Chapter 1

Introduction

This book contains designs for electrical installations which have been prepared with reference to Wiring Regulations and there are interpretations of particular technicalities.

This is not a do-it-yourself book for the amateur or untrained person. It is a guidance manual for competent electrical designers and students of installation practice.

As far as possible all information accords with the requirements of the 16th edition of the IEE Wiring Regulations under its new designation as BS 7671. Relevant Regulation numbers and other references are shown in the margin. (Because of the space allowance the following abbreviations have been used: Ch. – Chapter; Sec. – Section; Defs – Definitions; App. – Appendix.) Reference is also made to various other British Standards and related Health and Safety documentation.

Layout of chapters

Interspersed throughout the book are two types of chapter giving information in different formats.

- *Project chapters*. These may be compared with a selection of recipes for an experienced chef. The recipes give ideas for the design of typical electrical installations. Each project is dealt with on a stand-alone basis. Cross reference between these chapters is avoided and similar information may be found for more than one scheme.
- *Topic chapters*. These supplement the project chapters with in-depth discussion of generalized technicalities. They also provide study information on regulatory subjects. It may be necessary to refer to these details to finalise a design with particular problems.

Wiring Regulations

Throughout this book the terms Wiring Regulations (or Regulations) refer to the 16th edition of the Wiring Regulations issued by the Institution of

Electrical Engineers (now BS 7671). The Standard therefore represents a code of acceptable safety for electrical installations to protect:

- Persons,
120–01 - Property, and
- Livestock,

against electrical hazards which are described as:

- Electric shock,
- Fire,
- Burns, and
- Injury from mechanical movement of electrically actuated machinery.

The Regulations are not a statutory document but are quoted as a means of
120–02 compliance with certain statutory instruments. It would appear that a criminal charge could not be brought for failure to comply with the Wiring Regulations, but such failure could be used in evidence on a charge for breach of the Electricity Supply Regulations or the Electricity at Work Regulations.

It would be most unwise to ignore any of the requirements of the Regulations. They must be considered in their entirety and are a *pass* or *fail* test. An installation cannot partially comply.

Scotland

Different considerations apply in Scotland where the Wiring Regulations are quoted as a means of compliance with Building Regulations (Scotland).

Terminology

In order to understand technicalities, the importance of correct terminology is stressed throughout the book. In general, however, the use of over-complicated expressions and trade jargon has been avoided.

The Wiring Regulations carry a list of definitions for words and expressions which may not accord with standard dictionary definitions. Wherever there is any doubt, the Wiring Regulations definition should be applied.

Competence and responsibility

Any person involved with the installation of wiring in buildings takes on both legal and moral responsibilities for safety. A high level of technical and practical competence is essential. This can only be achieved with the appropriate study.

There are always three components to an electrical installation project:

- Design,
- Installation,
- Inspection and test.

Often one person or company takes on all three responsibilities, especially for simple repetitive jobs such as house wiring. On larger schemes, specialist companies may be contractually involved for each aspect and in turn use a team of operators. As the work progresses from planning to completion there must always be one or more supervising individuals who will eventually certify that the three aspects of the contract have been carried out in accordance with the Wiring Regulations and any other statutory or specification requirements.

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Procedures

Design

It is sometimes thought that the use of tried and tested methods removes the design aspect from a scheme. This is not the case. Every project involves electrotechnical design decisions which are not to be confused with architectural or customer instructions for the physical location of electrical equipment. Thus, a self-employed electrical contractor who makes a decision on the selection and connection of an electrical accessory is a designer. The same applies to an electrician who makes a similar decision on behalf of an employer.

All technical design information must be recorded. This is a Wiring
514–09 Regulations requirement. IEE guidance is that it is essential to prepare a full specification prior to commencement or alteration of an electrical installation. The size and content of the specification will correspond with the complexity of the work. For simple jobs a few lines may suffice.

The designs shown in the following chapters are for guidance and each one includes a suggestion for a suitable design specification. A person selecting this guidance makes a design decision and therefore becomes the responsible person.

742–02 Upon completion of the contract the designer certifies that the design work is in accordance with the Wiring Regulations.

Installation

Where a technical design is drawn up by an electrical engineer or other competent person, it should not be the installer's job to check design details, unless this is one of the contract requirements. The installer is always under an obligation to point out to the designer any obvious conflict with regulations or standards and an installer should always refuse to carry out substandard work.

There would be no defence in law against creating an unsafe installation on the basis of inherently bad instructions.

The installer will use the designer's specification document as required by the Wiring Regulations. This may only cover performance requirements or may give full technical details for the selection and erection of equipment. Once again it must be emphasized that a non-technical instruction to take an electrical supply to a particular appliance or location does not constitute design information.

The installer has the responsibility to ensure that equipment is installed correctly and in accordance with the specification, supplemented by manufacturers' information. The installer is often delegated other tasks such as that of negotiating with the electricity supply company and verifying local licensing requirements.

Upon completion of the project, the installer certifies that the installation work has been carried out in accordance with the Wiring Regulations.

Inspection and test

No matter how simple or straightforward the job, test procedures must be carried out both during the course of the work and upon completion. This
711-01 applies equally to work carried out by a single self-employed operator. Self-certification is normally acceptable provided that the contractor has the competence and equipment to test correctly. The customer or an insurer may require specialist certification. This applies more particularly in the case of safety alarm systems or work in hazardous areas.

Whether an in-house or independent specialist, the inspector must be given the full design documentation with amendments showing any relevant on-site modifications. On larger projects this will include 'as fitted' drawings.

Certain parts of the installation may be hidden from view upon completion. In such cases the inspector must arrange for inspection during the course of erection or receive certified confirmation that the work is satisfactory.

Upon completion of the project, the inspector certifies that the inspection
741-01 and test has been carried out in accordance with the Wiring Regulations.

Completion

The signatures of the designer, installer and inspector are required for the
742-02 Completion and Inspection Certificate. This cannot be issued until the work has been completed in accordance with the Wiring Regulations. Where there are acceptable departures from the Regulations, these must be shown on the certificate.

See Chapter 15 for inspection and test procedures.

Working methods and materials

130–01 The Regulations require that good workmanship and proper materials shall be used.

Operatives

Any person carrying out electrical work must be competent, trained and skilled in the type of installation work being carried out. Where trainees or unskilled operatives are employed for electrical work they must be appropriately supervised.

Workmanship must be of a quality appropriate to the location. A working knowledge of the building structure is necessary where holes and fixings are made to carry cables. Decor should be disturbed as little as possible with prearranged responsibility for making good.

Materials

The Regulations require that every item of equipment shall comply with a
511–01 British Standard or harmonized European Standard. Alternatively, equipment complying with a relevant foreign standard may be used provided that the designer confirms that the equipment provides a degree of safety acceptable to the Regulations. This may mean product certification by an approvals organization.

December 1994 amendment to BS 7671: 1992

There are over 300 individual amendments to the 16th edition of the Wiring Regulations. Most are relatively small changes resulting from harmonization. Where changes have been made which affect the technical or practical aspects of this book, the text has been changed accordingly. If an amendment noticeably alters conventional procedures, details of the change have been included. This particularly applies in the case of voltage harmonization.

Voltages

On 1 January 1995, the Electricity Supply Regulations 1988 were changed to take into account a change in the standard UK supply voltage (see Table 1.1). All specifications, designs and calculations should now use the 230/400 V figures. The change in voltage is minimal, therefore load assessments given in this book have not been recalculated, but there are other consequences to be considered.

Table 1.1 Changes in nominal voltage.

	Nominal voltage	Tolerance % +	Tolerance % –	Range volts max.	Range volts min.
Up to 1.1.95					
U_o	240	6	6	254	226
U	415	6	6	440	390
From 1.1.95					
U_o	230	10	6	253	216
U	400	10	6	440	376

The permitted tolerances on the mains voltage are such that UK supply companies will not have to make any immediate changes to the supply. Presumably there will be a gradual move to lower distribution transformer tappings. For the present the 240/415 V service will suit consumers' existing equipment. However, new consumer equipment being supplied by manufacturers will be rated at 230 V.

Taking all of the above factors and tolerances into account, it will be seen that under the most extreme circumstances, equipment rated at either 230 or 240 V may be supplied at anything between 216 and 254 V.

Voltage drop

The Regulations permit a 4% voltage drop within an installation from the supply intake to the terminals of current using equipment or a socket outlet. At 230 V, this is 9.2 V. Care needs to be taken in the selection of cables, particularly where equipment is voltage-sensitive.

- Motor starting currents may be such that machines may stall before achieving full speed running conditions.
- Inductive lighting loads take high current on start up and luminaires could fail to strike, especially in cold weather.

All of the designs shown in this book use cables that are capable of handling the prospective loadings with a reasonable margin of safety.

Chapter 2

Three Bedroom House

At one time, domestic electrical installations were simple and only basic design planning was necessary. A good electrician could be sent on site with a van load of wiring materials with no written instructions or drawings. The installation arrangements were rule-of-thumb and the quality of the job depended on the craftsmanship of the operative.

Any special requirements or missing information could be negotiated on site. Costing was repetitive and easy. The contract price was a simple multiple of the number of lights and sockets.

Times have changed. There is probably no such thing as an average householder. Most occupiers have specialist requirements based upon the choice of room utilization, decor, hobbies and the activities of the various residents.

It is not easy for an architect to forecast the furniture layout in a room. A modern speculative electrical installation cannot make universal provision for every conceivable arrangement. The IEE Guidance Notes suggest that a project should be discussed with the client. This is essential for a custom-built house. As an alternative the installation could incorporate some design flexibility so that the new family is not restricted to bed positions or where kitchen equipment may be plugged in.

Standards for the house industry are determined by the National House Building Council (NHBC). Most building societies and other mortgage lenders require compliance with NHBC requirements.

This chapter starts by illustrating a basic, cost-conscious electrical installation. A scheme may be lifted straight from the pages for such a contract. For more advanced schemes it is hoped that developers will be enticed into better electrical facilities with a 'modern living' theme. A good quotation will include optional extras for improved lighting and socket-outlet facilities. Not all house purchasers want the cheapest possible electrical installation.

The bare minimum

The following is an outline of basic requirements for a three-bedroom house with 120 m^2 floor area. This would be a typical speculative estate development (see Fig. 2.1):

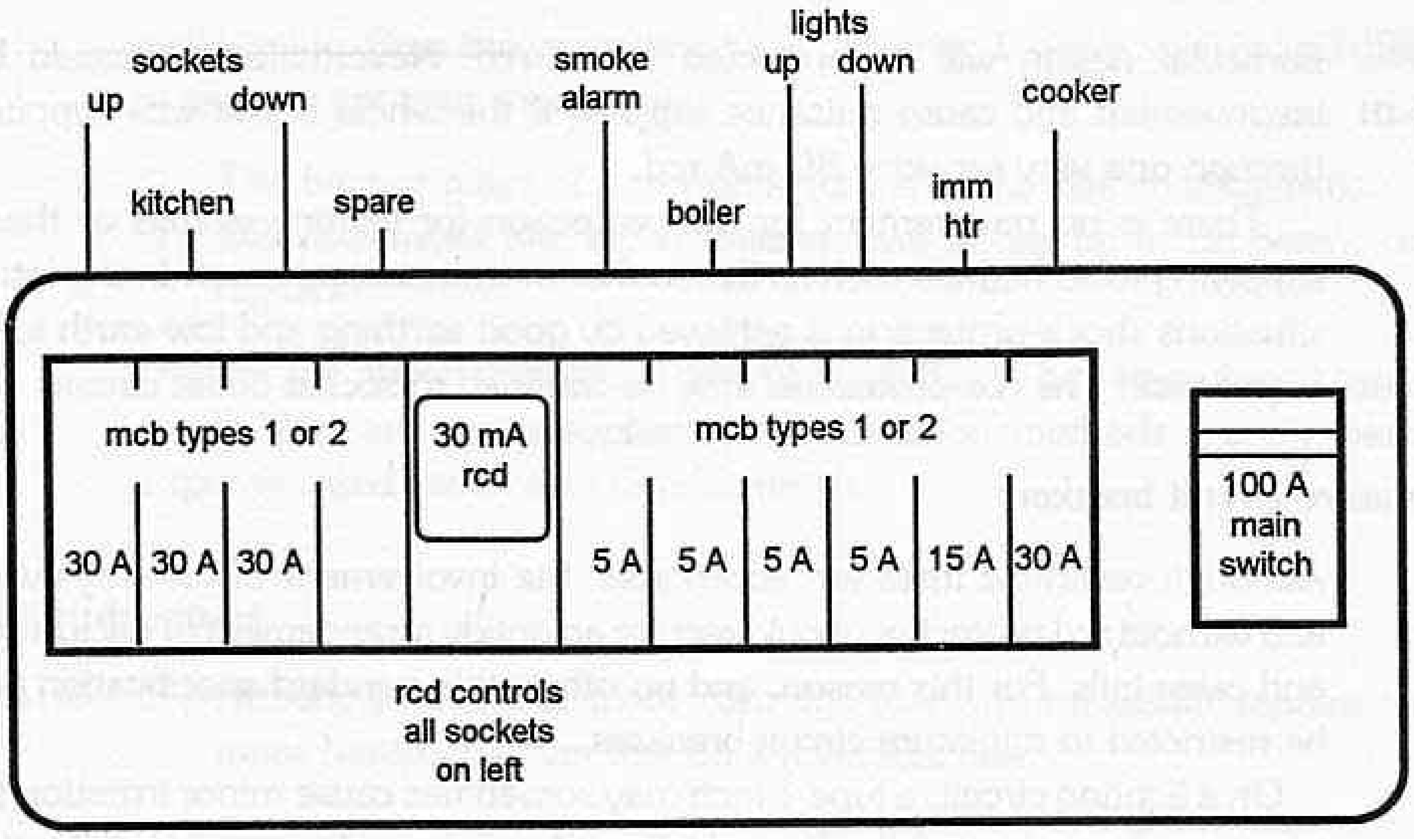


Figure 2.5 **Main switch controls all circuits.**

Earthing and bonding

542–04 A main earthing terminal (MET) must be established. This connects:

- The 16 mm^2 supply earthing conductor.
- 10 mm^2 main bonds to water, gas or oil services.
- 10 mm^2 circuit protective conductor to the distribution board.

547–02 All cable sizes are the minimum required for compliance with PME Regulations. It should be possible to remove any of the conductors for testing without disturbing others.

The MET should preferably be external to the consumer unit but in any case it must be easily accessible for disconnecting the supply earth for testing purposes.

If there is more than one consumer unit or distribution board the MET must carry all bonding conductors and should be externally accessible. Separate circuit protective conductors should then be taken to the earthing bar within each board (see Fig. 2.6).

Gas bonding and external meters

The Wiring Regulations require that bonding to the gas supply should, wherever possible, be within 600 mm of the point of entry into the house and before any branch pipework. This has often proved to be difficult where the

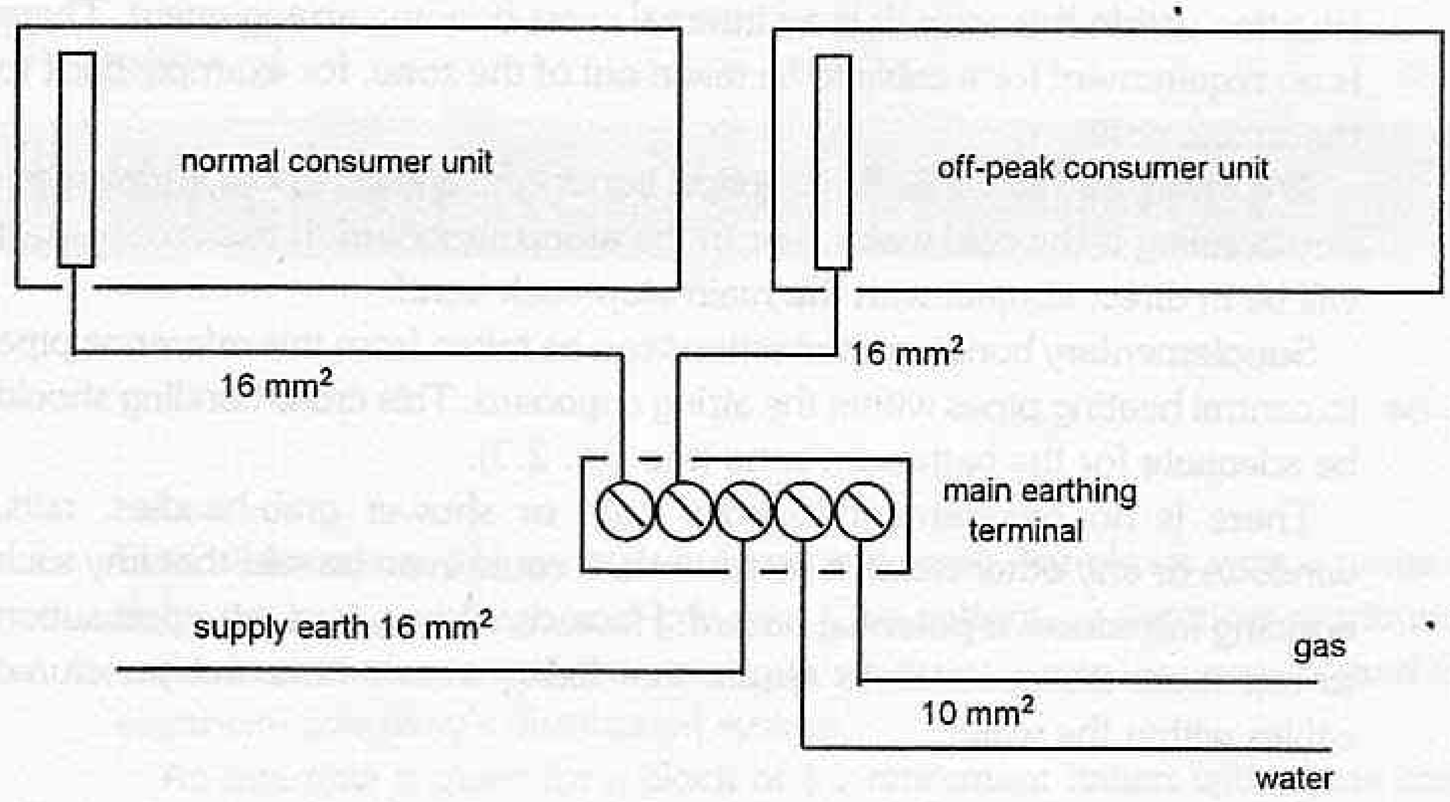


Figure 2.6 **Earthing connections to two services.**

gas pipe is buried in the floor. The only solution is to make the bond at the earliest point where the gas pipe surfaces.

