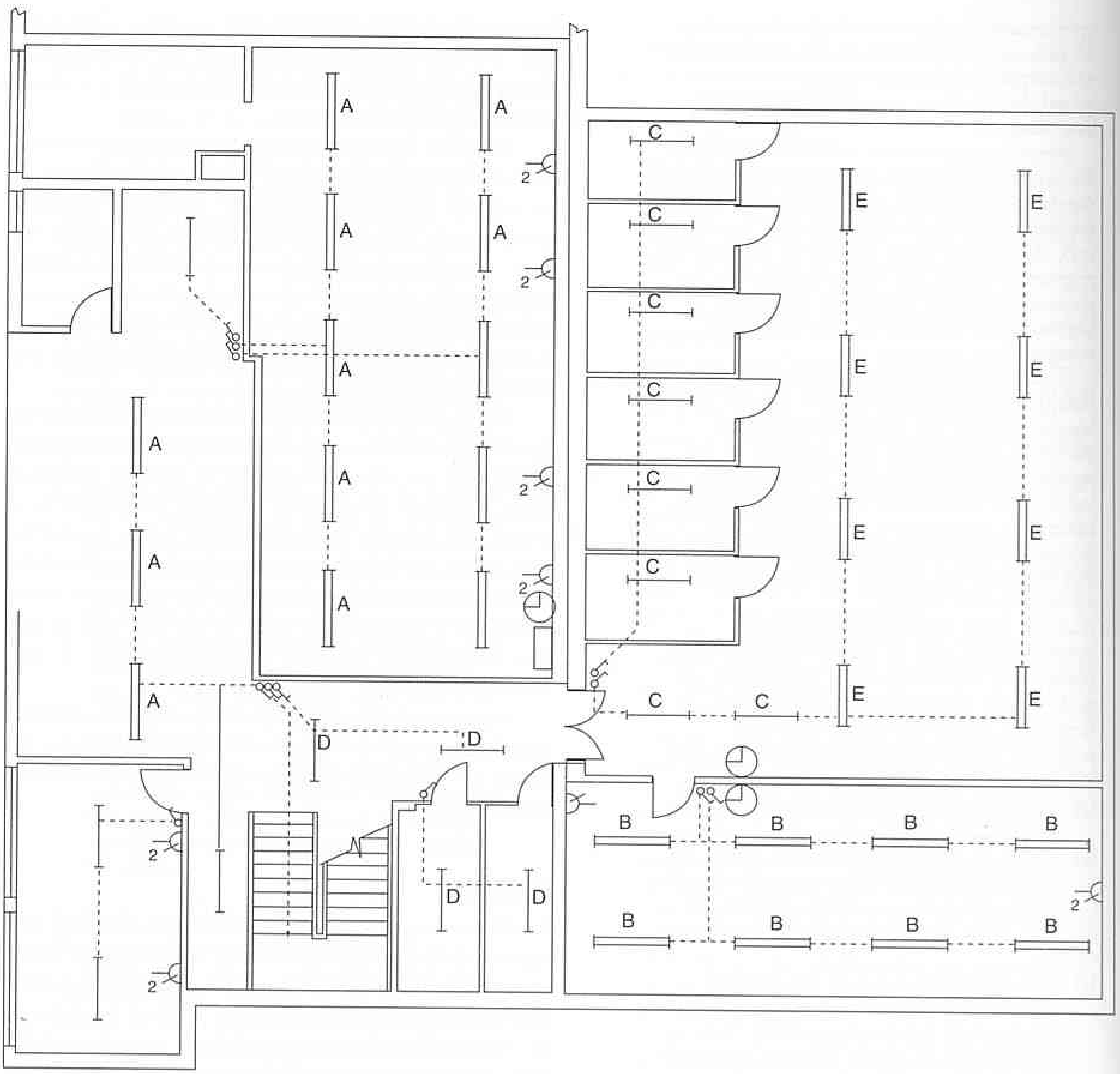


Fig. 6.43(a) *Layout plan for electrical work (light and power additions to storage area)* TAFE COMMISSION, NSW

be wired over five (5) circuits with not less than two (2) nor more than four (4) outlets on any one circuit'.

Figure 6.45 shows portions of a schedule of appliances for a domestic residence, and the plan for the associated installation is shown in Figure 6.46. The number in the second column of the schedule refers to the corresponding outlet number on the plan. Note the specific details given in columns 3 and 4 specifying the appliance type and make. Column 5 is provided for the allowance to be made in a tender or estimate for the PC items supplied. The power ratings are tabulated, the mountings specified and the supplier designated, and the remaining column indicates whether the contractor is responsible for the complete installation or for wiring only. An added remarks column would state any special provisions or other necessary particulars.

Any or all of the information contained in the schedule may be required in the compilation of a materials list.

Arrangements and layout of plans, specifications and schedules are flexible and vary with the size, type and complexity of the job. However, the electrical plan is the most standardised of the three and basically the three are necessary for any job. An example of a combined plan and specification is given in Figures 6.43(a) and (b).

An example of combined plan and schedule of lighting is given in Figure 6.47. This job involves the installation of an additional thirty-six lighting outlets with fluorescent luminaires. Details of the type of luminaire to be installed are given in the table in Figure 6.47, and their layout is shown on the lighting plan.

ELECTRICAL PART OF EXTENT OF WORK

- SUPPLY AND INSTALL LUMINAIRES, LIGHT SWITCHES, POWER OUTLETS AND SUB-DISTRIBUTION BOARD WHERE SHOWN AND AS SPECIFIED BELOW
- RELOCATE EXISTING LUMINAIRES AS SHOWN AND AS SPECIFIED BELOW
- NEW AND EXISTING LUMINAIRES

  TYPE A – 2 X 58 W, INDUSTRIAL, FLUORESCENT LUMINAIRE EQUAL TO 'GEC' CAT. NO. FN1560H/FN1566

  TYPE B – 2 X 58 W, FLUORESCENT LUMINAIRE WITH PRISMATIC DIFFUSER EQUAL TO 'GEC' CAT. NO. FN1560H/FN1586

  TYPE C – EXISTING 1 X 36 W, BATTEN, FLUORESCENT LUMINAIRE RELOCATE WHERE SHOWN

  TYPE D – EXISTING 1 X 36 W, BATTEN, FLUORESCENT LUMINAIRE TO REMAIN WHERE SHOWN

  TYPE E – EXISTING 2 X 36 W, BATTEN, FLUORESCENT LUMINAIRE RELOCATE WHERE SHOWN

  TYPE F – 2 x 36 W, BATTEN, FLUORESCENT LUMINAIRE EQUAL TO EXISTING TYPE E

  EXISTING LUMINAIRES NOT SHOWN TO REMAIN OR IN A RELOCATED POSITION SHALL BE REMOVED

  SCREW FIX TYPES A AND B LUMINAIRES TO WIRING CHANNEL EQUAL TO 'UNISTRUT' TYPE P2000 WHICH SHALL BE SUSPENDED 2900 MM ABOVE FLOOR LEVEL ON RIGID STEEL RODS. NUMBER OF RODS AND FIXING SHALL BE TO MANUFACTURER'S SPECIFICATION