Meters for new gas supplies are now being located in what are known as semi-concealed meter boxes. It is advisable to make the gas bond within this box. British Gas is making provision for the connection. There is a cable hole in the side of the meter box, close to the gas-pipe entry. Within the box, an earth-tag washer is provided at the outlet adaptor.

The 10 mm^2 bonding conductor should be taken through this hole and connected to the washer with a crimped lug and the appropriate label fitted. The cable should be as short as practicable with no spare length curled up. It must not be taken through the gas-pipe hole.

Supplementary bonding

The only requirement for supplementary bonding is within the bathroom or
601–04 shower room. For convenience consider a bathroom 'zone'. This may include the airing cupboard if it is within the immediate vicinity. Often two bathrooms back on to each other or the airing cupboard.

The Wiring Regulations require bonding connections to be accessible for inspection and testing. They are not required to be permanently visible or
543–03 obtrusive. Connections within the airing cupboard are preferable, or under the bath, or within a pipe duct. In such locations arrangements for access must be provided even if this requires screws to be taken out and bath panels removed.

The purpose of supplementary bonding is to ensure an equipotential situation within this zone. It is an internal cross-bonding arrangement. There is no requirement for a cable to be taken out of the zone, for example back to the mains position.

A convenient reference point for all bathroom/shower room supplementary bonding is the cold water riser in the airing cupboard. If this is copper, it will be in direct contact with the main stop-cock bond.

Supplementary bonding connections can be taken from this reference pipe
601–04 to central heating pipes within the airing cupboard. This cross-bonding should be adequate for the bathroom zone (see Fig. 2.7).

There is no requirement to bond bath or shower grab-handles, rails, windows or any other isolated metalwork. It could even be said that any such bonding introduces a potential hazard. However, it may be a wise precaution to test these isolated rails to ensure that fixing screws have not punctured cables within the wall.

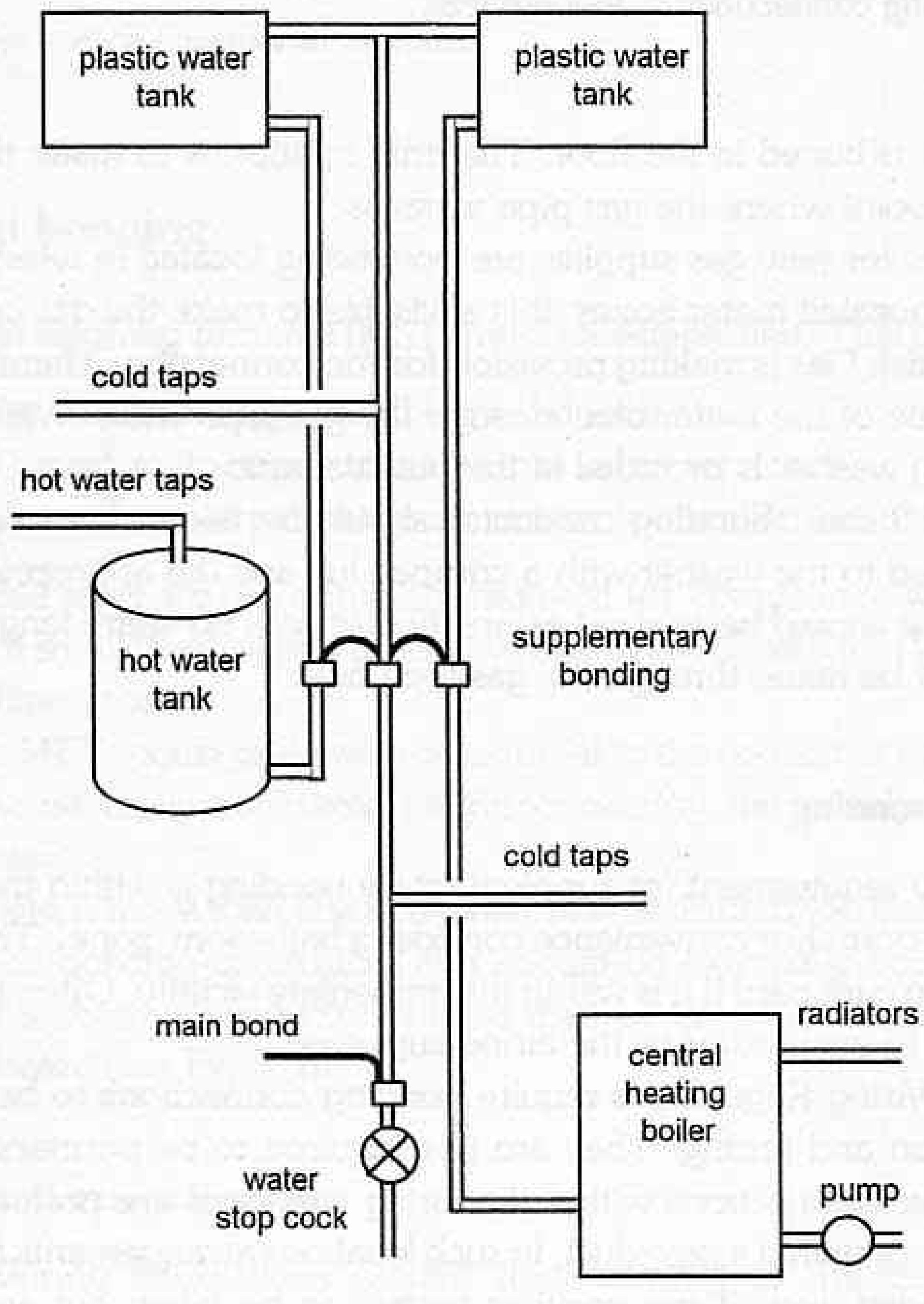


Figure 2.7 **Supplementary bonding in airing cupboard.**

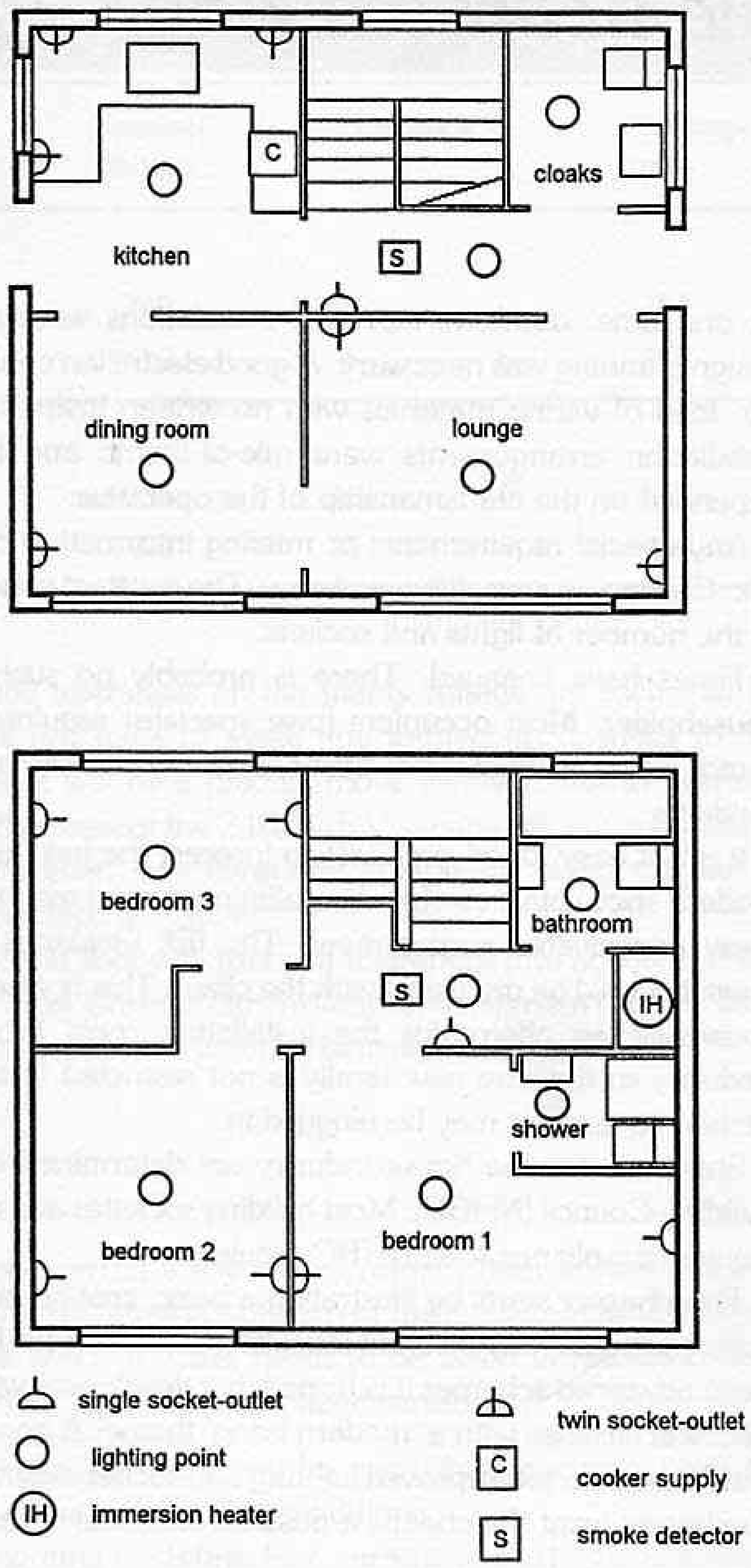


Figure 2.1 **Typical three bedroom house.**

- *Rooms* Small kitchen; Dining room; Lounge; Downstairs cloakroom; Main bedroom with en-suite bathroom; Second double bedroom; Small single bedroom; Landing bathroom or shower room.
- *Heating* Central heating by gas or oil.
- *Garden* There is a small garden at both front and rear.

Standards

National House Building Council (NHBC)

The NHBC gives minimum standards for living accommodation and services. The electrical requirements are shown in Table 2.1.

Relevant IEE Wiring Regulations

13 A socket outlets

471–16 ❐ Any socket outlet which may reasonably be expected to supply portable equipment for use outdoors must be provided with 30 mA rcd supplementary protection.

❐ No 240 V sockets are permissible in bathrooms or shower rooms.

601–10 ❐ Where a shower cubicle is located in a room other than a bathroom, e.g. a bedroom, any 240 V socket must be at least 2.5 m from the shower cubicle.

Table 2.1 **NHBC electrical requirements for a house.**

13 A socket outlets (twin sockets count as two outlets)

Room	*Outlets*	*Notes*
Kitchen/Utility	6	Where homes have separate areas, the kitchen should have a minimum of four outlets and the utility room two. Where appliances are provided, at least three outlets should be for general use.
Dining room	2	
Living room	4	At least one double outlet family room should be near the TV aerial outlet.
Bedroom	3(2)	Three for main bedroom. Two for other bedrooms.
Landing	1	
Hall	1	

Combined rooms should have sockets equal to the sum of the number for individual rooms with a minimum of seven in the case of kitchen/utility and another room.

Lighting
Every room should have at least one lighting point.
Two-way switching should be provided to staircases.

Smoke detectors
For this two storey house two mains operated, interconnected alarms are required.

Lighting

314–01 ▢ To avoid danger and inconvenience there should be more than one lighting circuit.

▢ In a bathroom or shower room the light must be operated by a pull cord
601–08 switch. (Alternatively the light switch may be outside the bathroom door.)
601–11 ▢ In a bathroom or shower room a lampholder within 2.5 m of the bath or shower cubicle must be shrouded in insulating material.

▢ A batten holder must be of the type with a protective skirt.

Building Regulations

Smoke detectors

All domestic dwellings, including conversions, must either have:

▢ A complete British Standard fire alarm system, or

▢ Mains operated smoke alarms, one on each floor and interconnected.

Load assessment

The Regulations require that the characteristics of the supply, including an
311–01 assessment of the maximum demand, should be determined by calculation, measurement, enquiry or inspection.

It is assumed that this house will be connected to an underground PME 240 V a.c. supply and that the maximum demand load will be less than 100 A. The other characteristics may be determined by enquiry to the electricity company.

A typical domestic supply

Except in unusual circumstances supply characteristics are:

▢ *Prospective short circuit current at the origin*
313–01 Never more than 16 kA and most likely less than 2 kA.

▢ *External earth fault loop impedance Z_e*
Not exceeding 0.35 ohms and most likely less than 0.2 ohms.

▢ *Main fuse*
This will be to the usual electricity company standard,
BS 1361 Part 2 or BS 88 Part 2 or Part 6. 100 A.

Provided that these figures apply, there are no problems in applying a standardized electrical design.

Project specification

It is necessary to produce a Project Specification as in Fig. 2.2. This will be used initially for pricing purposes. It will eventually be updated to form the basis of a user manual.

Project Specification BS 7671				
Name....................			Location................	
Reference................			Date.....................	
240 V 50 Hz. TN-C-S. Supply fuse 100 A BS 1361 or BS 88				
PFC less than 16 kA. Earth loop impedance less than 0.35				
Consumer unit BS 5486. Split bus-bar				
100 A main switch 4 + 4 way			63 A 30 mA rcd M6 type 2 mcbs	
Circuits	Rating (A)	Cable size (mm^2)	Max length (m)	Lights/points g = gang
1. Cooker	30	6.0	43	1
2. Ring 1 upstairs	30	2.5	71	...1g ...2g
3. Ring 2 downstairs	30	2.5	71	...1g ...2g
4. Ring kitchen	30	2.5	71	...1g ...2g
5. Immersion Heater	15	2.5	35	1
6. Lights upstairs) Bathroom fans)	5	1.0	43	
7. Lights downstairs	5	1.0	43	
8. Boiler	5	1.0	43	
9. Smoke detectors	5	1.0	43	

Figure 2.2 **Project specification for standard three bedroom house.**

Wiring systems and cable sizes

Circuit design is discussed in detail in Chapter 9. Traditionally domestic installations have been wired using the 'three plate rose' lighting system and ring circuits for power socket outlets.

The specification illustrated for this three bedroom house uses *conventional circuits* as described in the *IEE On-Site Guide*. The Guide explains that this system will comply with the Regulations and, provided that the circuit cable lengths are not exceeded, no calculations are necessary.

Lighting

Various arrangements for lighting circuits have become standardized in different localities. Two methods are shown in Fig. 2.3 and these utilize twin and earth cables for all runs except two-way switch linkages. It is important to
512–05 run conductors in pairs now that a European Directive requires the reduction of electromagnetic interference which may be a particular nuisance with fluorescent lighting or where dimmer-switches are used.

Wiring should be arranged with phase/neutral or feed/return cables twinned to minimize interference. Separate single-core cable runs should be avoided. For the same reason the most suitable two-way switching arrangement is as shown in Fig. 2.4.