  OTHER TYPES OF LUMINAIRES SHALL BE SCREW FIXED TO THE CEILING
- REDUNDANT LIGHT SWITCHES SHALL BE REMOVED AND RESULTING HOLES BLANKED OVER
- REPLACE EXISTING CIRCUIT BREAKER NO. 87 ON DISTRIBUTION BOARD, NO 13 (GROUND FLOOR) WITH A 3 POLE, 36 AMP, CIRCUIT BREAKER OF EQUAL MANUFACTURE AND INTERRUPTING CAPACITY
- SUPPLY AND INSTALL 4 X 7/1.04 MM + EARTH, T.P.I., CABLES IN RIGID PVC CONDUIT BETWEEN THE NEW CIRCUIT BREAKER NO. 87 AND THE NEW SUB-DISTRIBUTION BOARD
- THE NEW SUB-DISTRIBUTION BOARD SHALL BE EQUAL TO 'WESTINGHOUSE' CAT. NO. QC245DQ(100). THE BOARD SHALL BE COMPLETE WITH SIX, 16 AMP, SINGLE-POLE AND ONE, 20 AMP, THREE-POLE CIRCUIT BREAKERS EQUAL TO 'WESTINGHOUSE' QUICKLAG TYPE. WIRE NEW LIGHTING AND POWER FINAL SUB-CIRCUITS TO THE 15 AMP CIRCUIT BREAKERS AND THE EXISTING FINAL SUB-CIRCUIT PREVIOUSLY CONNECTED TO THE CIRCUIT BREAKER NO. 87 TO THE 20 AMP CIRCUIT BREAKER. LUMINAIRES NOT CONNECTED TO EXISTING LIGHTING CIRCUITS SHALL BE EVENLY DISTRIBUTED OVER THREE OF THE 15 AMP CIRCUIT BREAKERS PROVIDED
- SCREW FIX GENERAL-PURPOSE OUTLETS ON WALLS 120 MM ABOVE FLOOR LEVEL
- SUPPLY AND INSTALL SYNCHRONOUS, 300 MM DIAM., ELECTRIC CLOCKS EQUAL TO 'AUSTRALIAN TIME RECORDING' BREVETTE STYLE, SCREW FIX ON WALLS 2400 MM ABOVE FLOOR LEVEL WHERE SHOWN ON THE LAYOUT AND WIRE TO ADJACENT LIGHTING CIRCUITS.

NOTE: THIS DRAWING IS TO BE READ IN CONJUNCTION WITH DWGS NO. CB479 AND F8476. ALL DIMENSIONS ARE IN MILLIMETRES

Fig. 6.43(b) *Electrical specifications for the additions shown in Fig. 6.43(a) and included with plan drawing* TAFE COMMISSION, NSW

Separate specifications may be issued for the wiring installation to supply the luminaires and for the installation of any other equipment.

6.9 Interpretation of plans and specifications

To compile a materials list other than for a simple installation, the correct interpretation of the plans, specifications and schedules is of fundamental importance. The compiler must be familiar with the standard symbols of AS 1102.8 used in plans; any non-standard ones would be contained in a legend on the plan itself (see Fig. 6.47).

Despite the standards, there is still some lack of uniformity among architects and engineers with regard to the use of symbols; you must be wary of misinterpretation. For example, many existing plans contain the old symbol for a luminaire (▭), which could easily be confused, especially if wall-mounted, with the current Australian Standard symbol for a general appliance (□); so caution should be exercised when reading plans that may not be using current standard symbols.

The legend on a plan should always be checked to see that standard symbols are being used; but even when standard symbols are generally employed, care must be exercised. The use of alternative symbols is permissible and indeed often necessary to represent equipment not listed in the Australian Standard; for example, a two-tube fluorescent luminaire may be depicted as or 2. It is also possible that the symbol for an electric range (R) could be intended to represent a built-in refrigerator.

Be suspicious of each symbol until it has been positively identified; this is where cross-reference to the

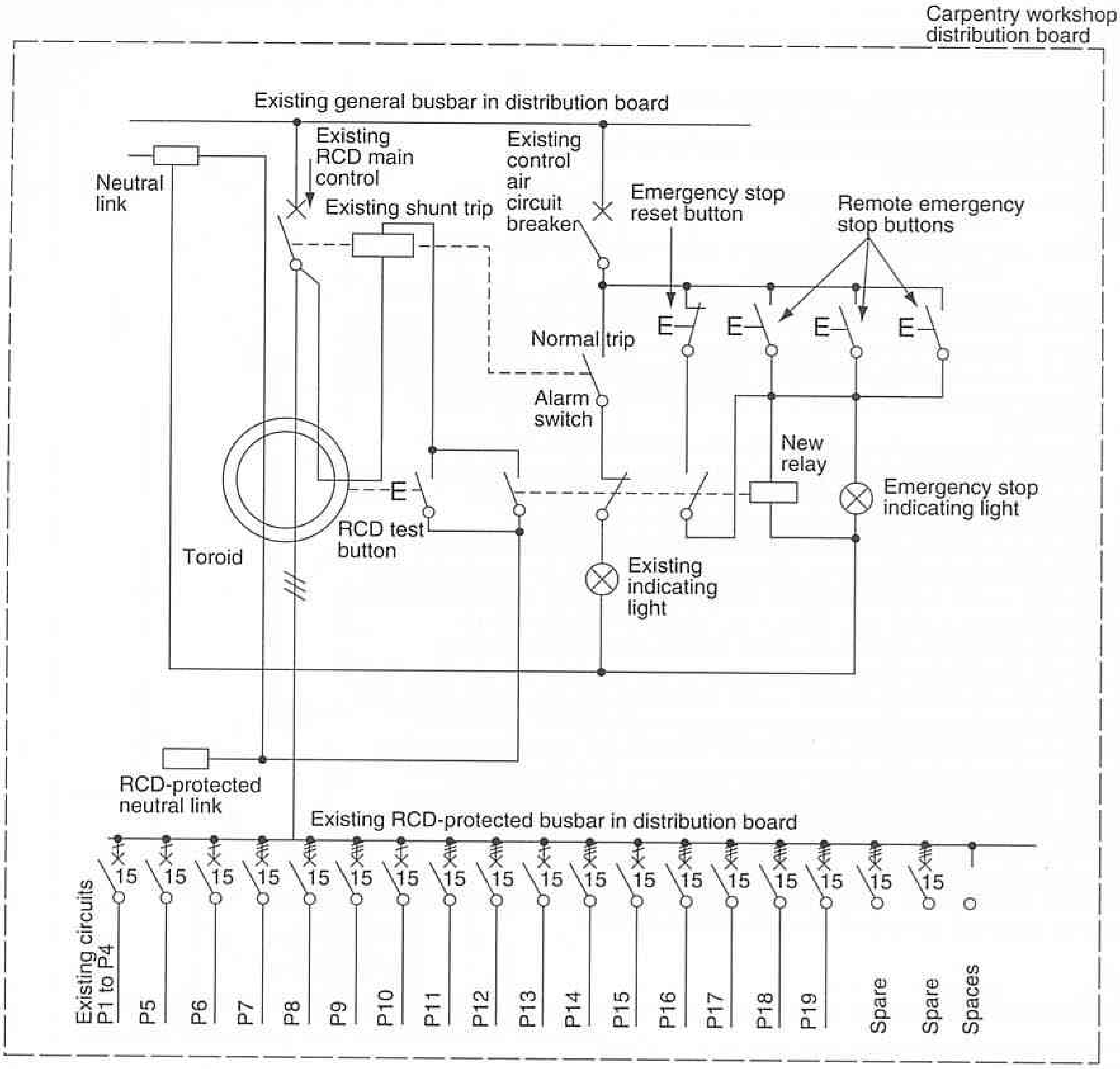


Fig. 6.44 *Single-line diagram of additions to a distribution board* TAFE COMMISSION, NSW

electrical schedule or specification may be necessary for checking purposes. AS 1102 series, published in fifteen separate parts, provides standard symbols for electrical drawings. Those of *Part 1102.8* are 'Location symbols electrical for building sites', and the standard shows three of many switch types as:

- single-pole
- double-pole
- time-delay.

Using a worn or copied plan, it would be easy to misinterpret the switch type, which could prove costly of both installation and materials.

A copy of the building plan usually shows only the approximate location of light and power outlets and appliances, and does not indicate cable routes or route lengths of circuits. For this reason, elevations and/or sections of a building structure must be studied to enable decisions to be made with regard to rising mains and submain routes, cable route lengths, whether above-ceiling space is available for wiring, and any other factors involved in the installation of wiring and equipment. Figure 6.48 is a section of a commercial building. Together with the floor plans, one of which is shown in Figure 6.49, and perhaps other sectional views of the building, this drawing would need to be consulted to enable planning of the manner in which the installation will be carried out. This would also enable a complete survey of materials requirements.