It is a matter of choice whether the connection on to the next lighting point is made at the wall switch or ceiling rose. As far as possible the systems should

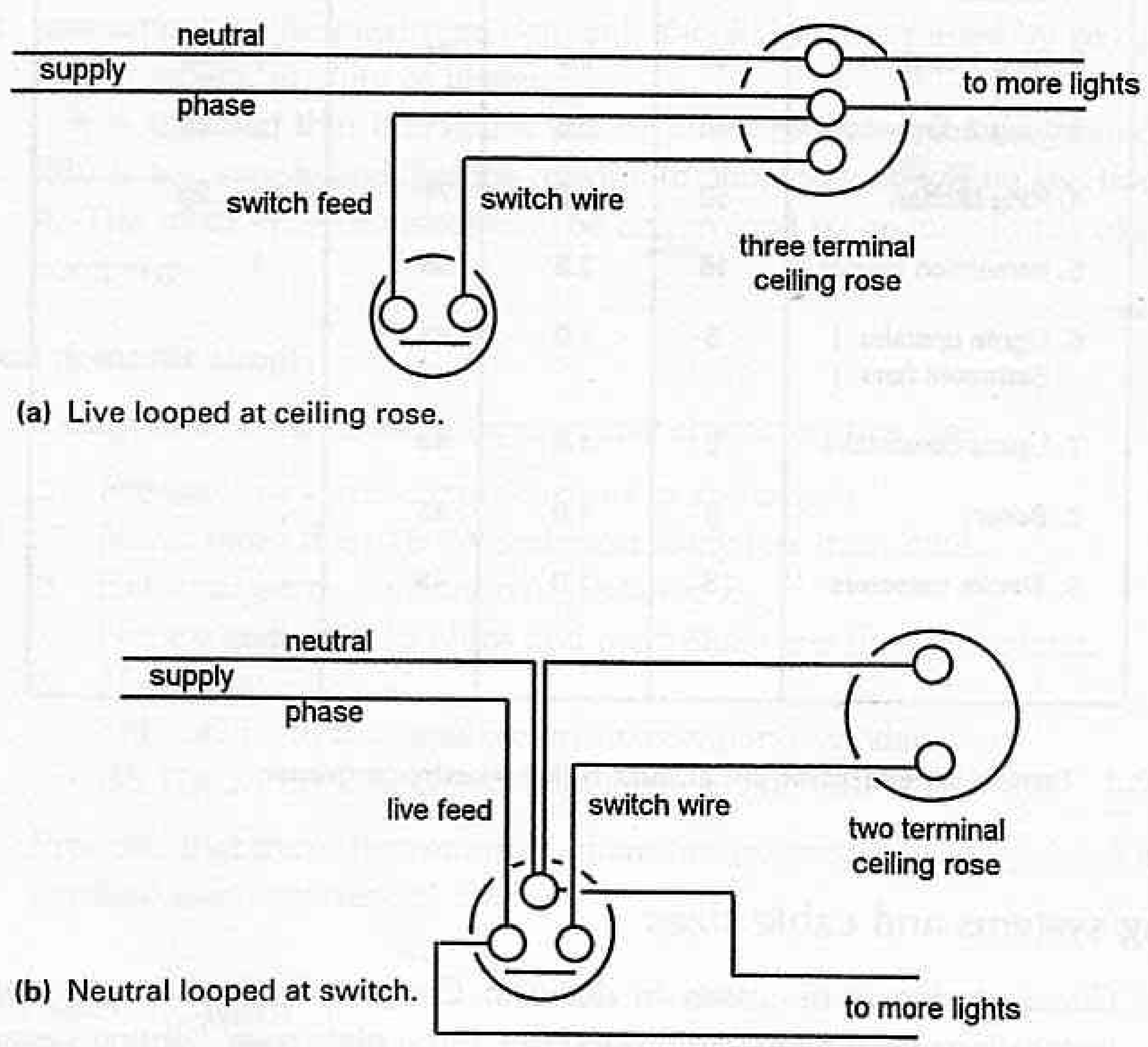


Figure 2.3 **Alternative lighting circuitry using twin cable.**

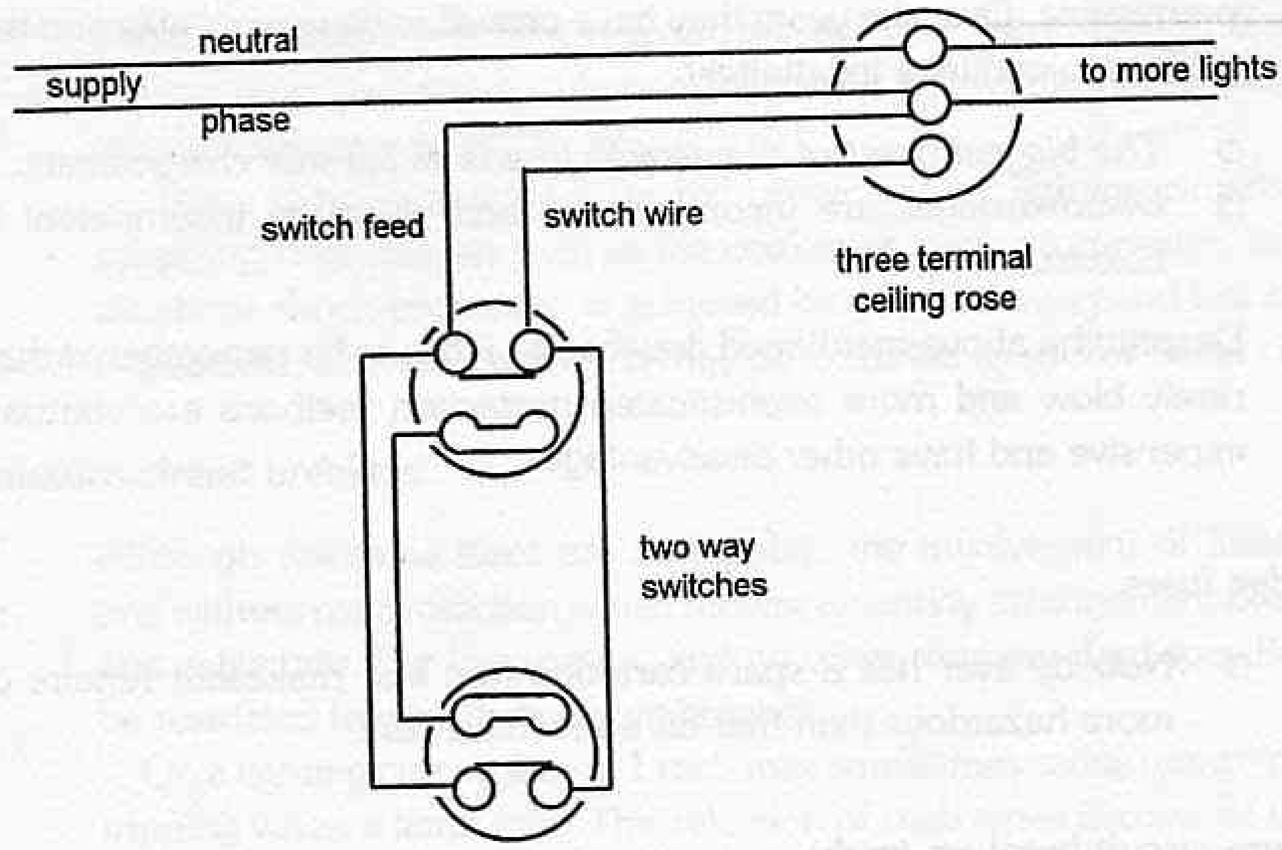


Figure 2.4 **Two way switching avoiding inductive problems.**

not be mixed. This will only cause confusion when alterations or periodic testing are undertaken.

13 A socket outlets

There are several reasons (see Chapter 9) why a ring circuit is not always the best way to service sockets. This design shows traditional arrangements with three ring circuits but alternative 'tree' circuits may be considered to be more appropriate and save wiring.

Cable sizes

Conventions on sizing have developed in the industry. These are the sizes shown on the Project Specification and are adequate for lengths of run as indicated. For very large houses it is generally more economic to run one or more sub-mains to remote areas, rather than increasing final circuit cable sizes.

Circuit protection

Rewirable fuses

533-01 Most people in the electrical industry would like to see the demise of rewirable fuses. The Regulations express a preference for other devices but they are still permissible. Over the years they have proved to be very reliable and their use is likely to continue indefinitely.

- *The biggest asset* of a rewirable fuse is its fail-safe characteristic.
- *Disadvantages* are inconvenience and abuse by incompetent householders.

Despite the above-mentioned drawbacks, it has to be remembered that fuses rarely blow and more sophisticated protection methods are comparitively expensive and have other disadvantages.

Cartridge fuses

341–01
- Nobody ever has a spare cartridge fuse and makeshift repairs can be more hazardous than that on a rewirable fuse.

Miniature circuit breakers (mcb)

- An mcb is very expensive for such infrequent use but it is the most user-friendly device when there is a fault.

Earth leakage protection

471–16 To a significant extent the overcurrent protective device debate has been solved by a new requirement for shock protection in the 16th edition of the Wiring Regulations. This is that any socket outlet rated at 32 A or less which may reasonably be expected to supply portable equipment for use outdoors shall be provided with supplementary protection, i.e. a 30 mA rcd.

For this particular design project it would be difficult to assess which of the domestic sockets come into this outdoor-use category. Certainly all the downstairs sockets are potential lawnmower connections. Therefore, for peace of mind and in the interests of standardization a decision has to be taken. It is recommended that the norm for all domestic installations should be for each socket outlet to be rcd protected. Various methods are considered in Chapter 7, but the result will inevitably be associated with an mcb consumer unit.

Arrangement of circuits

Residual current protection

It has been shown above that all socket outlets which could be used to supply portable equipment outdoors must have 30 mA protection. All sockets on this

particular design will be protected by an rcd. Nevertheless, it would be
314–01 inconvenient and cause nuisance tripping if the whole house was supplied through one very sensitive 30 mA rcd.

There is no requirement for rcd protection for lighting circuits or those supplying fixed heaters such as the cooker or immersion heater. In the latter situations shock-protection is achieved by good earthing and low earth loop
413–02 impedance. The rcd protection may be confined to socket outlet circuits.

Miniature circuit breakers

Although rewirable fuses are acceptable, the involvement of fuseways with and without rcd protection would require an untidy arrangement of enclosures and cable tails. For this reason, and no other, this standard specification will be restricted to miniature circuit-breakers.

On a lighting circuit, a type 1 mcb may sometimes cause minor irritation by tripping when a lamp fails. The selection of mcb types is covered in Chapter 4. For this domestic installation types 2 or B would be appropriate, with virtually any M rating in a 16 kA conditionally rated enclosure.

Split load consumer unit

There are many ways of making the separation:

- *Circuits with rcd protection*
  All 13 A socket circuits
- *Circuits without rcd protection*
  Lighting
  Immersion heater
  Cooker
  Boiler
  Smoke detectors

In this case, probably the most cost-effective consumer unit arrangement is to install a board with provision for ten outgoing circuits plus room for an rcd. The number of outgoing ways on the specification will depend upon the size of the rcd module (see Fig. 2.5).

Main switch

The purchaser of a single consumer unit has little choice in the selection of the main switch. This will be specified by the manufacturer. Most units will accommodate a 100 A double pole isolator. A switch with a lower current rating is inappropriate for a whole-house load.

476–01 amended A main switch for operation by unskilled persons, e.g. household or similar, shall interrupt both live conductors of a single phase supply.

Chapter 3

A Block of Retirement Flatlets

Flats and maisonettes are built in large and small complexes with a range of floor levels at both high and low rise. The pattern of electrical distribution varies in accordance with the developer's arrangements for metering and the electricity company's distribution system.

An example is given for a block of 11 retirement flatlets with some common facilities provided by the landlord. This may be local authority rented accommodation or a private scheme for sheltered housing.

The basic electrical installation specification could be adapted for student accommodation or self-catering holiday flats.

Two schemes

There are two components to the electrical design which will be treated separately:

- *Part 1*. Tenants' installations and wiring within flats,
- *Part 2*. Landlord's installation and services in common areas.

Early considerations

Metering and distribution

This subject requires early discussion with the electricity company and the client. The whole electrical distribution system depends upon who pays the electricity bills and where meters are to be sited.

Metering alternatives include:

- One landlord's metered supply with either unmetered services to tenants or landlord's metering within flatlets,
- Individual electricity company services to tenants with meters in flats,
- Individual electricity company services to tenants with central metering.

The last arrangement is usually preferred by the electricity company.

There are advantages with centralized meter reading and having the a 16 mm^2 twin and earth cable is large enough for the pme earthing conductor.

Main earthing terminal

The consumer's earthing terminal will be located within, or adjacent to the consumer unit. This is the point where the supply earthing conductor joins the main bonding conductors within the flat.

Bonding

Standard main bonding requirements apply for 10 mm^2 connections to
547–02 incoming water, gas or oil piping. This bonding is to be applied within 600 mm of the point of entry into the flat.

601–04 Supplementary bonding is required in the bathroom. This is best achieved in the adjacent airing cupboard, as described in Chapter 2.

PART 2 – LANDLORD'S AREAS

Meter cupboard

This cupboard is used to enclose:

- The electricity company's intake and metering equipment.
- Eleven meters and main switches for tenants' supplies.
- The landlord's meter and distribution board.

It is preferable for the meter cupboard to be used exclusively for electrical
513–01 equipment and it must not be used for the storage of cleaning materials. There should be clear space in front of equipment for routine meter reading and clear access for emergency attention, e.g. fire-fighting.

Supplies to flats

The loading for each flat will be handled by a 100 A switch fuse with a 63 A
523–04 BS 88 fuselink. This will protect the 16 mm^2 rising/lateral main. Cables should not be bunched and routes should avoid thermal insulation, otherwise downrating factors will require the use of 25 mm^2 cables.

Cables should be routed in protected ducts, through public areas. It is not normally acceptable to run one consumer's cables through another consumer's property. Steel-wire-armoured cable is generally used but non-armoured sheathed cable would be acceptable provided that it is adequately protected against physical damage.

Table 3.3 **Landlord's services, cable sizes and circuitry.**

Circuits	*mcb rating* (Type 1 or 2)	*Cable size* (mm^2)
Lighting, lounge	6 A	1.0
Lighting, stairs	6 A	1.0
Smoke detector	6 A	1.0
Sockets		
kitchen	32 A tree	4.0
	or	
	32 A ring	2.5
lounge	20 A tree	2.5
	or	
	32 A ring	2.5
Washing machines	32 A tree	4.0
	or	
	32 A ring	2.5
Cooker	32 A	6.0
Lift	10 A	2.5

Landlord's electrical requirements

The full schedule is given in Table 3.3. Fire alarms, smoke detectors and emergency lighting are not included, these must be discussed with the relevant statutory authorities.

Diversity

The IEE Guidance Note does not show a situation that exactly fits these landlord's premises. The nearest type of accommodation listed in the Guide is
313-01 that for a small hotel. Estimation of diversity is not an exact science and some judgements must be made based upon experience and consultation with the client.

It is possible that the kitchen facilities in the common room may be used fully on winter evenings, but at such times it is unlikely that the laundry equipment will be in use.

For current loading calculations, fluorescent lamp ratings must be multiplied by 1.8 to take into account control gear losses.

Lighting

Stairs, etc.	$12 \times 24\,W \times 1.8$	=	518 W
Toilets	$2 \times 24\,W \times 1.8$	=	86 W
Lounge, kitchen and laundry	$5 \times 58\,W \times 1.8$	=	522 W

Apply 75% diversity

$$\text{Current} = \frac{1126 \times 75\%}{240} = 3.5\,A$$

Socket outlets

There is central heating. Kitchen equipment and a laundry iron will be used:

Assume 100% load of one circuit = 32 A

Other equipment

Cooker at 80% = 32 A

Washing machine and drier at 75% = 18 A

Boiler and lift – Ignore.

Total load

Estimated maximum demand = Approx. 86 A

A single phase 100 A service will be appropriate.

Cable sizes and circuitry

This is a conventional building structure. PVC twin and earth 6242Y type cables are acceptable (see Table 3.3). Refer to the notes for wiring in flats for installation details, including cables in false ceiling cavities.

Lighting

The total lighting load is low. To avoid inconvenience in the event of a fault, two circuits are suggested using 1.0 mm^2 cables.

Socket outlets

Socket outlets will carry heavy loads in the kitchen and in the laundry. In other rooms only small appliances will be plugged in. It is suggested that three circuits will be appropriate. Table 3.3 provides for the use of both 2.5 mm^2 ring or 4.0 mm^2 tree circuitry.

Project Specification
BS 7671

Name...................... Landlord's services in block of flats

Reference................ Date.....................

240 V 50 Hz. TN-C-S. Supply fuse 100 A BS 1361 or BS 88

PFC less than 16 kA. Earth loop impedance less than 0.35

Consumer unit in landlord's cupboard BS 5486
100 A main switch

8 way M6 Type 2 mcbs

Circuits	Rating (A)	Cable size (mm^2)	Max run (m)	Lights/points g = gang
1. Cooker	32	6.0	43	1
2. Ring 1 kitchen)	32	2.5	71	3 x 2g
Boiler)				1
3. Ring 2 lounge & stairs	32	2.5	71	6 x 2g
4. Washing machines	32	2.5	71	2
5. Lights lounge)	6	1.0	43	7
Toilet fans)	2			
6. Lights stairs	6	1.0	43	10
7. Smoke detectors	6	1.0	43	
8. Lift	10	2.5	43	1

Figure 3.4 **Project specification for landlord's services.**

Other equipment

Separate circuits will be necessary for the cooker and the lift. Spare ways will need to be provided for emergency lighting and fire alarms. The minimal boiler supply requirement can be taken from a local socket outlet circuit.

Distribution board

A conventional domestic type is appropriate. This should be easily accessible.
513–01 If the unit is locked for security purposes, the location of the key should be clearly indicated.

Residual current protection

The Wiring Regulations only require rcd protection for sockets which may be used to supply portable equipment outdoors. To satisfy this requirement for
476–16 landlord's gardening maintenance, one integral 30 mA rcd socket could be designated for this use.

The local authority may require rcd protection for sockets in the common room which may be used for public social activities. It is also sensible to protect cleaners' sockets in public areas.

In the circumstances, the system has been designed using a split bus-bar mcb consumer unit. Circuit arrangements are shown in Fig. 3.5. Lighting circuitry and the lift supply should not be given rcd protection.

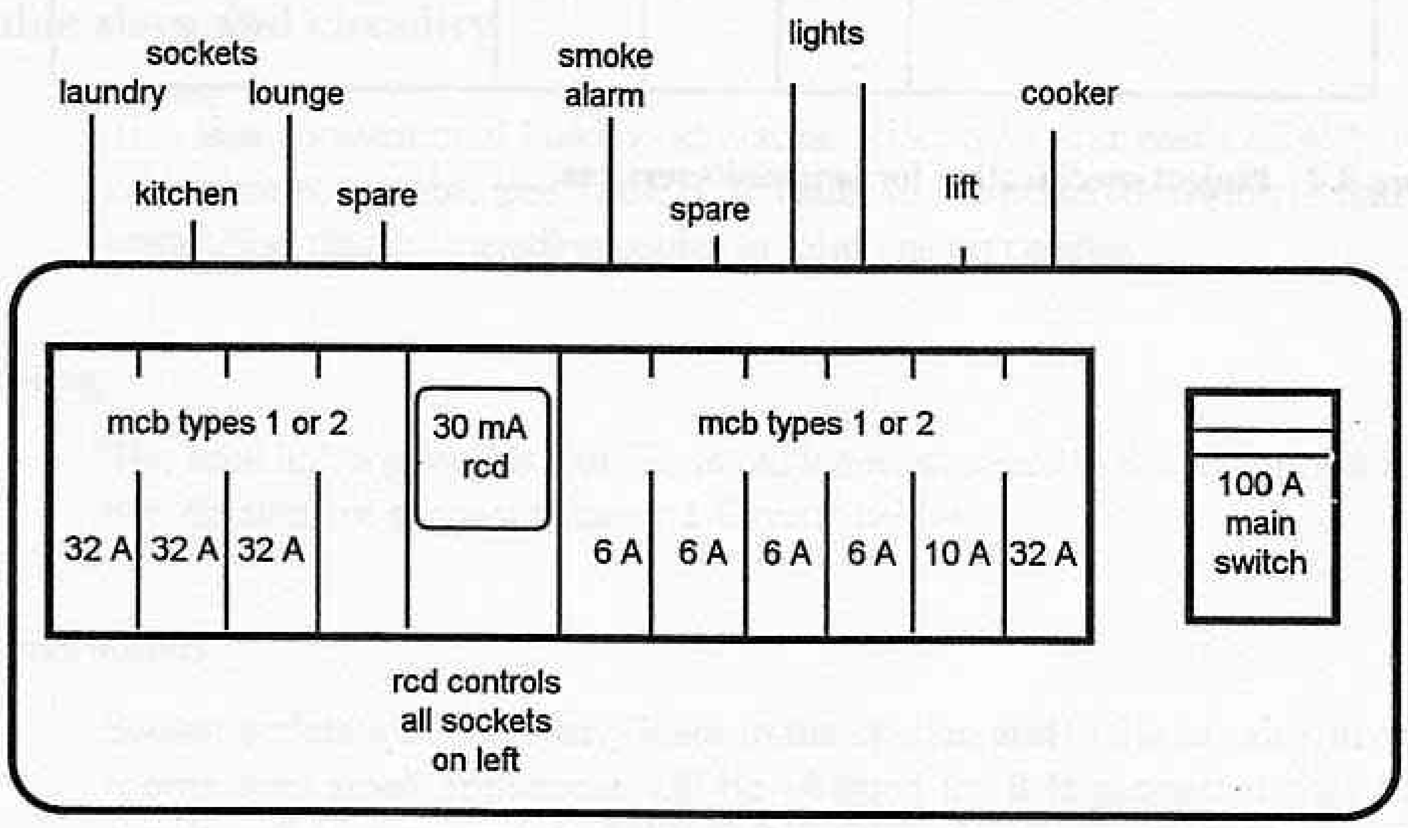


Figure 3.5 **Landlord's distribution board.**

Switchgear

Labelling

514–09 All equipment in the meter cupboard must be carefully labelled giving flat numbers corresponding to switchgear. It is probable that a 415 V label will be
514–10 required to indicate the presence of three-phase voltages between different consumers' equipment.

Switching

Standard requirements apply as in flats.

Wiring

514–01 amended As far as is reasonably practicable, wiring should be arranged and marked so that it can be identified for testing, repair or alteration.

Earthing

The installation of the landlord's supply may be treated in a similar manner to
542–04 that of the supply to flats. Main bonding is required between the landlord's distribution board, main earthing terminal and other landlord's service entries, in the same way as that shown in Fig. 3.2 for flats.

Emergency systems

Details of fire alarm and emergency lighting provision should be added to the specification.

landlord take responsibility for electrical distribution in the building. A disadvantage may be the possibility of vandalism at the central meter room.

This exercise uses the above central metering system. The plan provides the opportunity to design distribution mains to flats and to answer common problems with earthing arrangements for multiple dwellings.

Other interested parties

- *Fire authority*
  Fire alarms and emergency lighting
- *Environmental health authority*
  Landlord's kitchen and common rooms
- *Lift installer*
  Special requirements
- *Aerial specialist*
  Amplifier for TV distribution system
- British Telecom

Building details

Construction

This is a new development, but the electrical scheme could be adapted for a refurbishment or conversion contract.

- *Design* (see Fig. 3.1)
  Three storey, four flats per floor on the upper two levels, three flats plus common rooms on the ground floor.
- *Walls*
  Externally and between flats, brick or other masonry.
  Partition walls within flats, plasterboard on timber studding.
  Plastered internally.
- *Floors*
  Ground floor, heavy concrete base, upper floors concrete beams all with 50 mm levelling screed.
- *Ceilings*
  Ground and first floor, plasterboard on battens.
  Second floor, plasterboard on timber beams under a pitched roof.
- *Lift*
  Hydraulic mechanism.
- *Heating*
  Gas or oil central boiler in each flat and one in the landlord's common room area.

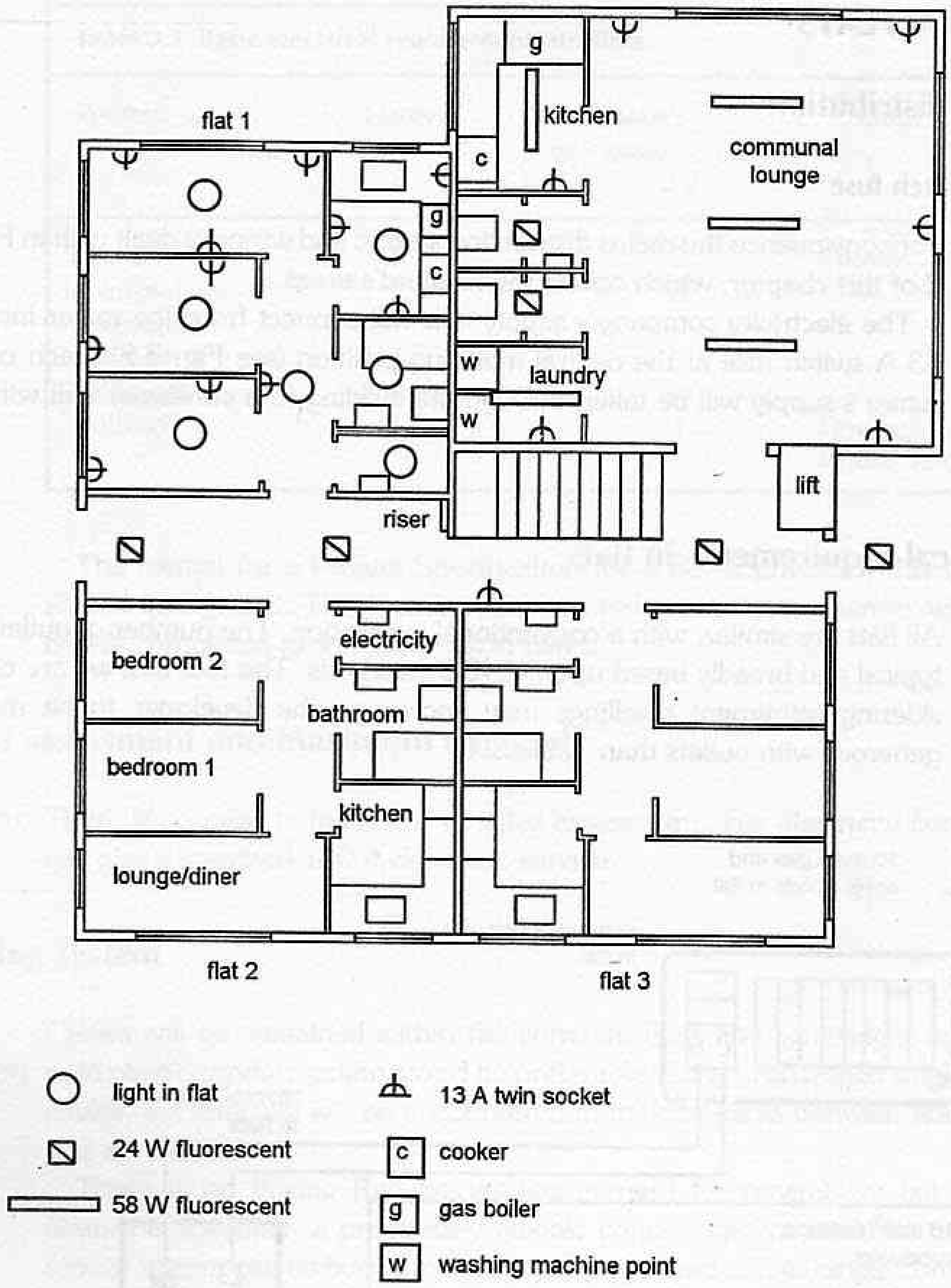


Figure 3.1 **Layout of ground floor flats.**

PART 1 – FLATS

Mains distribution

Main switch fuse

For convenience the mains distribution system and wiring is dealt with in Part 2 of this chapter, which covers the landlord's areas.

The electricity company's supply tails will connect from the meter into a 63 A switch fuse at the central metering position (see Fig. 3.2). Each consumer's supply will be taken through the building to a consumer unit within each flat.

Electrical requirements in flats

All flats are similar, with a conventional installation. The number of outlets is typical and broadly based upon NHBC standards. The fact that we are considering retirement dwellings may encourage the developer to be more generous with outlets than Table 3.1.

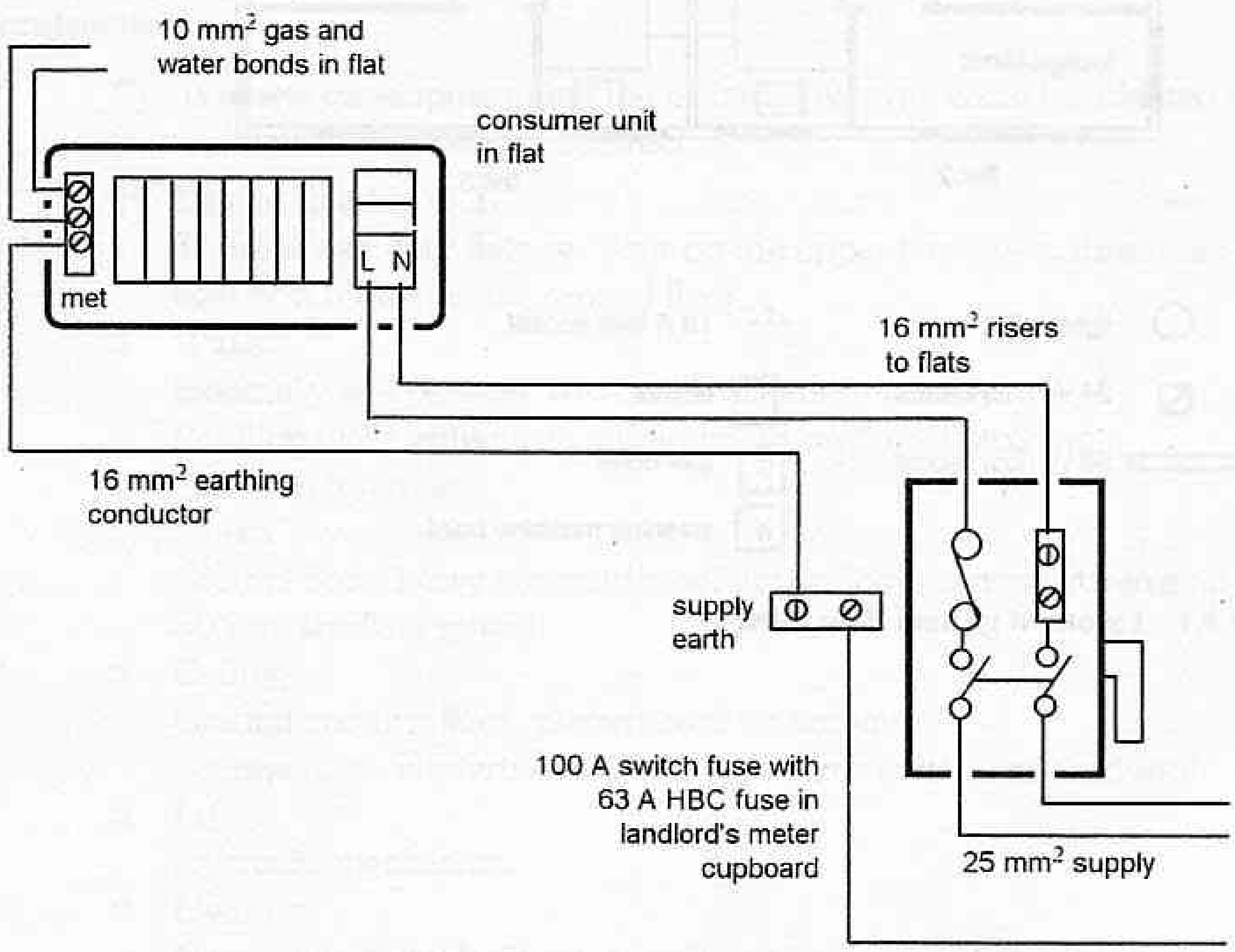


Figure 3.2 **Distribution to flats.**

Table 3.1 **Basic electrical requirements for flats.**

Rooms	*Lights*	*13 A sockets (g = gang)* 1 g	2 g	*Other*
Kitchen	1		3	Cooker
Lounge/diner	1	—	3	
Bedroom 1	1	—	2	
Bedroom 2	1	—	2	
Bathroom	1	—	—	
Hallway	1		1	Doorbell Smoke detector

The format for a Project Specification for a development of this type is shown in Fig. 3.3. This layout could be used for various schemes with full details completed to suit the work in hand.

Load assessment and maximum demand

311-01 There is no need to make any detailed assessment. The electricity company will give a standard 100 A domestic service.

Wiring system

Cables will be contained within the concrete floor and lightweight walls. A
522-06 rigid plastic conduit system would be preferable, using unsheathed single-core cables, but difficulty will be encountered in making joints between floor and wall conduits.

There is no Wiring Regulations requirement for rewirability but if this feature is specified, a proprietary flexible conduit system could be used. A typical system can be buried in concrete screeds and utilises single core cable with special outlet boxes and jointing arrangements.

Probably the best 'off the shelf' solution, without rewirability, is to use standard twin-and-earth cable. Theoretically, twin-and-earth cable may be buried direct into concrete but for wiring convenience, plastic conduit will be cast into the floor screed.

Wiring hints

- Light gauge, rigid PVC conduit is suitable for casting into concrete screeds but care must be taken to prevent damage to the conduit before

Project Specification BS 7671				
Name...................... .Flat No. .... Location........................ Reference................ Date.....................				
240 V 50 Hz. TN-C-S. Supply fuse 100 A BS 1361 or BS 88 PFC less than 16 kA. Earth loop impedance less than 0.35				
Main switch-fuse in meter cupboard 63 A BS 88 fuse Sub main to flat 16 mm^2 swa 3-core				
Consumer unit in flat BS 5486. 100 A main switch 6 way M6 Type 2 mcbs				
Circuits	Rating (A)	Cable size (mm^2)	Max length (m)	Lights/points g = gang
1. Cooker	32	6.0	43	1
2. Ring 1 kitchen) Boiler)	32	2.5	71	3 x 2g
3. Ring 2	32	2.5	71	7 x 2g
4. Lights 1) Bathroom fan)	6	1.0	43	3
5. Lights 2	6	1.0	43	4
6. Smoke detector	6	1.0	43	

Figure 3.3 **Project specification for a typical flat.**

the concrete is poured. Heavy gauge conduit is more robust but has slightly less cable space.

- It is essential to have at least 16 mm of concrete cover over plastic conduit. This may be difficult if there are crossovers in the conduit runs.
- Ensure that there are draw wires or strings left in all unwired buried conduits.

Wiring in false ceilings

On the ground and first floors the ceilings are of plasterboard fixed to timber battens on the soffit. The use of sheathed cable is acceptable in this space but subject to the same protective requirements as those for cables under floor-
522–06 boards. The Wiring Regulations require that unprotected cables which do not incorporate a metallic sheath, when installed above a plasterboard false ceiling, must be at least 50 mm from the underside of the batten.

A convenient arrangement to comply with this requirement is to cross-batten the ceiling to give a 75 mm space above the plasterboard. This has the added advantage that cables may be easily routed in any direction with minimal drilling or notching.

Cross-battening arrangements should be negotiated early in the contract. Where there are on-site objections from the builder, cables must either be mics; or PVC installed in earthed conduit; or given equivalent physical protection against penetration by nails. This is obviously an expensive alternative to the cross-battening or a notched 75 mm batten.

The use of thin metallic or plastic cable capping as physical protection is not adequate in these locations.