Before assessing cable route lengths and the positioning of outlets and equipment, the scale used should always be checked. One reliable method is to check the scale against the measurements shown on the drawing, but in checking it should be remembered that the drawing may have been photographically reduced. There may be more than one scale; however, there is usually a note on the drawing indicating the scales used. A check should be made to ascertain that the drawings comprise

APPENDIX A TO GENERAL SPECIFICATION FOR THE INSTALLATION OF ELECTRICAL WIRING IN DOMESTIC PREMISES

SCHEDULE OF APPLIANCES

Location	*No.*	*Appliance*	*Make*	*Allow $*$*	*Wattage*	*Mounting*	*Supply*	*Install*
Lighting								
Front gate	1	Garden lantern	Hi-lumen 3604	—	100	Concrete footing	P	C(W)
Carport	2	300 mm square diffuser	Candelor A/17	—	100	Ceiling	C	C
Carport	3	300 mm square diffuser	Candelor A/17	—	100	Ceiling	C	C
Carport	4	Fluorescent batten 1/36	Multiflux 7031	—	36	Ceiling	P	C
External	5	250 mm square diffuser	Candelor A/18	—	100	Eaves	C	C
External	6	250 mm square diffuser	Candelor A/18	—	100	Eaves	C	C
External	7	250 mm square diffuser	Candelor A/18	—	100	Eaves	C	C
External	8	250 mm square diffuser	Candelor A/18	—	100	Eaves	C	C
External	9	Adjustable bracket	Hi-lumen 3600	—	150	Fascia	P	C
External	10	Adjustable bracket	Hi-lumen 3600	—	150	Fascia	P	C
External	11	Adjustable bracket	Hi-lumen 3600	—	150	Fascia	P	C
External	12	250 mm square diffuser	Candelor A/18	—	100	Eaves	C	C
External	13	250 mm square diffuser	Candelor A/18	—	100	Eaves	C	C
Swimming pool	14	Underwater floodlight	Aqualite	—	100	Swimming pool	P	C
Linen press	36	Bulkhead	Candelor A30	—	60	Cupboard	P	C
Family room	37	Nightlight	Safetyglim	—	15	2100 mm	P	C
Passage	38	Round diffuser 10"	Hi-lumen 3603	—	60	Ceiling	C	C
Kitchen	39	Undercabinet downlight — shielded	Candelor A8	—	40	Beneath o/h cupboard	C	C
Kitchen	40	Undercabinet downlight — shielded	Candelor A8	—	40	Beneath o/h cupboard	C	C
Kitchen	41	2/36 W diffusing troffer	Hi-lumen 7033	—	2/36	Beneath o/h cupboard	P	C(W)
Kitchen	42	2/36 W diffusing troffer	Hi-lumen 7033	—	2/36	Beneath o/h cupboard	P	C(W)
Lounge room	43	200 mm recessed downlight	Multiflux 6030	—	100	Ceiling	C	C
Lounge room	44	200 mm recessed downlight	Multiflux 6030	—	100	Ceiling	C	C
Lounge room	45	200 mm recessed downlight	Multiflux 6030	—	100	Ceiling	C	C
Lounge room	46	200 mm recessed downlight	Multiflux 6030	—	100	Ceiling	C	C
Lounge room	47	Fluorescent batten 4/36	Multiflux 7031	—	36	Ceiling	P	C
Maximum mark-up 10% on net cost.			P = Proprietor		C = Contractor		(W) = Wiring only	
Power								
Carport	48	Double GPO white	Wattmore B7	—	2000	1200 mm	C	C
Bed no. 1	49	Double GPO white	Wattmore B7	—	2000	700 mm	C	C
Bed no. 1	50	Double GPO white	Wattmore B7	—	2000	300 mm	C	C
Bed no. 1	51	Single GPO white	Wattmore B6	—	1000	300 mm	C	C
Bed no. 1	52	Single GPO white	Wattmore B6	—	1000	300 mm	C	C
Dressing room	53	Strip heater	Xtrawarm	—	750	2100 mm	P	C
Shower room	54	Strip heater	Xtrawarm	—	750	2100 mm	P	C
Shower room	55	Single GPO white	Wattmore B6	—	1000	1050 mm	C	C
Laundry	56	Double GPO white	Wattmore B7	—	1000	1350 mm	C	C
Lounge room	84	Double GPO white	Wattmore B7	—	2000	300 mm	C	C
External	85	Double GPO: weatherproof	Wattmore K2	—	2000	1200 mm	C	C
External	86	Single GPO: weatherproof pillar-mounted	Wattmore K1	—	1000	Above ground level in filter pump box housing	C	C
External	87	Single GPO: weatherproof	Wattmore K3	—	1000	1200 mm	C	C

*PC sum

Fig. 6.45 *Schedule of applicances for installation shown in Fig. 6.46*

a complete set and that any amendments are either shown on the drawing itself or attached to it together with a note to that effect.

Specifications should be carefully and critically read for scope and for compliance with all codes and standards with which the installation is to conform. Together with supplementary notes these specifications should be studied in conjunction with the plans. A check should be made that the specifications are complementary to the plans of the building and that the plans and specifications taken together provide complete information on the building structure.

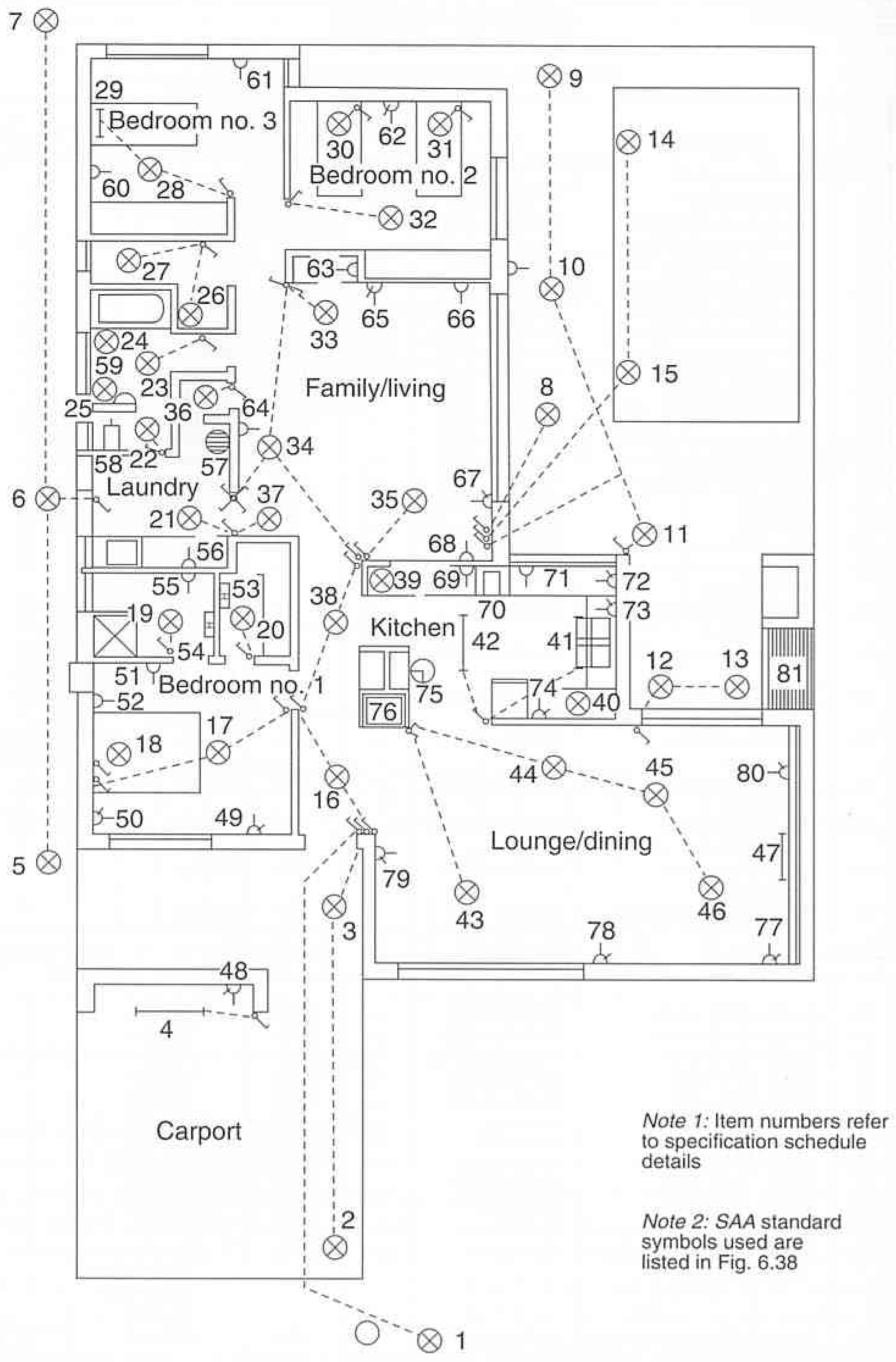


Fig. 6.46 *Plan of a domestic installation, showing electrical installation details*

It should be remembered that specifications, drawings and schedules are the basis for legal contracts and any modification or alternative arrangements to those specified may break a contract or require extra work and material.

Refer to 'Model clauses for electrical specifications' (page 151) to review the scope and coverage of a model specification designed to be used as a guide in the writing of specifications for most installations. The **intention** of each section of the specification must be understood. Notes should be made of any important items mentioned in the specification but not shown on the plans, such as submains, special outlet provisions and supply to special equipment. Attention should be paid

LIGHTING SCHEDULE	
Symbol	Description
3T	3 x 36 W totally enclosed fluorescent fitting Luxalite Lighting Pty Ltd Cat. No. EP/W/403 HPF
2T	2 x 36 W totally enclosed fluorescent fitting Luxalite Lighting Pty Ltd Cat. No. EP/W/402 HPF
"B	2 x 36 W batten fluorescent fitting Luxalite Lighting Pty Ltd Cat. No. BU/402 HPF
21D	2 x 58 W industrial fitting to be reused, from existing installation, and fitted with 'slide-in' acrylic lens panel to be supplied by Luxalite Lighting Pty Ltd

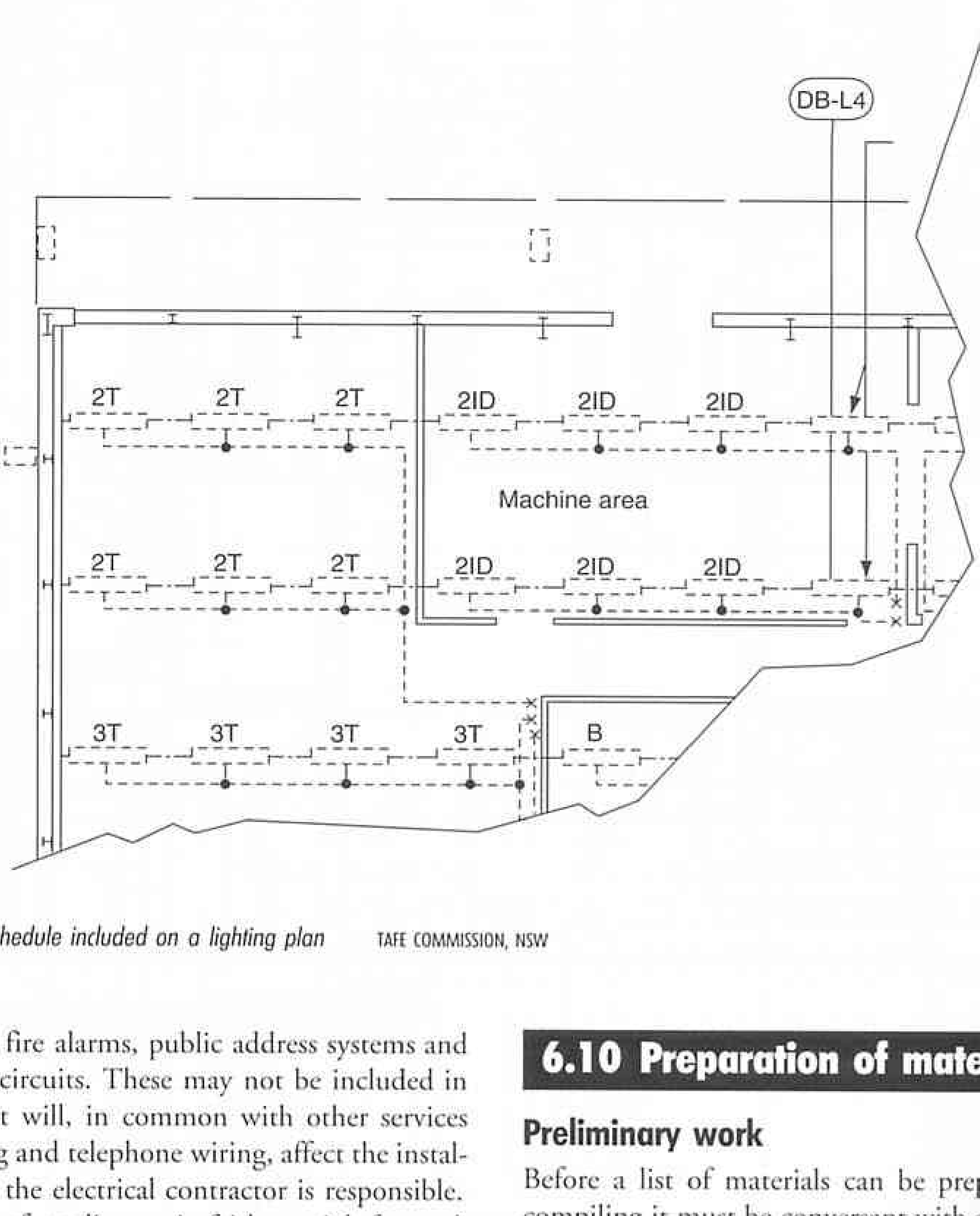


Fig. 6.47 *Lighting schedule included on a lighting plan* TAFE COMMISSION, NSW

to items such as fire alarms, public address systems and communication circuits. These may not be included in the contract, but will, in common with other services such as plumbing and telephone wiring, affect the installation for which the electrical contractor is responsible.

A schedule of appliances is fairly straightforward, inasmuch as it is a tabulated list showing equipment to be installed (see Fig. 6.45), but it must be checked and read in conjunction with the plans and specifications. The reader of the schedule should have access to trade lists, catalogues, guides to installation procedures, and instructions for the appliances and accessories listed. All relevant material should then be filed for future reference, as it may save time on a similar job in the future and could be the basis for future materials lists or estimates.

6.10 Preparation of materials lists

Preliminary work

Before a list of materials can be prepared, the person compiling it must be conversant with all the relevant AS 3000 *Wiring Rules*, the local service rules and any special codes or regulations that are applicable to the installation. The compiler must have referred or be able to refer to an electrical schedule or its equivalent for a list of luminaires, appliances and outlets, and the plans and specifications or their equivalent must also be available.