Wiring in roof space

This may be conventional twin-and earth cable fixed to the timber joists. The
523–04 roof space will get hot in summer months and it is advisable to keep cables clear of thermal insulation. The lighting loads for flats is minimal and no cable derating is necessary.

Cable sizes

All cable loads are relatively low and distances are short. No special factors
App. 4 apply (see Table 3.2).

Table 3.2 **Cable sizes and circuitry for flats.**

Circuits	*mcb rating* (Type 1 or 2)	*cable size* (mm^2)
Lighting 1	6 A	1.0
Lighting 2	6 A	1.0
Smoke detector	6 A	1.0
Sockets 1	20 A tree	2.5
	or	
	32 A ring	2.5
Sockets 2	32 A tree	4.0
	or	
	32 A ring	2.5
Cooker	32 A	6.0

Arrangement of circuits

Lighting

314–01 Even though these are small flats, there must be more than one lighting circuit per dwelling to ensure that the operation of a single device does not plunge the flat into darkness. This applies to all types of dwelling with more than about four lights and is especially important for sheltered accommodation.

Smoke detector

A separate 6 A circuit is required to comply with the Building Regulations.

Socket outlets

The kitchen should be considered separately. Either a 30 A ring or 30 A tree system is appropriate for heavy loading. For the rest of the flat a 20 A tree system would be acceptable or a 30 A ring circuit. See Chapter 9 for ideas on circuitry.

Boiler supply

The electrical loading for the gas/oil central heating system is negligible and may be fed through a fused spur on the local socket outlet circuit. British Standards require a switch adjacent to the boiler or programmer to isolate the complete system.

Consumer unit

Residual current protection

471–16 If there are no gardens associated with flats and no likely use of portable equipment out of doors, there is no requirement for any rcd protected sockets. However, many specifiers require 30 mA rcd protection to all sockets, especially for sheltered accommodation.

If rcd protection is given to sockets it is not acceptable to use a 30 mA rcd as
314–01 a main switch. This could cause nuisance tripping. Protection of sockets should be given separately either with a split bus-bar consumer unit, preferably with combined mcb/rcd units.

Circuit protection

If it is decided that no rcd protection is required, this is one situation where it
533–01 may be economical for the installer to use rewirable fuses. The subject should be discussed with the client and careful note taken of the long-term main-
341–01 tenance requirements of tenants. Regulations require that equipment shall be suited to the intended purpose. Rewirable fuses are not suitable for disabled or
512–06 sheltered accommodation.

Accessibility

The consumer unit must be accessible for the intended occupier. Once again note must be taken of occupier requirements.

A similar judgement should be made on the location of the cooker control
476–03 switch which may be required in an emergency. If a sink waste disposal unit is installed, this must also have an emergency switch conveniently to hand.

Earthing and bonding

Each flat has a separate electrical installation with a metered supply. An
542–04 equipotential zone must be set up within the flat. Bonding of a landlord's water and gas mains to the 100 A switch in the remote meter cupboard would not give reliable protection to the installation. It is necessary to take a full size 16 mm^2 earthing conductor to the main earthing terminal in the flat. This is shown in Fig. 3.2.

The supply company may permit the use of the third wire in a 16 mm^2 three-core steel wire armoured cable to be used as an earthing conductor on a pme supply. If a two-core cable is used, a separate 16 mm^2 earthing conductor will be required. Neither the armouring of an swa cable or the 'earth' in

Chapter 4

Overcurrent Protection

There are two reasons for overcurrent:

- *Overload*

Defs This is overcurrent occurring in a circuit which is electrically sound. Examples are a user connecting too many appliances or applying excessive mechanical load to a machine.

- *Fault*

  This is overcurrent occurring as a result of a faulty installation. Examples usually involve the failure of insulation causing a short-circuit between conductors or to earth.

The two conditions are quite different by way of cause and effect. Action to lessen safety hazards is either with practical measures to detect and remedy fault conditions or to apply regulations which are intended to prevent the occurrence of overcurrent. In most circumstances, overload and fault current protection willl be given by one common device.

Overload

There are many reasons for the overloading of healthy wiring, including:

473-01
- An electric motor undertaking mechanical duty in excess of design parameters,
- Faulty running of machinery caused by bearing failure or uneven loading,
- A motor starting current,
- Loss of a phase from a three-phase load,
- Excess loading added to a socket outlet circuit,
- An underestimate of the maximum demand of an installation.

Overloads often arise gradually and at the early stages may not be apparent when testing is carried out. The transition from excess loading to overloading on a main service may result as a combination of unplanned extra sub-circuit demand.

The purpose of overload protection is to detect and clear an overloaded circuit before it becomes dangerous or damages the installation. A small overload may not cause an immediate hazard and may be tolerated by protective devices for a long time A simple example is with a 13 A fuse. This will not rupture if the load current creeps up to 13 A. It should operate indefinitely at this nominal load without producing dangerous overheating. The consequence is that it will continue to operate with a load of 18 A for some minutes. Additionally, it will tolerate even larger overload surges to avoid nuisance operation.

Thus, for example, the 13 A fuse will accept an 'instantaneous' overload of double its rating.

Overload protection

A protective device must be used to break overload current before any thermal damage is done to cable insulation or other load-carrying parts of the installation.

433–02 ☐ The *nominal rating* of the device must be:

· Greater than the design current for the circuit and less than the operational rating of any conductor being protected.

☐ The *operating current* must not exceed:

1.45 × the current rating of any conductor being protected after correction for grouping, etc..

There are some conditions where the above overload protection need not be applied to a conductor:

473–01 ☐ Where there is a reduction in conductor size but the upstream protection gives effective protection to the smaller conductor, or

☐ Where the load is such that it is unlikely to be overloaded, e.g. a fixed lighting system, or

☐ At the intake position where the supply authority's equipment gives appropriate protection.

473–01 amended The above relaxations may not be applied where there is an abnormal fire risk or risk of explosion and where special requirements apply.

Overload protective devices

Rewirable fuses

Although accepted by the Wiring Regulations, preference is given to other
533–01 devices. Provided that they are correctly wired, these fuses are fail-safe and for s nple situations are troublefree until abused.

One major technical disadvantage is that a cable down-rating factor of 0.725 has to be applied to a circuit protected by a rewirable fuse. Fault current breaking capacity is limited. This will be covered later in this chapter.

To avoid the above complications, rewirable fuses are not specified for projects in this book. However, if note is taken of technical and practical limitations there is no reason why they should not be used in suitable circumstances.

HBC fuses

341–01 These are fail-safe devices with excellent characteristics but liable to abuse when no spares are available. The installations covered by this book usually do not have skilled electrical maintenance personnel. For this reason HBC fusing is not specified.

HBC fuse protection will be fitted by the supply authority in sealed meter heads and HBC type g(G) fuses may be used for large main distribution fusegear as an alternative to moulded case circuit breakers.

Motor circuit protection fuses have a g(M) characteristic. This gives a
435–01 continuous operating rating and a motor starting rating. The subject is beyond the scope of this book but is an essential study for motor installers. Suppliers' technical literature.usually provides the best scource of information.

Miniature circuit-breakers

It is often said that these devices may not fail to safety, nevertheless their reliablity is beyond question for most installations. If there is no choice but to install switchgear in a damp arduous situation, HBC fuses may give better long-term operational reliability.

In all normal locations, the use of mcb distribution boards is recommended to give the most user-friendly protection.

The mcb type number

Mention has already been made of the necessity for an overload protection device to be able to withstand moderate overloading. By their nature, fuses run warm on full load and have a 'fusing factor' set by their operating characteristics. It is possible to design a circuit-breaker with an exact operational cut-off point and, in fact, a residual current device is designed to disconnect at not more than the rated current. However, this would be inconvenient for an mcb.

For large fault currents a British Standard mcb will trip *instantaneously*, i.e. within 0.1 s. There is a range of characteristics related to overload conditions. These are designated by the *type* of an mcb (see Table 4.1).

An example will indicate the method of selection:

Consider a 30 A type 2 mcb used on an office socket outlet circuit. Table 4.1 shows that this will carry between 120 A and 210 A for a few seconds before disconnection. The actual tripping current between 120 A and 210 A depends upon manufacturing tolerances and the way that the overcurrent builds up. With an overcurrent in excess of 210 A the mcb will trip in less than

Table 4.1 **Type characteristics of an mcb.**

mcb type	*Tripping current range* (Factor to be multiplied by nominal rating)	*Typical application*
1	2.7 to 4	Domestic and where overload surges are not anticipated.
B	3 to 5	General purpose and commercial.
2	4 to 7	General purpose and commercial.
3	7 to 10	Motors and highly inductive discharge lighting.
C	5 to 10	Motors and highly inductive discharge lighting.
4	10 to 50	Only for special conditions, e.g. some welding plant.
D	10 to 20	Only for special conditions, e.g. some welding plant.

0.1 s. A type 2 or type B mcb is usually a suitable standard choice for most domestic and commercial installations but, as will be seen later, this depends on the earth loop impedance.

Fault current

473–02 Fault current is invariably caused by some failure in the installation. This may be because:

- Cable insulation has been damaged by heat or abrasion,
- Water has entered into a badly protected connection,
- A motor has burned out,
- A metal tool has fallen across bus-bars.

The consequences of a fault may be a fire or explosion resulting in serious burn injuries or even death.

A fault may occur between any conductors of the supply system, or to earth, or between both simultaneously. Speedy disconnection is essential.

The initial surge of fault current is usually measured in thousands of amps (kA) and is only limited by the impedance of the supply up to the fault position. This is known as the Prospective Fault Current (pfc). There will be a very short period of time before any protective device reacts to this overcurrent.

Fault current protection

The purpose of fault current protection is to disconnect the supply speedily and to restrict damage and danger as far as possible.

All parts of an installation must be protected against the highest pfc that can be anticipated at any particular point in the system. The pfc is at its highest protection at the intake position and will decrease or *attenuate* through the installation as the resistance of cables is added to the fault path.

Omission of fault current protection

473–02 In some conditions, fault current protection may be applied downstream, on the load side of part of the system. The conditions are:

- If the unprotected conductor up to the protection device is less than 3 m in length, and
- This conductor is so located that it is unlikely to experience a short circuit or earth fault, and
- Has superior physical protection against risks of fire and shock.

This arrangement usually applies where short and relatively small cables are connected to heavy current bus-bars to take a supply to lightly loaded fuse switches.

Enclosure in conduit or trunking is regarded as superior physical protection and the cables in question should be separated from other circuitry. Consideration must be given to the consequences of 'flash-over' between live parts.

473–02 amended The above relaxations may not be applied where there is an abnormal fire risk or risk of explosion and where special requirements apply.

Short circuit rating

Under short circuit conditions there will be a considerable current surge. This is the pfc referred to previously. For a standard 100 A supply the pfc may be as high as 16 000 A (16 kA). Much will depend upon the supply authority network and distance from the substation.

More usually the figure will be less than 5 kA. This current will flow until the
432–02 fuse ruptures or mcb contacts separate. During this period, before the separation arc is extinguished, the protective device must be able to withstand

Table 4.2 **Breaking capacity of devices.**

Device	*Breaking Capacity* (kA)
BS 1361 fuse, Type 1	16.5
Rewirable fuses (see marking on fuse carrier)	S1 = 1 S2 = 2 S4 = 4
mcbs to BS 3871 (see marking)	M6 = 6 M9 = 9

the heat and physical stress. This is known as the breaking capacity of the device and on mcbs it is given an M rating.

Typical ratings are shown in Table 4.2.

It will be seen that rewirable fuses have a low rating. This is one of the reasons why they are excluded from the project examples given in this book.

British Standard domestic consumer units using rewirable fuses are a special case. Most units will be certified to have a conditional rating of 16 kA. This means that these units may be used for conventional housing applications, where it is known that the pfc will not exceed 16 kA. The conditions rely upon the ability of the consumer unit to withstand the stresses involved and the back-up provided by the supply authority fuse.

For simple domestic installations without the usual rcd requirement (e.g. flats), a rewirable consumer unit normally complies with the Regulations.

Disconnection times

The Wiring Regulations specify various maximum disconnection times for different types of circuits:

	Socket outlet circuits:	0.4 s
413–02	Fixed appliances:	5.0 s
	Supplies to outdoor equipment:	0.4 s
Part 6	Farm circuits:	0.2 s
	Bathroom conditions:	0.4 s

A British Standard mcb has characteristics such that it will disconnect in less than 0.1 s provided that sufficient fault current can flow.

App. 3 On the above basis, an mcb will be appropriate for any of the disconnection times covered by the Regulations.

Earth loop impedance

The prospective fault current through an earth fault depends on the maximum earth loop impedance at the point of the fault. If this is lower than figures given in the Regulations there will be 0.1 s disconnection.

413–02 amended The amendments to BS 7671 indicate that standard mcb protection is deemed to comply with the need to take account of the increase in temperature and resistance of circuit conductors as a result of overcurrents. Circuit loop impedances given in the Regulations cover this condition and should not be exceeded where the conductors are at their normal operating temperature. However, if the conductors are at a different temperature when tested, the reading should be adjusted accordingly.

This requirement creates a special problem in that the person carrying out tests will not be certain of the normal operating temperature. In the circumstances it will be safe to assume the maximum permissible operating temperature of the cable. In the case of pvc insulated cables, this is 70°C. Table 4.3 has been derived for typical test conditions on projects in this book. For other situations, refer to the Wiring Regulations and IEE Guidance Notes.

Summary of mcb specification

413–02 amended Projects covered in other chapters have selections made for each mcb to be used in the standard circumstances described.

For non-standard projects or conditions, the following data must be assessed in order to specify an mcb for overload and short-circuit protection. Similar rules apply for fuses, but for rewirable fuses an additional 0.725 derating factor must be applied to I_Z.

- Establish the pfc to give the M rating
- Select an mcb Type to suit the application
- Calculate the nominal current rating I_n of the mcb as follows:

  The normal load current of the circuit = I_b
  Use I_b to find the next highest suitable mcb = I_n
  I_n must be adjusted for cable grouping,
  thermal insulation, ambient temperature, etc. = I_t
  I_t will be used to select a cable with a rating = I_Z

- Establish the maximum earth-loop impedance = Z_S
- Check Z_s against I_n in the appropriate tables for Disconnection Times.

Table 4.3 **Typical maximum earth loop impedance for test readings.**

mcb BS 3871/EN 60898 type	*Nominal rating* (A)	*Max. test earth loop impedance at 20°C* (ohms)
1	5	10
2	5	5.7
B	6	6.6
3 and C	6	3.3
D	6	1.6
1	15	3.3
2	15	1.9
B	16	2.5
3 and C	16	1.2
D	16	0.6
1	30	1.7
2	30	0.9
B	32	1.2
3 and C	32	0.6
D	32	0.3
3 and C	63	0.3

Conclusion

The choice of a cable size always follows the selection of a suitable overcurrent protection device.

In practice, rule-of-thumb cable sizes are used for conventional circuits and standardized designs as shown in this book. These cable sizes have been selected taking into account the type and rating of the overcurrent device.

Once a firm choice of cable has been made, it is not acceptable to change the mcb or fuse specification without a complete circuit redesign.

Chapter 5

An Architect's Office

This could be a local branch of a national organization or the operational headquarters of a small business. It could be the premises of an estate agent or an insurance broker.

For the purposes of this exercise the project is an architectural practice with two or three partners and a small staff. Electrical requirements are modest but include storage heaters and mains services for computers. Some ideas are given for clean lines and uninterruptible power supplies.

Lighting design will be specialized and is beyond the scope of this book. Basic lighting circuitry is givèn and general suggestions for extra low voltage spotlights in two areas. The layout as illustrated shows lighting and heating in order to establish loads and circuitry only. This is not a lighting or heating design scheme. Where an installer is not experienced in this type of design it is suggested that reference is made to product suppliers who usually provide a design service.

Other interested parties

Before settling the full electrical schedule a check must be made upon special or additional requirements.

- *Fire authority*
  Fire alarms, emergency lighting and other safety features especially if this office is part of a multi-occupancy building.
- *Client's insurers*
  There may be special requirements for the security of an office which contains valuable computers and documentation.
- *Computer specialist*
  Requirements for clean earth and uninterruptible power supply.
- *Landlord*
  The subject of common alarm or security systems may be of interest.
- *Health and safety*
  Lighting may be important where operators view computer screens for long periods.

Low voltage lighting

Two office areas have been planned to have decorative extra low voltage lighting.

This scheme is intended to give guidance upon wiring practice. The actual number and selection of luminaires will be a special design detail and is not included here. References should be made to suppliers regarding SELV lighting systems.

There is a choice of lv transformer systems.

Group transformers

This involves the use of relatively large transformers, each of which will supply a group of luminaires. This may have cost advantages but rating is important.

- ❐ LV lamps are voltage critical. Only the designated number of luminaires may be connected to the transformer and with some designs the output voltage will rise upon failure of one lamp. This will shorten the life of other lamps connected to the same transformer.
- ❐ The transformer may run hot and good ventilation will be essential. There
422–01 must be adequate clearance above and around the unit. Manufacturers' instructions should give this information.
- 526–04 ❐ There must be access to transformer terminations. The length of cable runs is critical and this may cause problems in locating a good accessible mounting position.
- ❐ Wiring between the transformer and a luminaire must be completely
413–06 segregated from other cables. The connection to the fitting must be contained in a fire-resistant enclosure and the final tails to the lampholder
528–01 will need to be heat resistant.
- 526–02 ❐ The wiring system is subject to SELV regulations which include no pro-
411–02 vision for earthing.