For small jobs, schedules, plans and specifications may not have been produced, and in these circumstances equivalent information may be provided by brief written notes, sketches or even verbal instructions. The most important and essential factor, however, is a personal

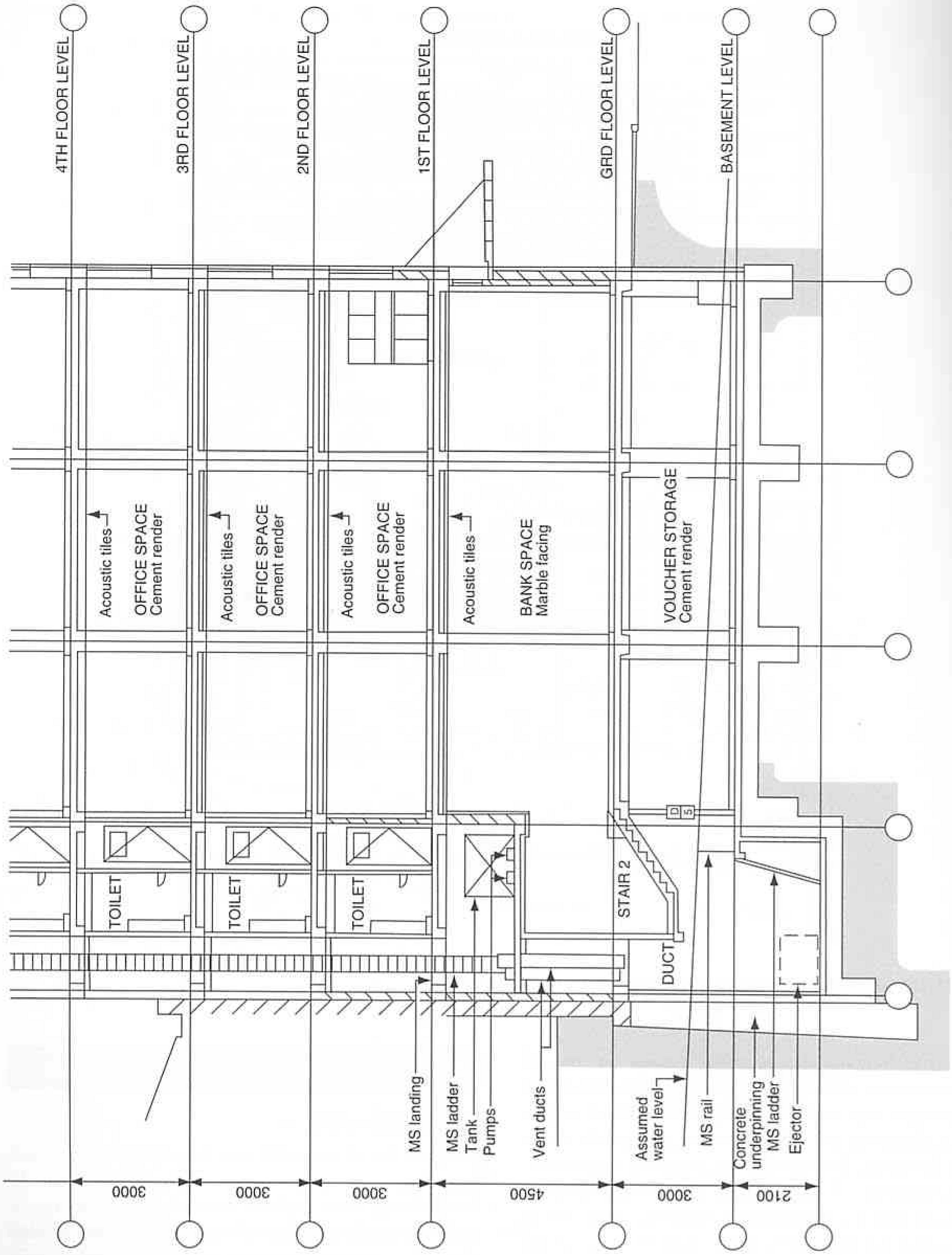


Fig. 6.48 *Section of a commercial building* TAFE COMMISSION, NSW

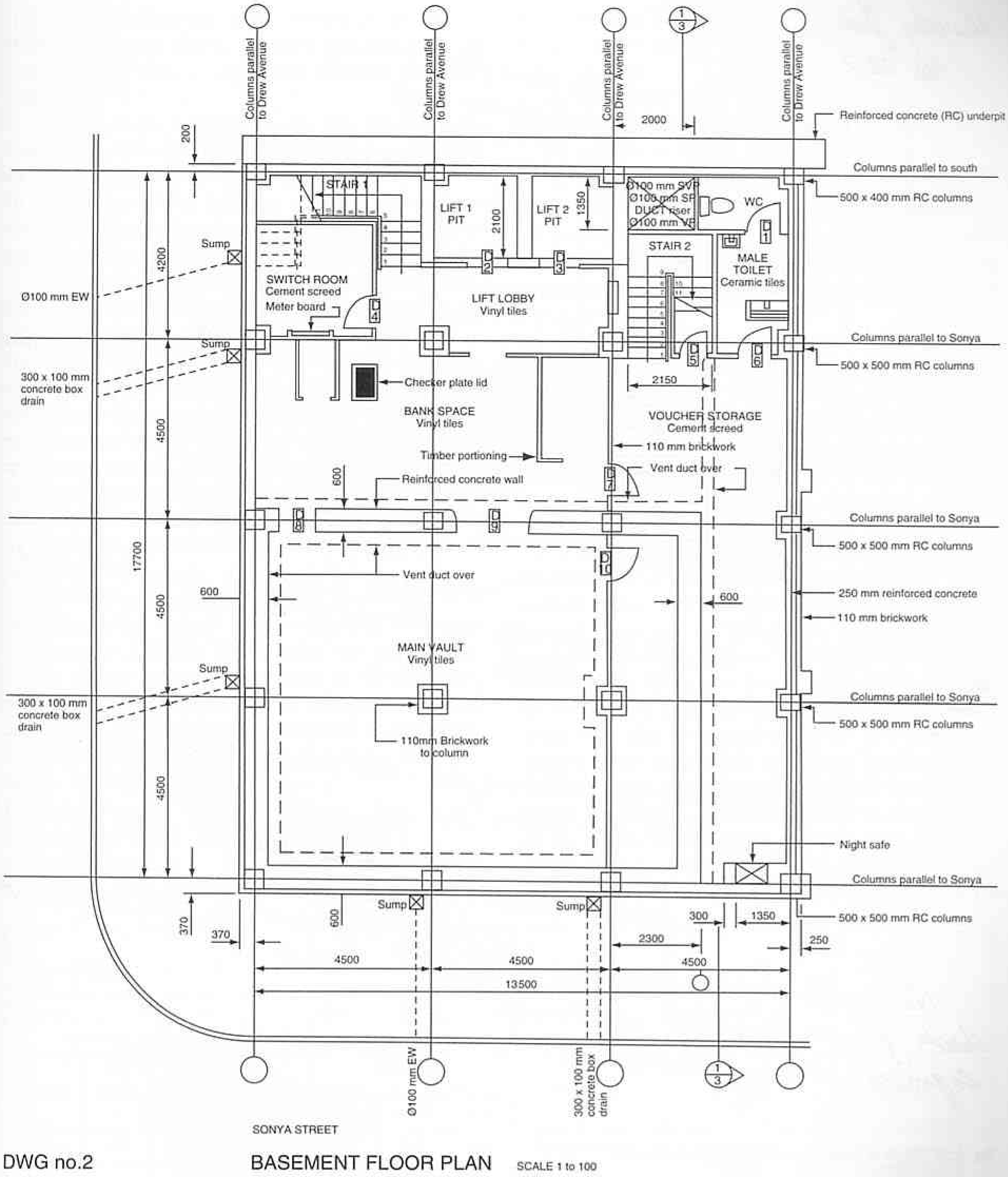


Fig. 6.49 *Floor plan of the commercial building in Fig. 6.48* TAFE COMMISSION, NSW

one. The person who compiles the materials list must have gained adequate background experience of job procedure and requirements and must be able to use creative thinking, in order to visualise the best wiring layout and method of wiring to be employed. The compiler must also be able to plan a systematic approach to the work to ensure the efficient utilisation of labour and material.