Individual transformers

These are matched to single luminaires; they usually run cool and have protective thermistors. Probably the most convenient is the type that fits through the luminaire mounting aperture and stands alongside within the ceiling cavity.

Fire prevention

All flush-mounted luminaires which project to the rear of ceiling linings must be enclosed and have adequate ventilation. Care must be taken to ensure that no combustible materials can come into contact with hot surfaces and that thermal insulation does not restrict ventilation.

422–01 LV lamps that cause a focusing or concentration of heat must be of suffi-
amended cient distance from other objects to prevent dangerous temperatures arising.

Table 5.2 **Arrangement of circuits across phases.**

Phase		*Amps* (approx.)
Red	*Lights*	
	Executive offices and conference area	4.0
	Storage heaters	37.5
	Print machine	20
	Possible total	62
Yellow	*Lights*	
	Centre office and toilets	8.4
	Storage heaters	37.5
	Window wall sockets	10
	Inside wall sockets	10
	Possible total	66
Blue	*Lights*	
	Inside office and reception	3.7
	Storage heaters	37.5
	Floor sockets	10
	Dedicated sockets (clean line)	10
	Heaters in toilets	12
	Possible total	71

Materials used for the construction of enclosures must comply with heat resistant standards.

Arrangement of circuits

Table 5.2 indicates a possible spread of circuits across phases. There is flexibility in the arrangement but it is sufficiently accurate for general applications. Actual conditions will vary with inevitable load diversification.

Distribution boards

There will be two, Type B, three phase distribution boards to accommodate normal and off-peak services (see Fig. 5.5). These will be located at the meter position. The office layout is compact and no sub-mains are required. None of the equipment has any especially high starting loads, so type 2 or type B mcbs will be appropriate. There is no requirement for rcd protection and the use of an rcd could cause nuisance tripping, especially on the computer service.

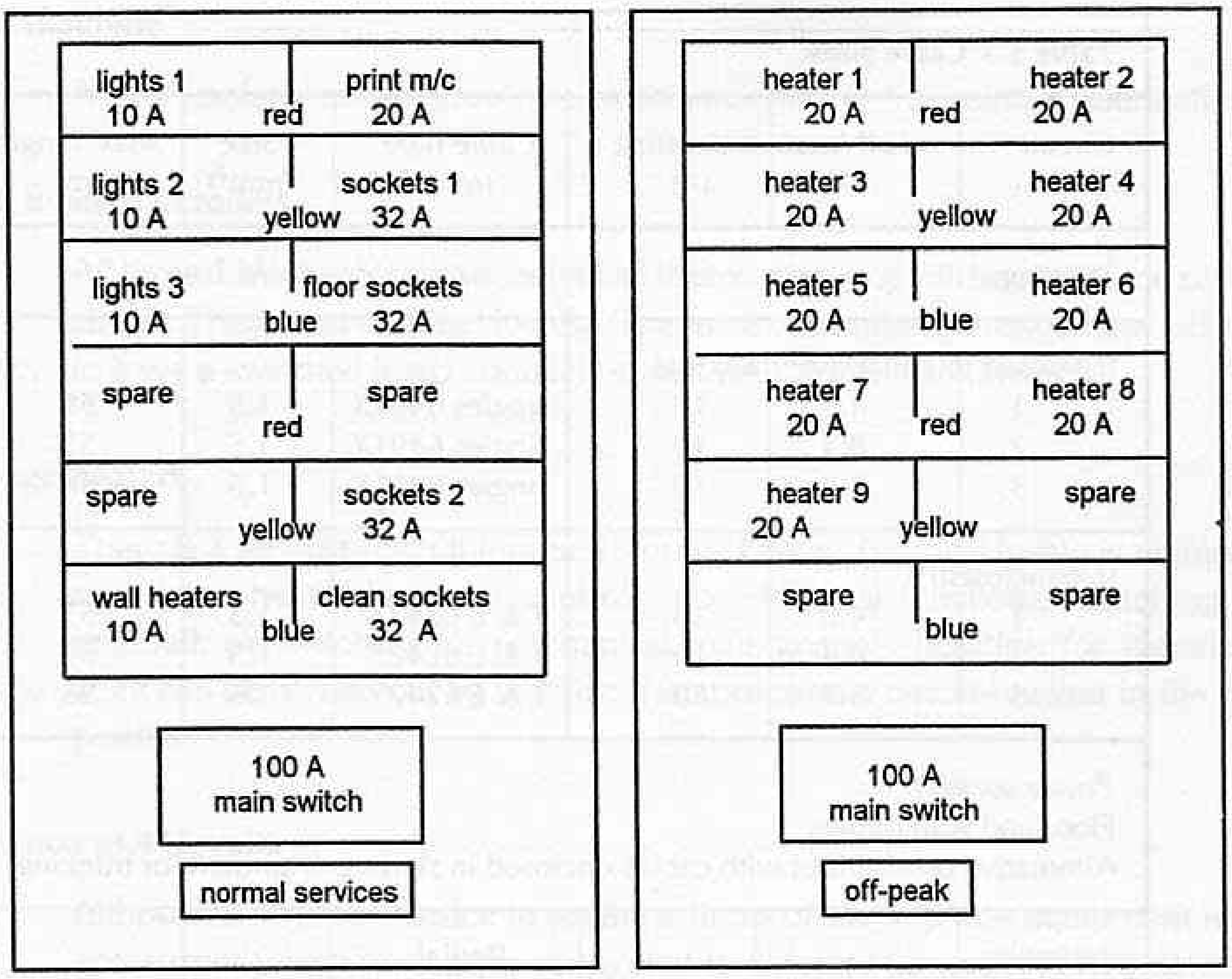


Figure 5.5 **Two distribution boards for office.**

Cable sizes

Cable sizes are given in Table 5.3. It will be seen that these relate to:

- The maximum design current for the circuit or appliance
- App. 4 The rating of the protective mcb
- Installation methods and enclosures
- Grouping as shown
- Maximum length of run
- Maximum earth loop impedance of the pme supply at 0.35 ohms
- Voltage drop.

If any of these variables change or exceed the limits shown, sizes must be re-calculated.

Switchgear

Ch. 46 Standard requirements for isolation and switching apply.

Table 5.3 **Cable sizes.**

Circuit	Full load (A)	mcb rating (A)	Cable type (ref.)	Size (mm^2)	Max. length (m)
Lighting					
(Enclosed in conduit or trunking)					
1	4.0	10	singles 6491X	1.5	55
2	8.4	10	singles 6491X	1.5	55
3	3.7	10	singles 6491X	1.5	55
(Unenclosed)					
1	4.0	10	T & E 6242Y	1.5	55
2	8.4	10	T & E 6242Y	1.5	55
3	3.7	10	T & E 6242Y	1.5	55
Power sockets Floor and wall outlets Alternative possibilities with cables enclosed in skirting or underfloor trunking					
3 circuits each	20 A max.	20	Radial singles 6491X	2.5	30
3 circuits each	32 A max.	32	Radial singles 6491X	4.0	45
3 circuits each	32 A max.	32	Ring singles 6491X	2.5	70
Dedicated power circuit for computers As above for power circuits with cables enclosed in skirting or underfloor trunking					
Storage heaters All similar with a maximum of three circuits enclosed in skirting trunking					
9 × 3 kW	12.5	16	singles 6491X	2.5	45
Wall heaters One circuit, three heaters with cables enclosed in skirting trunking					
3 × 1 kW	12.5	16	singles 6491X	2.5	45

Print machine

A 20 A isolator makes provision for this machine at the point of connection.

Wall heaters in toilets

All three 1 kW heaters have individual thermostats and will be fed off the same circuit. They must be fused locally. The most convenient arrangement will be
432–02 to have a switched fused connection unit adjacent to each heater.

Storage heaters

There is a separate circuit for each storage heater. No local fusing is required and if the heater has user controls, no additional functional switching is required, or switching for mechanical maintenance. Isolation for electrical
476–02 work can be carried out by securing the appropriate circuit-breaker in the off position.

Presence of 415 volts

Although it is good practice to separate items of single-phase equipment and accessories which have been connected to different phases, the Regulations do not prohibit such connection.

Where separate items of equipment have between them voltages in excess
514–10 of 250 V at terminals that are simultaneously accessible, a suitable 415 V warning label must be applied. The label is not of consumer interest but is to warn any person having access to live parts. The most secure place for a label is under the terminal cover or within a switchbox.

Large items of three-phase switchgear should have external 415 V labels.

Access to switchgear

In this instance the main switchgear is located in a cupboard. Unless there is
513–01 no possibility of confusion, the cupboard door should be labelled to indicate the presence of electrical equipment. Normally the door should not be lock-
514–08 able, but where this is found to be necessary, a clear indication of where the key may be found should be given for emergency access.

130–07 Wherever possible the occupants should be advised of the need to keep clear access to controls.

Earthing and bonding

This unit is part of a multi-occupancy building complex, nevertheless this individual electrical installation must have the full earthing treatment. It may well be that water supplies are fed from a main riser which is bonded to the landlord's electrical service elsewhere, but regardless of this, the water pipe must be bonded at the point of entry into the architect's office.

Main earthing terminal

A single main earthing terminal is required which will be used to service both normal and off-peak installations. It should be possible to disconnect the earth
542–04 from either installation without intefering with the other; therefore the terminal must be a separate item and be accessible for test purposes without exposing live parts (see Fig. 5.6).

A 16 mm^2 main earthing conductor from the supply pme earth will be
547–02 taken to this main earthing terminal. Main bonding conductors at 10 mm^2 are required from the main earthing terminal to:

- Mainswater stop cock,
- Main gas stop cock (if applicable).

Additionally

- Two 10 mm^2 (minimum) circuit protective conductors will connect to the
543–01 earthing bars in the distribution boards,
- A special 2.5 mm^2 earthing conductor will be provided for the clean earth on dedicated socket outlets.

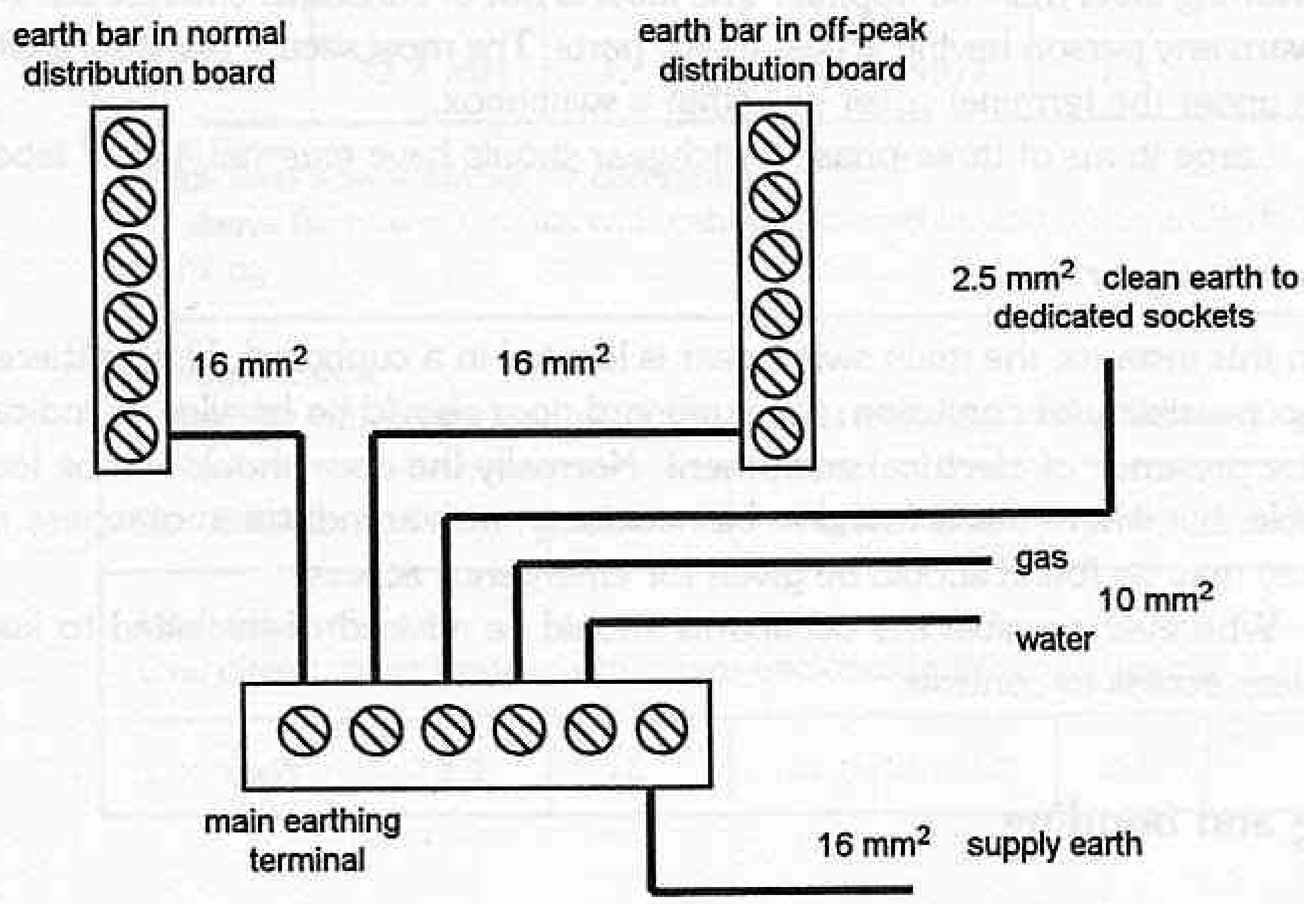


Figure 5.6 **Earthing arrangements for office.**

False ceiling grid

Previous mention has been made of the protection of wiring within a plasterboard false ceiling. Alternatively there may be a proprietary metallic ceiling grid with inset tiles. This raises the issue of bonding and the definition of an extraneous conductive part.

The definition of an extraneous part implies that it is liable to bring a different earth potential into an otherwise equipotential zone. This would not apply to a metallic ceiling grid which is entirely within the office equipotential zone. There is no requirement for main or supplementary bonding.

If the ceiling grid is carrying lighting fittings, they will have circuit protective conductors which may or may not make fortuitous contact with the grid. In either case this is of no consequence as far as the equipotential bonding is concerned. If there are no lights in contact with the grid, it will be isolated metalwork within the zone and no bonding is required.

547–02 If it is the case that a ceiling grid is continuous into the landlord's corridor or another equipotential zone, it will be necessary to bond the office grid to the main earthing terminal for the office to ensure that it could not carry an imported potential into the office equipotential zone.

Clean supply for computers

A clean supply requires a separate *functional earth* which does not carry *protective earth* currents. This conductor will be taken from the main
542–04 earthing terminal, directly to the isolated special earth terminal on dedicated non-standard sockets (see Fig. 5.6).

607–05 Any requirement for protective earthing on exposed conductive parts of equipment should be connected through the normal earthing facility. This will
413–02 apply to the print machine and photocopier.

The only point of interconnection between the protective earth and the functional clean earth should be at the main earthing terminal.

Computer installations

Apart from giving a clean earth connection, there are other implications to the use of Information Technology equipment in offices. These apply to a
Sec. 607 greater or lesser extent according to whether a particular office computer is a basic word processor or if it is part of a 'networked' system involving data exchange with other equipment on or off the premises.

High earth leakage currents

In order to filter out mains spike and surges, computerised equipment incorporates capacitor bridge circuitry connected to earth. This means that each item will have an inbuilt and normally harmless earth leakage current in the order of a few milliamps.

This subject is dealt with in depth in Chapter 7 and should be noted for large office installations. On this small project, the few desk-top computers will produce minimal earth leakage which will be handled by the specified earthing arrangements.

Mains filters

512–05 Special provision may be required for filtered mains supplies to desktop computers, especially where mains-borne interference is significant. Spikes and transients from external supply network loads can cause problems with both hardware and software.

Filtered, switch socket outlets are available to deal with electronic noise. These could be fitted at all points where computers may be plugged in. Alternatively low cost special plug adaptors are available.

Uninterruptible power supplies (UPS)

Unexpected power failure causes loss of computer data. The installation of
313–02 basic UPS equipment will supply power for a limited period of time to enable the operator to carry out regulated shut-down procedures. An operational period of five minutes may be adequate in normal circumstances. More expensive equipment will give continuity of supply for longer periods.

The client may choose to have centralised UPS equipment with all dedicated sockets connected to a system which can carry the full load. Alternatively, single desktop units may have a local individual UPS source.

The subject should be discussed at the quotation stage of the project to ensure that mains switchgear and wiring takes account of UPS distribution requirements. It is always preferable to segregate UPS cables from normal
331–01 power cables and communications circuitry. The topic is becoming increasingly important with new applications for Information Technology equipment.

- *Electricity company*
  Check availability of a supply to suit the potential load and confirm the location of the intake position.

Building structure and finishes

This is a part of a new building yet to be completed. Fig. 5.1 shows the intended layout.

Total office floor area: 180 m^2.
Floor below and above: concrete beams, as yet unscreeded.
Ceiling: suspended false ceiling with 300 mm void.
Walls, external: masonry, with plaster finish; *internal*: lightweight partitions, plasterboard on steel framework.