No-one knows job requirements and procedure better than the person who has had practical wiring experience, for which there is no substitute. To cite an example, a person without background and training would be foolish to attempt, say, a tender price for the electrical work in a concrete multistoreyed city building;

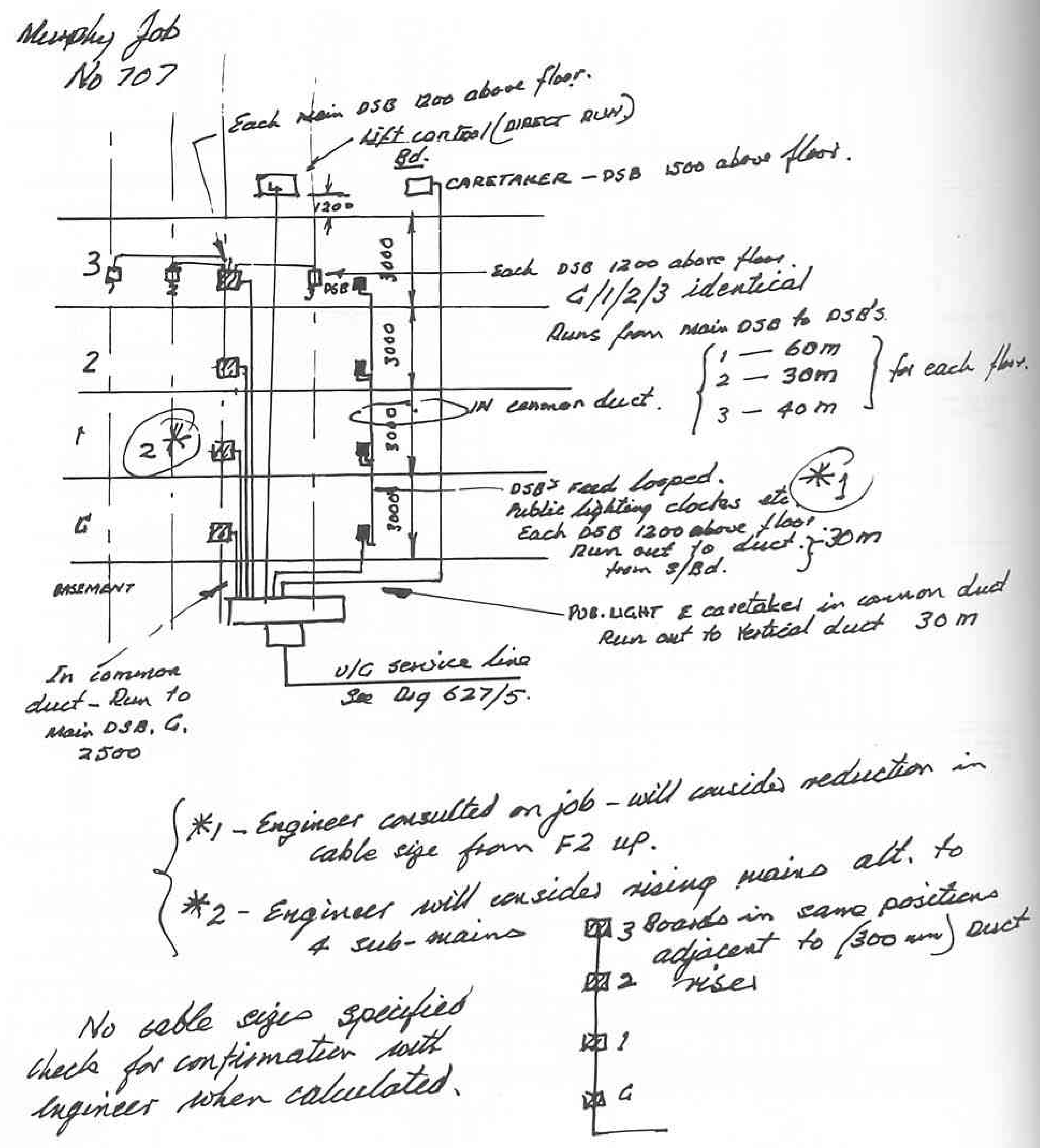


Fig. 6.50 *Sketch of installation details taken on the job*

the task would be better left to a professional estimator or to an electrician with considerable experience and estimating ability.

Although a small electrical installation may require only a mental picture of the wiring plan and procedure, in the case of a larger project the task of retaining all relevant details would be impossible, and field or on-the-job layout sketches and materials lists would be necessary. These sketches and notes should be made in a notebook, not on scraps of paper, which may be easily lost. The sketches and notes may relate to submain routes and lengths and include other details not shown in the plan or specification.

Where cable routes are indicated on the plan, they should still be checked thoroughly. Architects, draftspersons and even engineers can sometimes indicate a route that is not practicable, or provide for wiring to be installed in a space that is already overloaded by an air-conditioning duct or plumber's waste pipes. A check on other trades for access, layout and use of cable trunking or ducts is also necessary, plus a review of the general building structural details. Sketches may also indicate circuitry where this is considered necessary (see Fig. 6.50).

All the major cable routes are thus located, and their lengths determined, either by measurement from the plan or from on-the-job field sketches. Protection for the wiring (duct, conduit, double insulation) is noted. Switchboard locations are also pinpointed before the materials list is compiled.

Materials lists for the wiring of final subcircuits are also necessary, but the actual planning and layout of the subcircuit wiring are usually an on-the-job exercise. For this reason, only **average** route lengths, cables and accessories are listed for each light or power outlet, and the route length from the supply point to the first outlet of each circuit is noted. The layout of all items such as appliances, controls, any special equipment or provisions, and special-purpose outlets must be known. The materials or order list compiled would be different from an estimator's 'materials take-off' estimating form or pricing sheet.

The principles involved in the preparation of a materials list for a small factory extension or a large multistoreyed building are basically the same. They involve having adequate information on all job details and requirements, to permit the systematic listing of data, which should follow an estimated flow pattern. One logical pattern would follow that of the electricity supply, as below:

1. source of supply
2. consumer's mains
3. main switchboard
4. submains and/or rising mains
5. distribution boards
6. final subcircuits
   (a) lighting
   (b) power (GPOs)
   (c) special-purpose outlets
   (d) appliance circuits
7. any other special provisions.

If the electrician is responsible for the wiring of auxiliary services such as telephones, internal data and communication systems, public address systems and fire alarms, these may be similarly treated, commencing at the source of supply.

The compiler of the list is now armed with data sheets, plans, specifications, schedules, and layout and/or circuit sketches, plus a mental picture of the job procedure and attack plan. Light and power loadings are calculated from the list counts; then submains and consumer's mains loadings are calculated right back to the source of supply. See Chapter 16, Volume 2, for cable selection procedures.

The materials lists must include all materials with the exception of sundry items of relatively low value, such as screws, nails and clouts. These items would be covered by an average estimate for each run, and the total would be listed under 'incidentals' or 'sundries'; otherwise the time spent in itemising these would cost more than the items themselves. This averaging technique may also be applied to items such as lighting circuits, where for example the average length of switch feeds and the distance between outlets may be multiplied by the number of outlets in each case to obtain a total for the circuit. This assumes that the outlets are reasonably uniformly spaced. The cable run from the subcircuit fuse or circuit breaker to the first outlet of the

Section: Lighting Name: .... Address:					Job No. .... Date			Architect .... Engineer	Plan .... Specification .... Schedule	Sheet No. 5/L ....
Location	Supply	Circuit	Rating	Outlets	Length of run *Switch to outlets	*Between outlets	To first outlet	Accessories	Protection and cable type	Remarks
1st Floor	DB6	L1	10 A	15	5 m	6 m	4 m	Circuit-breaker protection L1-L4 V75 TPS 2 x 1.0 mm^2 with earth	All 10 A SP Architrave Switches Cat. No. .... except 3 x 3 way control (2-way and intermediate) and 4 x 2 gang surface-mounted switches. Luminaires – see Schedule L5	Wiring between suspended ceiling and uppermost floor 2-way on L1 surface-mounted on L2
"		L2	10 A	20	6 m	7 m	10 m			
"						7 m	5 m			

Note: Values marked * are average quantities

Fig. 6.51 *Data sheet for an electrical installation*

Reference	Circuit	V75 TPS 2 x 1.0 mm^2	V75 TPS 2 x 1.0 mm^2 with earth	Switches			Mounting Blocks 2 gang Cat. No.	Remarks
				10 A Architrave	10 A Int. Architrave	Surface		
Data	L1	75 m	94 m	15	–	–	–	
Sheet 5/L	L2	120 m	150 m	16	–	–	4	Add 4 x 2 gang flush architrave switches (L2)
					3	–	1	

Note: 1. Add 10% to cable totals for wastage
2. Cable clips etc. are listed under 'sundries'

Fig. 6.52 *Materials list associated with the data sheet of Fig. 6.51*

circuit must also be added, and allowance must be made for any extra cable required, such as for two-way switching.

List compilation

The lists must be comprehensive for all important items and be in such a form as to permit the addition of common items for totals. It is obvious that some type of tabulation is the only choice, the layout and column headings being dependent on job type and compiler, unless some standard form can be adapted. Figure 6.51 illustrates a simple type of data sheet, while Figure 6.52 shows a portion of a materials list.

It will be obvious to you that these are elementary illustrative examples, that layout and format are largely reflections of the system employed by the electrical firm and that, for simple jobs or sections of an installation, the data and materials sheets could be merged into a combined sheet. For even simpler jobs, a single materials list covering the whole installation could be compiled in the first instance. The basic underlying principles are the same, however, for the preparation of all electrical materials schedules.

Some basic rules to observe in compiling the lists are:

1. List materials in the same order as they appear on the data sheet and in such a way as will facilitate easy checking.
2. Check measurements each time for use of the correct scale.
3. Treat each circuit separately with regard to cable type, accessories and protection: for example trunking, conduit length and any special provisions, such as 'final run of 10 m in a hazardous area'.
4. Check the materials list for each run against all references provided.
5. Allow a reasonable and practical percentage for cable wastage at connecting-up positions (e.g. light outlets, switches; see note on Fig. 6.52).
6. To avoid an excessive number of blank vertical columns, it is advisable to have separate sheets of divisions listed, such as:
   (a) lighting and luminaires
   (b) GPO circuits
   (c) switchboards
   (d) submains
   (e) appliance circuits (motors, welders etc.)
   (f) special systems
   (g) consumer's mains.
   On a job large enough to require separate data sheets and materials schedules for different divisions (e.g. as lighting, appliances, power outlets), it is usual to transfer the division totals to a summary sheet.
7. After obtaining totals, check them for accuracy. For example, divide cable length by the number of light outlets on a lighting circuit to check that the cable per outlet is reasonable. Do the same for accessories such as switches and wall boxes.
8. List sundry items (e.g. saddles, screws, lock nuts, wall plugs) as an incidental total, and check this total against the route lengths.

Some points to watch for with the different provisions are given below.

Lighting and luminaires

Make certain that the outlet count is correct, as this affects all other lighting material. Check for special luminaires or fittings, such as cove lighting, window lights, spotlights, floodlights, yard and roof lighting, standards and flameproof fittings. All these could be shown on the plan as light outlets.

Note the specified mounting heights of luminaires and that diffusers may differ for the same basic luminaire type; so may lamp ratings and suspension arrangements.

GPO circuits

Check the mounting height of GPOs, and determine whether any weatherproof, ironclad or other special types of accessories are requested.

Check for any double-pole, safety shutter or pilot-lamp types of outlets specified, or any protected by a residual current device (RCD).

Note any locations where additional mechanical protection of cable is necessary.

Switchboards

Carry out a complete check of types and ratings of switchboards to be installed and whether they are to be supplied 'ex stock' or custom-built by the contractor.

Check the distribution system plan to determine the number and ratings and distribution boards required, and assess material that may be required for supporting frames or for mounting main switchboards and distribution boards.

Submains and/or rising mains

Check that diagrams are clear enough for the preparation of an accurate list of materials and equipment needed for submains, switchboards, meter panels, metering equipment, rising mains or feeder support systems, large cable supports, trays, and so on. With most of this equipment the current ratings are high; even a single omission of material would prove costly.

Appliance circuits

Check on any control accessories to be supplied or wired (e.g. remote control or metering circuits).

With motor and other appliances, ascertain that, in addition to the main run, the material has been listed for the run between the appliance and control panel, starter, remote push buttons and similar control equipment. Material required for the support or mounting of appliances must also be included in the materials list.

Check especially on motor types; for example, a flameproof or explosion-proof type of motor would require special materials.

6.11 Use of computers in estimating

In section 6.10 some guidance is offered in the planning of an installation and in the preparation of materials lists. The next logical step for the electrical contractor is to estimate costs of materials and labour for a job. Estimating is beyond the scope of this book, but it is appropriate here to draw your attention to some of the aids available for this purpose in the form of computer software.

The cost of cable, particularly in large installations, is probably one of the most significant factors to be considered when pricing a job. The first step is to determine cable sizes required in an installation in terms of maximum demand and voltage drop. The selection of cable size by calculation in conjunction with the requirements of AS 3000 and AS/NZS 3008.1.1 is described in Chapter 16, Volume 2. However, a computer software package based on these standards, designed by Spearhead Software Pty Ltd and marketed as Powerpac IV, is available from Standards Australia. As pointed out by its supplier, it is not designed to replace the hard copy of the above standards but is intended as an aid that will complement their use.

For the above software aid to be used effectively, it is essential that the user have a background of trade training. For example, an electrical contractor who can carry out calculations and use AS 3000 and AS/NZS 3008.1.1, as described in Chapter 16, would have adequate background to use the above program with ease.

The program will work on any IBM-compatible personal computer. It enables the user to carry out speedily and accurately all calculations and selections from the following areas:

- cable sizing and selection
- physical properties of cables
- maximum demand calculations
- conduit and pipe sizing
- aerial lines and post sizing
- aerial cable sag and stringing data
- substation earthing—selection of cable size
- busbar sizing.

The software package is menu-driven. The user selects from the menu the design feature required. The program then prompts a series of questions necessary to establish the correct data to enable the computer to perform the calculations. The solution displayed, which often offers alternatives to choose from, can be printed out together with the input data, if required.

Spearhead also produces Cable, which is a smaller and less expensive cable design program than Powerpac and which mirrors the calculations and selections from AS/NZS 3008.1.1. Its target is the smaller electrical contractor, who needs to carry out only limited cable design but who requires assurance of design calculation accuracy. Design inputs permit the contractor to verify easily the input data, menu route and solution from AS/NZS 3008.1.1, and this in turn allows the submission of the design data to the appropriate energy distributor for approval. The selections made are demonstrated to the distributor as being strictly in accordance with the requirements of AS/NZS 3008.1.1.

Standards Australia also supplies an electronic version of AS 1102, the national reference for graphic symbols used in electrotechnology. This software package provides for the direct transfer of each symbol contained in the standard into virtually any computer-aided design (CAD) system.

In an electrical contracting and estimating course conducted at some TAFE collegues, a program marketed as Cost Manager forms part of the course of instruction. This software package was specially written for electrical and plumbing contractors and the like. It is designed to assist a business in controlling labour and materials costing and in preparing quotations for a job. Appropriate materials database files are stored in the program, and the software includes 'on-disk' updates of products and prices at regular intervals to be incorporated into the program. There is provision in the package for automatic invoicing, listing of sundry debtors, analysis of projects on a job-by-job basis, and rise and fall variations on larger jobs.