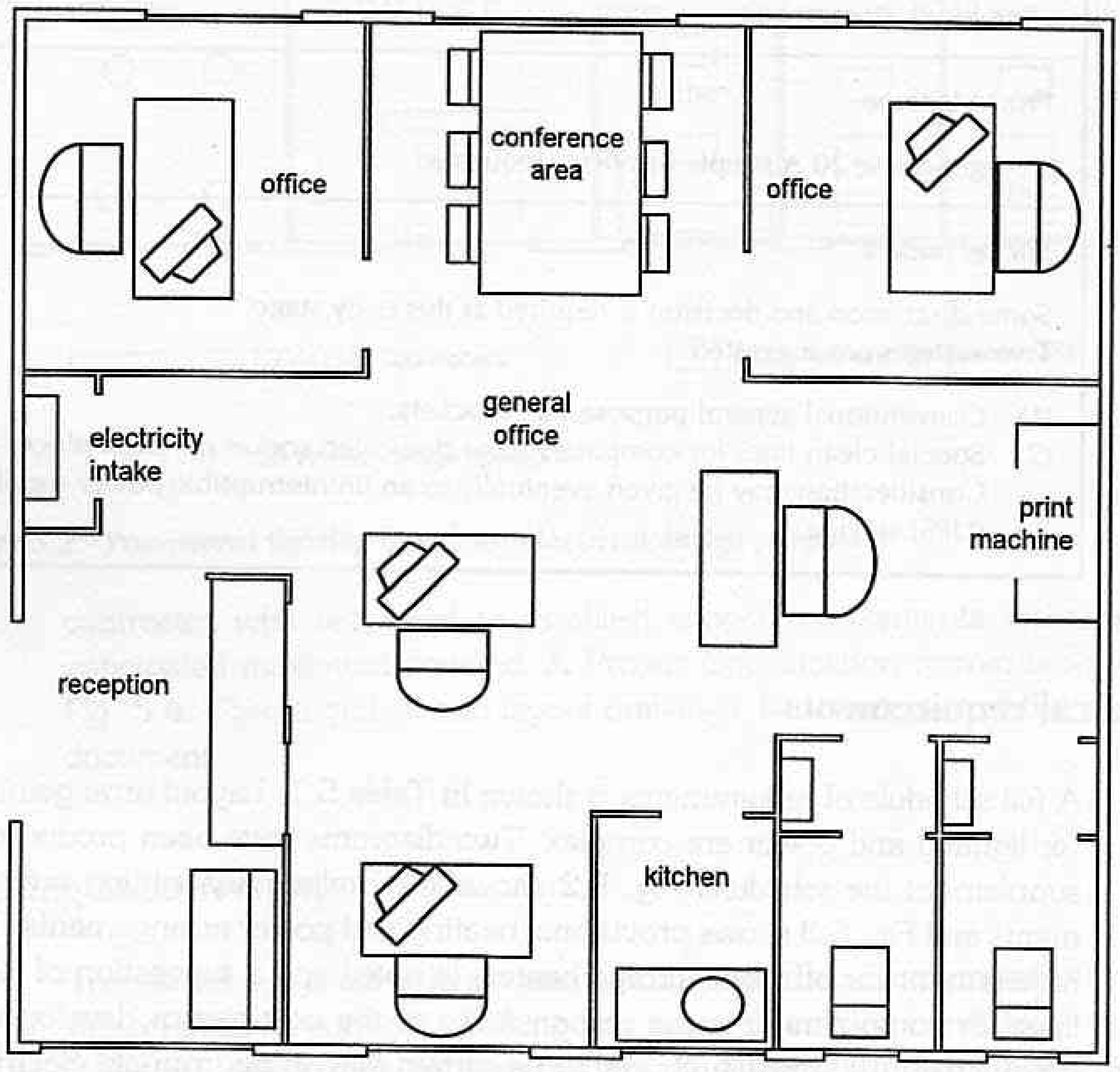


Figure 5.1 **Layout of offices and furniture.**

Table 5.1 **Electrical requirements.**

Provisional electrical schedule	
Lighting	
General office lighting	9 × 1.8 m 70 W twin fluorescents
Two executive offices	2 × 1.8 m 70 W twin fluorescents
Conference area	9 × 50 W elv spotlights
Reception area	8 × 50 W elv spotlights
Toilets and kitchen	6 × 24 W low energy fluorescents
Direct acting heaters	
Three wall panel heaters in the kitchen and toilets, with individual thermostatic control	4 × 1 kW
Storage heaters on off-peak supply	
Nine block storage units	9 × 3 kW
Print Machine	
A single-phase 20 A supply has been requested	
Socket outlets	
Some discussion and decision is required at this early stage. Two systems are suggested: (1) Conventional general purpose 13 A sockets. (2) Special clean lines for computers. One dedicated socket per desk place. Consideration may be given eventually to an uninterruptible power supply (UPS) service.	

Electrical requirements

A full schedule of requirements is shown in Table 5.1. Layout arrangements for lighting and power are complex. Two diagrams have been produced to supplement the schedule. Fig. 5.2 shows the preliminary lighting arrangements and Fig. 5.3 shows provisional heating and power arrangements. The requirement for off-peak storage heaters is noted and a suggestion of clean lines for computers. It is the responsibility of the occupier or developer to consult with the supply authority to be certain that an appropriate electricity supply will be available. This task is normally delegated to the electrical

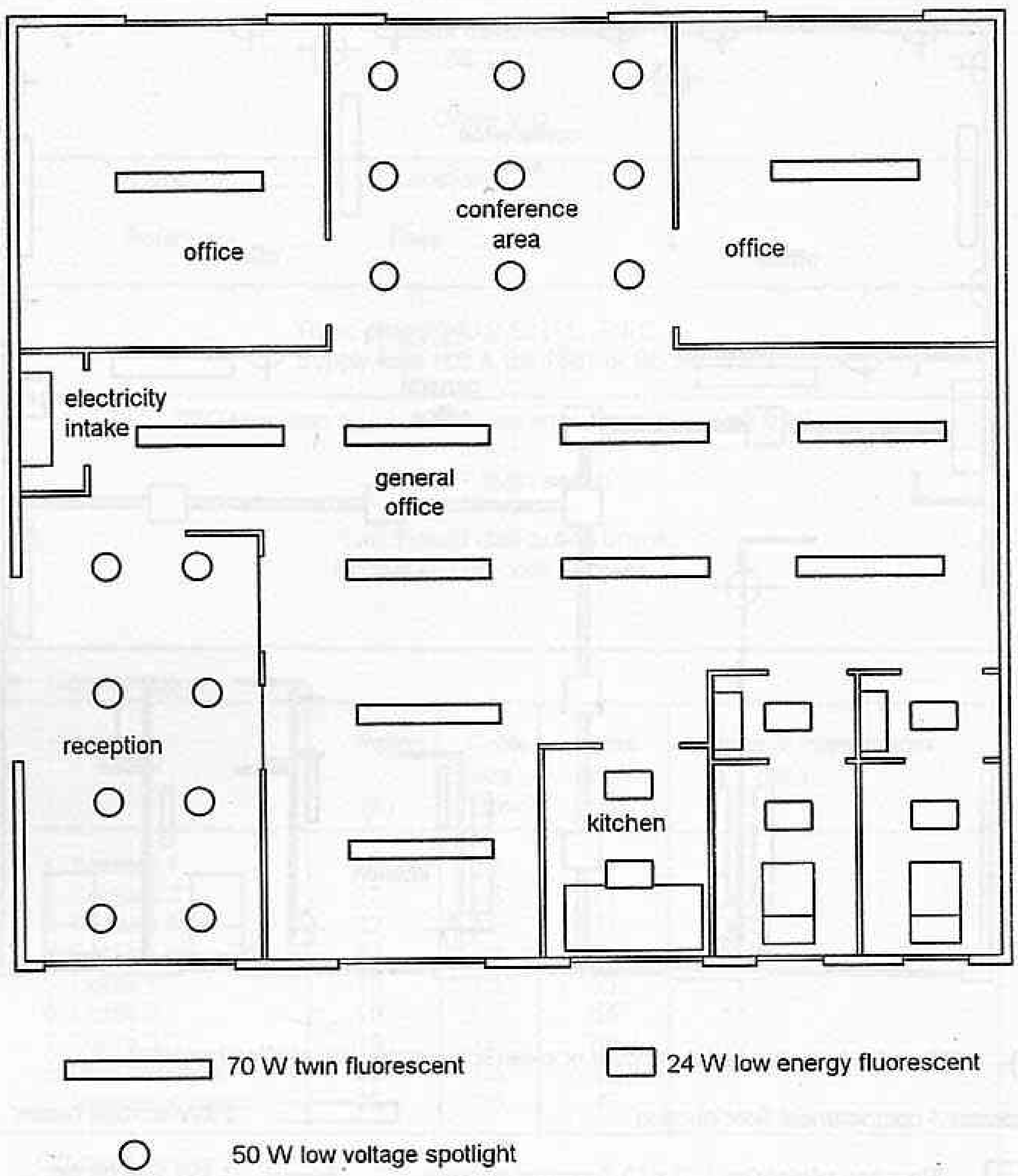


Figure 5.2 **Provisional lighting layout for electrical design purposes.**

contractor who will need to establish supply requirements including the anticipated maximum demand. A Project Specification format is shown in Fig. 5.4. This, together with layout drawings, becomes part of the contract document.

Loading and diversity

This is not an exact scie ce and calculations may be rounded off. Every project must be considered taking into account working conditions.

311-01 A small office situation illustrates the condition where lighting and heating loads are likely to be used simultaneously at maximum capacity on certain

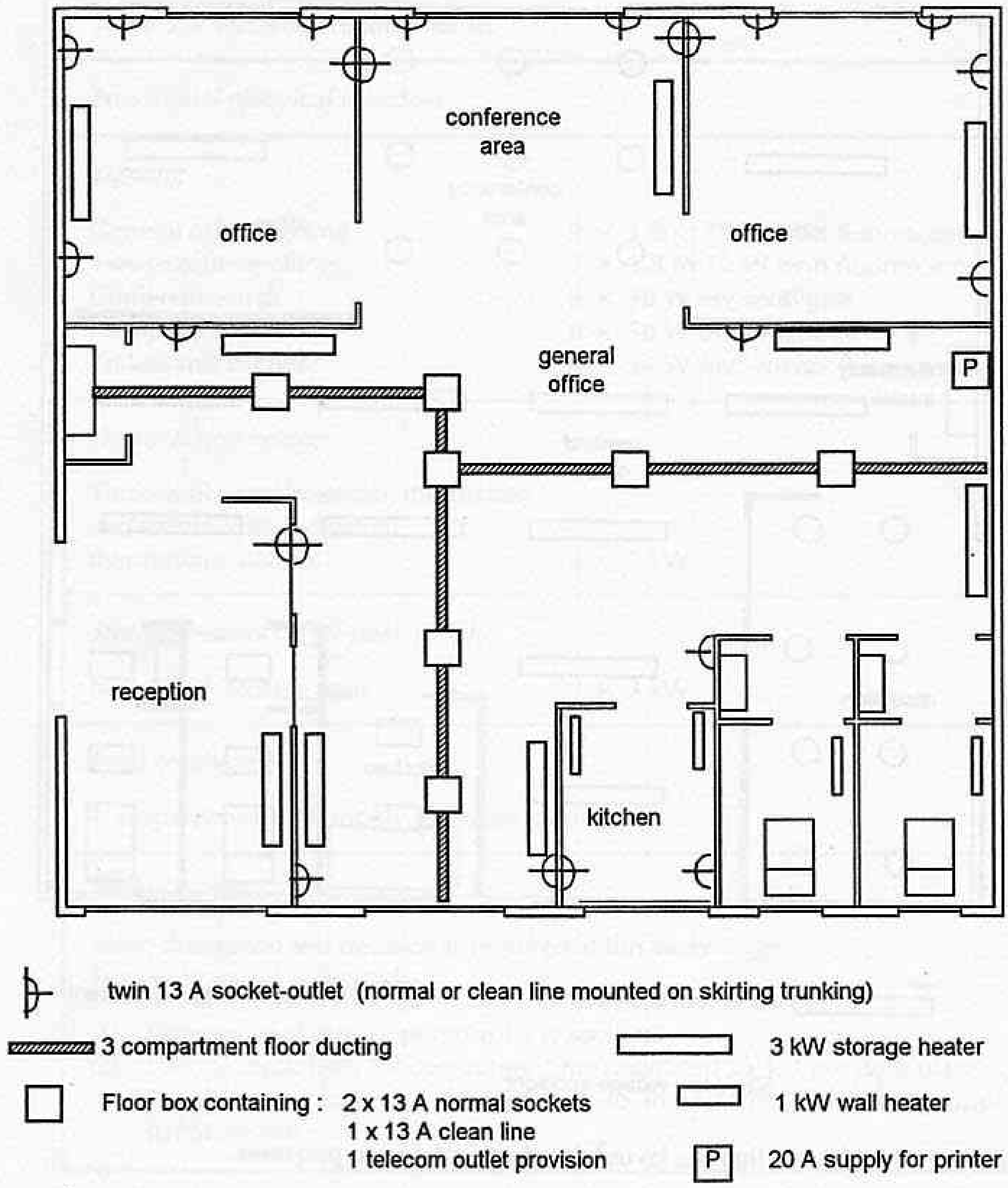


Figure 5.3 **Provisional power and heating design layout.**

Project Specification BS 7671 Office Unit				
Name...................... Location.......................				
Reference................ Date.....................				
Three phase 240 V 50 Hz. TN-C-S. Supply fuse 100 A BS 1361 or BS 88				
PFC less than 16 kA. Earth loop impedance less than 0.35				
100 A TP main switch				
Two Type B distribution boards Normal and off-peak supplies				
Normal supply				
Circuits	Rating (A)	Cable size (mm^2)	Max length (m)	Lights/points g = gang
1. Sockets 1	32	2.5	71	10 x 2g
2. Sockets 2	32	2.5	71	8 x 2g
3. Sockets floor	32	2.5	71	7 x 2g
4. Sockets clean line	32	2.5	71	5 x 2g
5. Lights 1	10	1.5	55	11
6. Lights 2	10	1.5	55	13
7. Lights 3	10	1.5	55	10
8. Print machine	20	2.5	45	
9. Heaters in toilets	20	2.5	45	4
Off-peak service				
1-9 Storage heaters	20 A	2.5	25	9

Figure 5.4 **Project specification for offices.**

occasions. The off-peak heaters may also be brought on line at a time when the office is working. No diversity can be allowed on these loads. However, it is probably acceptable to ignore the lighting and thermostatically controlled heaters in toilets.

Lighting

For current loading calculations, fluorescent lamp ratings must be multiplied by 1.8 to take into account control gear losses.

$$\text{Fluorescents} \quad \frac{22 \text{ lamps} \times 70\text{ W} \times 1.8}{240} = 11.5\text{ A}$$

$$\text{ELV spotlights} \quad \frac{17 \times 50\text{ W}}{240} = 3.5\text{ A}$$

Storage heaters

$$\frac{9 \times 3000\text{ W}}{240} = 112.5\text{ A}$$

Print machine

20 A supply = 20 A

Socket outlets

These will only be used for desktop equipment. Any reference to floor area or number of outlets is meaningless. A suitable estimate of desktop loading is between 1 A and 3 A per station. Some diversity can be written in.

Assume here 2 A per desk, with room for eight desks = 16 A

Total load

Total current (approx.) = 164 A

This will be distributed across three phases and a three-phase 100 A supply will be appropriate. It is understood that the electricity company will give a pme service.

Wiring system

Discussions with the client indicate that the best method of socket outlet distribution would be with electrical skirting and underfloor ducting with outlet boxes. To a large extent the building construction has determined the wiring systems to be used.

Skirting system

This will be a proprietary steel or non-metallic system. A rigid PVC skirting
528–01 may be most attractive for a prestigious office. Three compartments are necessary throughout with suitable segregated door-crossing adaptations.

Compartments will be used for:

- General power circuitry and storage heaters,
- The computer clean line,
- Telecommunication and data cables.

Provided that the skirting is installed to give a completely fire-resistant enclosure, ordinary unsheathed 6491X PVC-insulated cables may be used. Special care is needed at corners and junctions to ensure that the cable enclosure is complete. Socket outlets will be mounted directly on the skirting at positions related to user requirements. The skirting design should be suitable for future outlet additions.

Underfloor system

521–07 This will be a three compartment system with segregated floor access boxes. These floor boxes have been planned on a 3 m module. Office users will either find socket outlets specially located for desk positions or within 1.5 m.

The mains cables will be fully protected and enclosed within floor trunking. Standard unsheathed 6491X, PVC-insulated cables may be used.

Socket outlets

Two systems will be in use:

- The general-purpose 13 A standard BS 1363 type, and
- A special 13 A plug with non-standard pin orientation for the dedicated 'clean' service to computers.

It is recommended that the wiring for this clean line should, wherever possible, take a different route or be contained in a segregated trunking compartment. A dedicated circuit protective conductor will be taken to isolated earthing pins on the special sockets. This conductor will be insulated green/yellow throughout its length and finally connected to the main earthing terminal for the installation.

Lighting circuits

There are various wiring possibilities. A choice of two is given below. In both
553–04 cases the use of luminaire support connectors (LSCs) is recommended. These provide a good accessible plug-in facility for maintenance work.

(1) Conduit and trunking system

Outlet positions will be fixed to the underside of the soffit and interconnected with plastic trunking or plastic conduit fixed to the ceiling. A flex connection is then made from these ceiling outlets to luminaires or extra low-voltage transformers.