Other software packages available include payroll management, a 'cashbook manager' and a package designed to keep track of the contractor's creditors. The larger contractor might opt for Micronet's total accounting package, which includes cost management, general ledger, credit ledger, pricebook facilities, an estimating system and a reporting module.

Not counting contractors who use only the word-processing software on their personal computers, only about 20 per cent of Australian contractors use computers in their business. However, as programs become easier to use, and as contractors become more willing to learn and use the power and capabilities of the programs available, this percentage will rise.

Computers store and sort large volumes of information quickly and accurately. With the number and variety of software packages available, together with the automatic updating facilities provided, computers have the potential to save the electrical contractor considerable amounts of time. A computerised estimating program can improve the contractor's productivity, minimise errors and improve the flow of information required for a quotation.

SUMMARY

- The two main types of electrical diagrams are:
  - wiring diagrams, and
  - circuit diagrams.
- A wiring diagram is close to being a pictorial representation of the circuit, with components shown in their actual relative positions with other physical details (see Fig. 6.1).
- A circuit diagram (or 'schematic') depicts the 'scheme' of the electrical circuit in logical sequence in 'cause–effect' order. In a circuit diagram components are arranged in their electrical relationship to each other (see Fig. 6.1).
- Architectural drawings or plans are used to show the physical position of electrical items in an installation.
- A single-line diagram is a simplified form of wiring diagram, showing only essential details.
- A block diagram is a simplified form of a circuit diagram, using rectangles or other symbols to represent complete component circuits and joined by lines to indicate the sequence of operation and/or control of the system.
- A basic electrical circuit comprises:
  - a source of supply
  - some form of protection
  - some form of control
  - the load, which usually converts electrical energy to another form of energy
  - a return to the source of supply (see Fig. 6.2).
- In a practical circuit the energy loss in the conductors feeding the load are kept to a minimum to ensure that the rated voltage appears at the load terminals.
- Most motors, appliances and lamps have a voltage rating the same as the supply, and must therefore be connected in parallel with each other.
- In parallel circuits, 'like' ends are connected together and there should be as many parallel paths as load components.
- Switches are connected in series with the load devices they control, and correct polarity must be observed.
- In series circuits, unlike or similar ends are joined; the finish of one component is connected to the start of the next component.
- There is only one current path in a series circuit, the current being the same value throughout the circuit.
- If there is a break or open circuit, current will cease to flow and the full-supply voltage will appear across the break.
- The basic circuit connections are series and parallel. A complete circuit may contain many such connections in combination with supply sources and circuit devices.
- Common methods of lighting control by switching are:
  - single-pole or one-way from one position
  - single-pole double-throw (SPDT) or two-way control from two positions
  - two-way and intermediate switch control from any number of positions
  - switch multipliers that convert a single switch into two separate independent switch circuits or a multiple switching arrangement.
- The 'loop-in' wiring system makes the join in conductors accessible at common looping terminals provided at accessories such as switches, ceiling roses and batten holders. This method maximises the use of multicore cables without the need for junction boxes (see Figs 6.7 and 6.8).
- The single-pole single-throw (SPST) one-way switch has two operative terminals plus one looping terminal. The single-pole double-throw (SPDT), which may be used as a one-way or two-way switch, has three operative terminals plus one looping terminal (see Fig. 6.12).
- The most common circuit arrangement for two-way switching is active to the first switch, two conductors, known as 'straps', between the switches, and a switch wire from the second switch to the load (see Fig. 6.14).
- There are many other circuit configurations and applications of two-way switching (see Figs 6.15 and 6.16).
- Control from more than two positions is achieved by two-way switches at each end of the control circuit and as many switches at intermediate positions as required.
- 'Intermediate' switches have four operative terminals and are connected in the 'strap' between the two-way switches at each end of the control circuit. Care must be taken in

connecting the straps to the switch terminals to ensure that the correct switching arrangement is achieved (see Fig. 6.20).

- Switch multipliers are typically used as a convenient method of changing existing switching arrangements without the need for major wiring alterations (see Figs 6.24 and 6.25).
- Power outlets are wired by looping from point to point, commonly using twin TPS cable with enclosed earthing conductor.
- Correct polarity and location of the controlling switch are essential for the safety of persons using the outlets (see *Clauses 4.14.5.4* and *4.14.8*).
- In single domestic installations general-purpose outlets (GPOs) may be connected in parallel on a 'ring' circuit (see Fig. 6.29).
- Interlocking switching arrangements (*Clause 2.9.6*) can be used as an economical solution to wiring problems (see Fig. 6.28).
- A wiring circuit for a motor is generally simpler than for other circuits, usually entailing a single run of wiring from the supply source to an isolator, starter or control panel.
- The circuit wiring to a single-phase motor consists of an active and neutral conductor, and for a three-phase motor three active conductors. A three-phase motor does not require a neutral conductor.
- The number of wires from the starter or control panel will depend on the motor and starter type (see examples on pages 125 and 140).
- The construction types for single domestic dwellings are usually either cavity brick, brick-veneer, timber-framed and clad, block or concrete masonry, prefabricated, or steel-framed and clad.
- Each component of the building structure has a common term and function, which must be understood to enable the electrician to work with other trades and comply with building and wiring regulations. Also, the electrician must understand the sequence of building operations in order to plan the electrical work appropriately.
- Building codes place restrictions on drilling and notching timber frames (AS 1684, *Clause 4.3.3.1*).
- No matter how simple or how complex a job may be, it is essential that plans, specifications, materials lists and appliance schedules are prepared.
- Plans, specifications and schedules describe in drawings and writing what is required for a job, and are the basis of the contractual arrangements between the owner and those engaged to do the work. These will invariably include the electrical contractor.
- On large projects separate contracts may be let for general light and power, heating, ventilation, air conditioning, lifts and communications cabling.
- The electrical plan is the architect's floor plan, with outlets, lighting points and control devices marked in their required location.
- On larger jobs there is a separate plan for each trade and a separate drawing for each floor.
- Generally the electrical plan is included on the general plan for small jobs, and in many cases it is left to the electrician to devise a work procedure and layout plan.
- Standard symbols used on electrical plans are those of AS 1102, *Part 8*, 'Location symbols, power supply systems and electrical services for buildings and sites'.
- Drawings related to other services and structural details that may affect the wiring method and materials must be consulted when planning electrical work.
- An electrical specification will generally include information on types of wiring and wiring methods to be employed, luminaires, types of accessories, numbers of circuits and types of circuit protection required. Reference is also made to specific codes of practice, rules and regulations to be observed and the supply and distribution system for the installation, including the position of switchboards.
- In large jobs, schedules are used as a supplement to the specifications to clarify details about appliance and outlets. Schedules include information on location, make/type, power rating, summary of mounting arrangements and source of supply.
- The following points will help in interpreting plans and specifications:
  - Become familiar with the standard symbols of AS 1102.8.
  - Check legends on plans for non-standard symbols.
  - Make sure copies of plans are in good order and not worn.
  - Consult specifications for any exact location details of appliances and accessories.
  - Check drawing scales before taking-off route lengths of cable runs; there may be more than one scale on a drawing.
- The compiler of a materials list must be conversant with the relevant *SAA Wiring Rules*, local service rules and any special codes or regulations that may apply.
- For small jobs, where there is not a plan of written specification, sketches and notes or verbal instructions should be made.
- Proposed cable routes should be checked for practicality and interference from other services.
- Materials lists should follow a logical pattern to help ensure that no items are left off. Some basic rules for compiling the list are given on page 166.
- Many software programs are available to assist in estimating and managing electrical installation jobs and projects. They include programs for selecting cables to meet Australian Standards, materials costing from manufacturers' and suppliers' software catalogues, integrating standard symbols into computer-aided design (CAD) systems, and accounts and personnel management.