Plastic conduit drops will be used for services to wall switches.

(2) Sheathed twin and earth cables

Twin and earth cable can be used, concealed in the ceiling void. It must be
522–08 fixed to the ceiling either directly or on a timber batten and not draped across a metallic ceiling grid.

The cable can be taken straight into the luminaire connector or transformer
526–03 terminals provided that there is no excessive heat and the cable is protected against abrasion at the entry point. This tends to be an untidy installation and
130–01 note must be taken of the Wiring Regulations requirement for good workmanship.

A much tidier job can be achieved with the use of ceiling roses or luminaire supporting couplers with flex connections to luminaires and transformers.

Battened out ceilings

Where headroom is at a premium, or for reasons of economy, false ceilings are often constructed of plasterboard fitted to timber battens. Wiring run in
522–06 this space is subject to restrictions similar to those imposed on wiring installed beneath floor boarding.

(1) Unprotected cable must run at least 50 mm from the underside of the batten, or
(2) Cables must incorporate an earthed sheath (mics or swa), or
(3) Cables must be enclosed in earthed steel conduit or given equivalent mechanical protection.

Options 2 and 3 are expensive and may be impracticable. In order to use unprotected twin and earth cable a convenient method for lowering the ceiling to comply with the 50 mm requirement is to cross-batten the ceiling. If battens are orientated in the right direction, this has the added advantage that cables may be easily routed without the need to drill or notch-out wiring channels.

Chapter 6

A High Street Shop

A small shop with just a counter and storage areas is simple to design. The electrical system follows the layout for a house but care must be taken on loading factors if direct acting electric heaters are switched on all day.

These days, many shops have specialized equipment for cooking food or providing other services such as shoe repairs or photographic processing. It is this type of shop that sometimes causes problems for the electrical installer in the estimation of loads.

This exercise takes a High Street bakery shop as a typical project. The design may be adapted for similar conditions.

Special considerations

The electrical contractor is often given a shop-fitter's layout plan with minimal electrical information. This is not sufficient to even offer a quotation.

For design purposes it is essential that the electrical contractor has a full summary of services required. There may be specialized lighting and a mix of single and three-phase machinery. The fact that food is processed on the premises implies strict hygiene rules which may affect surface runs of conduit. The public have access to the shop, therefore equipment must be suitably located away from unauthorized interference.

Early consultation with the client is necessary. Sometimes equipment is brought from old premises and most clients should have some idea of their actual requirements.

Other interested parties

Before settling the full electrical schedule a check must be made upon special or additional requirements.

- *Local authority*
  Food preparation hygiene facilities.
- *Fire authority*
  Fire alarms, emergency lighting and other safety features.

Temperature limit of 90°C

If a higher temperature rating is considered to be important, the use of 90°C XLPE cable is possible. This insulation is available on single-core conduit cable. Care should be taken with armoured cable with XLPE insulation. Off-the-shelf supplies will probably have PVC sheathing.

In theory, rigid PVC conduit and trunking could also be used at 90°C but the fixing arrangements to accommodate expansion and prevent sagging would be impracticable.

Final selection and cable sizes

Having taken all factors into account, the final selection of wiring systems on this project can be made. This is shown in Table 6.3. It should be noted that cable sizes and maximum lengths are based upon the scheme as illustrated:

- 0.35 ohms maximum earth loop impedance,
- Maximum voltage drop of 4%,
- 525-01 Type 2 mcbs.

Bakery wiring

- *Cable*
  70°C PVC-insulated Ref. 6491X, single-core cables.
- *Steel or PVC trunking*
  522-02 Main distribution from distribution board at high level to avoid any heat from appliances.
- *Heavy gauge PVC conduit*
  (1) Drops to outlets at worktop mounting height,
  (2) Ceiling mounted exposed to luminaires.

As an alternative, and to make cleaning easier, PVC mini-trunking could be used for wall drops.

Shop wiring

- *Cable*
  Twin and earth PVC-insulated Ref. 6242Y.
  (1) Cables clipped to soffit within false ceiling,
  (2) Plaster depth down walls with PVC or steel capping.

Table 6.3 Proposed cable sizes.

Circuit	Full load (A)	mcb (A)	Type ref	Size (mm)	Max length (m)
Bakery lights in conduit and trunking.	4.7	6	Singles 6491X or Singles 6491X	1.0 1.5	36 55
Shop lights, surface or embedded in plaster.	4.3	6	T & E 6242Y or T & E 6242Y	1.0 1.5	36 55
Baker sockets, ring in conduit and trunking.	—	32	Singles 6491X	2.5	66
Shop sockets, ring, surface or embedded in plaster.	—	32	T & E 6242Y	2.5	66
Mixer 3-phase, in conduit and trunking.	3.2	6	Singles 6491X	1.0	100
Hob, in conduit and trunking.	25	32	Singles 6491X	6.0	40
Oven, in conduit and trunking.	42	50	Singles 6491X	10.0	40

Distribution board

This is a small layout and no sub-mains are required. Switchgear selection must take account of the total connected load and not take diversity into account. A suitable distribution board is shown in Fig. 6.4.

There is at least one three-phase appliance; therefore a type B board is appropriate.None of the equipment has any especially high starting loads. Standard miniature circuit-breakers, type 2, are suitable.

If there is no reasonable possibility of portable equipment being used out of
471-16 doors, no rcd protected sockets are necessary. If however outside equipment

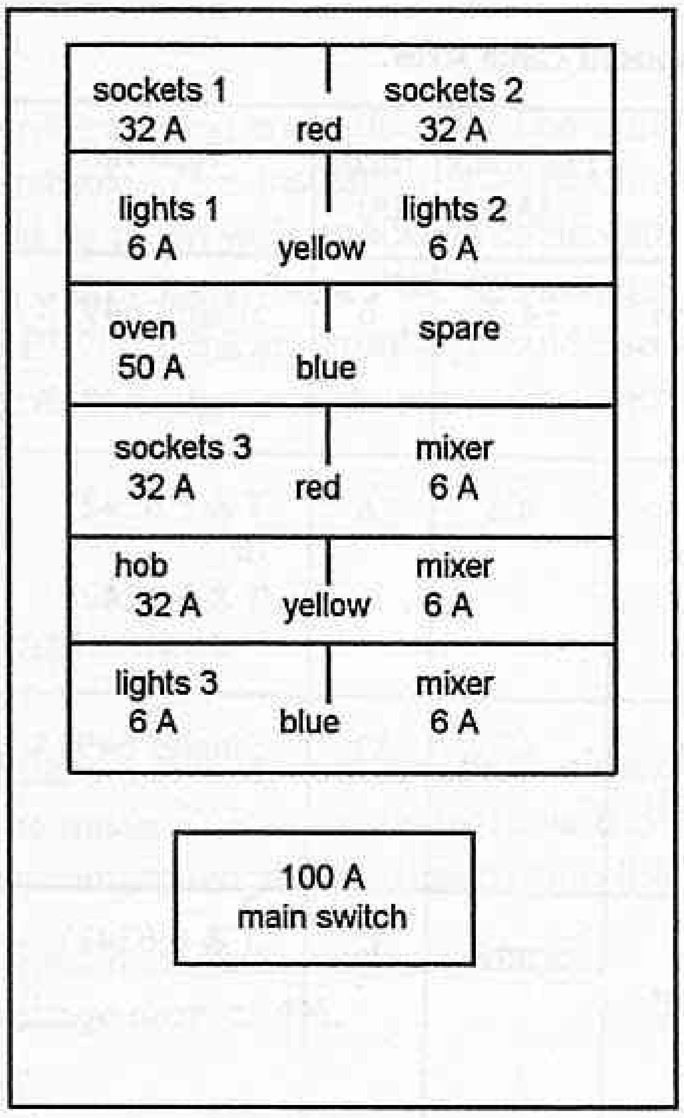


Figure 6.4 **Arrangements at distribution board.**

may possibly be used, the easiest method of compliance would be with an rcd protected socket adjacent to the back door.

Cable sizes

App. 4 Sizing must take account of mcb rating, any applicable derating factors, earth
525–01 loop impedance and voltage drop on full load. Suitable cable sizes are shown in Table 6.3. Maximum lengths of run should be noted if the design is used for a different layout.

Switchgear

Care should be taken in the location of the metering and main distribution
512–06 board. Conditions may be dusty with steam on occasions. The installer should recommend a cupboard to enclose the switchgear.

Isolation and switching

Main switch

460–01 This should be three pole. Switching of the neutral is not required.

Appliances

Cooker, hob unit and power mixer

All three appliances require individual treatment:

464–01 amended ❑ Functional switching,
Each appliance will have its own integral controls.
461–01 ❑ Switching for isolation,
462–01 ❑ Switching for mechanical maintenance,
463–01 ❑ Emergency switching.

All of these functions can be carried out with a suitably rated local isolator. For
Sec. 537 the emergency switching function this isolator must be immediately accessible to the user of the appliance. It is quite possible that the mixer will be supplied through a three-phase BS 4343 plug and socket. This connection would be acceptable as the means of disconnection for isolation and mechanical maintenance, but not for emergency switching.

The mixer has a rating in excess of 0.37 kW and is required to have no-volt provision. This may be incorporated in the machine or with an external starter. The starter stop button would then be acceptable as the emergency stop device.

Deep freezers, refrigerators and microwave ovens

Plug and socket disconnection is adequate for all of these appliances. To avoid accidental disconnection it may be desirable to plug deep freeze cabinets into unswitched socket outlets, or use fused connection units.

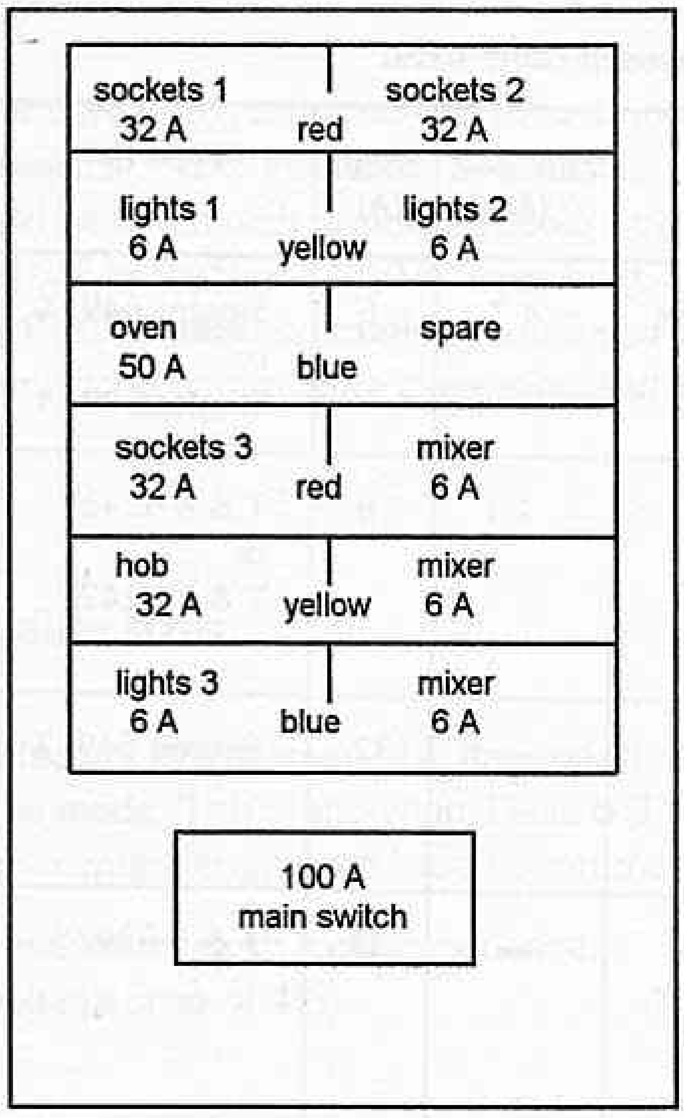
Earthing and bonding

547–02 Standard arrangements apply for a pme service.

Main earthing terminal

542–04 The 16 mm^2 main earthing conductor from the supply earth is taken to the main earthing terminal (MET) (see Fig. 6.5).

Main bonding conductors at 10 mm^2 are required from the MET to:



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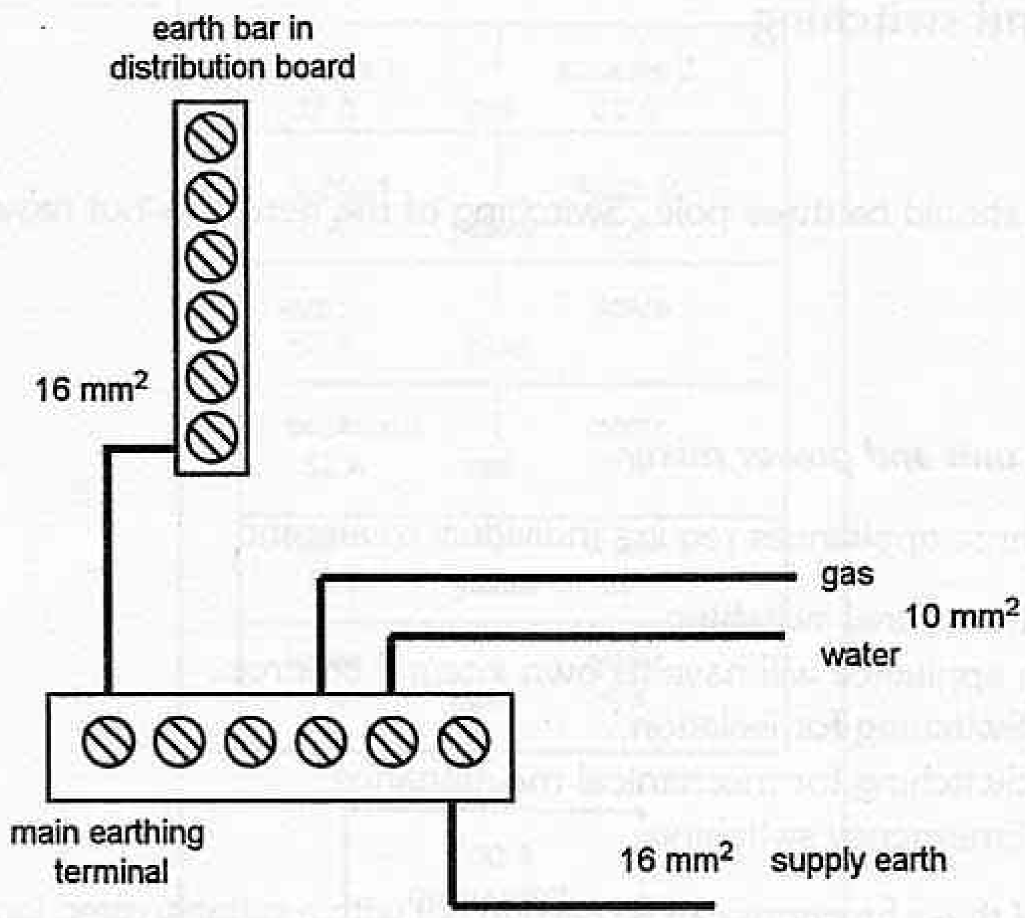

Figure 6.5 **Earthing arrangements for shop. (The two bars may be combined if accessible.)**

- Main water stop cock,
- Main gas stop cock,
- Structural steelwork (if any).

False-ceiling grid

The Wiring Regulations' definition of extraneous conductive parts would not apply to a metallic false ceiling grid which is entirely within the existing equipotential zone. There is no requirement for main or supplementary bonding. This subject is explained in detail in Chapter 7.

Steel tables in the bakery

Using the same logic as for ceiling grids free-standing, stainless steel, tables do not require bonding – even if electrical appliances are used. It is possible that a table bolted to a concrete floor could import an earth potential. In such a case bonding may be necessary.

If it is considered to be advisable to cross bond metal tables, the sizes of protective conductors should be shown in the contract documentation.

- *Client's insurers*
  Safety equipment in the shop and food preparation areas.
- *Landlord*
  Common alarm or security systems may be used in a shopping complex.
- *Health and safety*
  There may be safety restrictions regarding the use of machinery in some areas.
- *Electricity company*
  Check availability of a supply to suit the potential load and confirm the location of the intake position.

Building structure and finishes

- Total floor area, 100 m^2.
- Concrete floor, tiled throughout.
- Concrete soffit, exposed in bakery; suspended false ceiling in shop area.
- Walls, brick or building block. Fair-faced exposed in bakery; tiled or plastered in shop and toilets.
- Space heating by gas.

Electrical requirements

Proposed electrical layouts are shown in Figs 6.1 and 6.2. A full schedule of requirements is shown in Table 6.1. It will be noted that space heating is by gas although cooking is electric. This may not be realistic. In practice a more likely situation would have gas cooking and heating. However, many catering establishments do have mixed services and in this case the electric cooking has been chosen in order to calculate diversity. A suitable Project Specification is shown in Fig. 6.3.

Loading and diversity

It will be seen that the assessment of maximum demand is very much a matter
311–01 of experience. There is a tendency to overestimate high fixed loads which in practice only occur for short periods of time. Thermostats and energy regulators switch heater elements on and off at irregular intervals.

The biggest load on this project is the oven in the kitchen and it is extremely unlikely that the fully loaded 10 kW condition will coincide with full loading on other appliances.

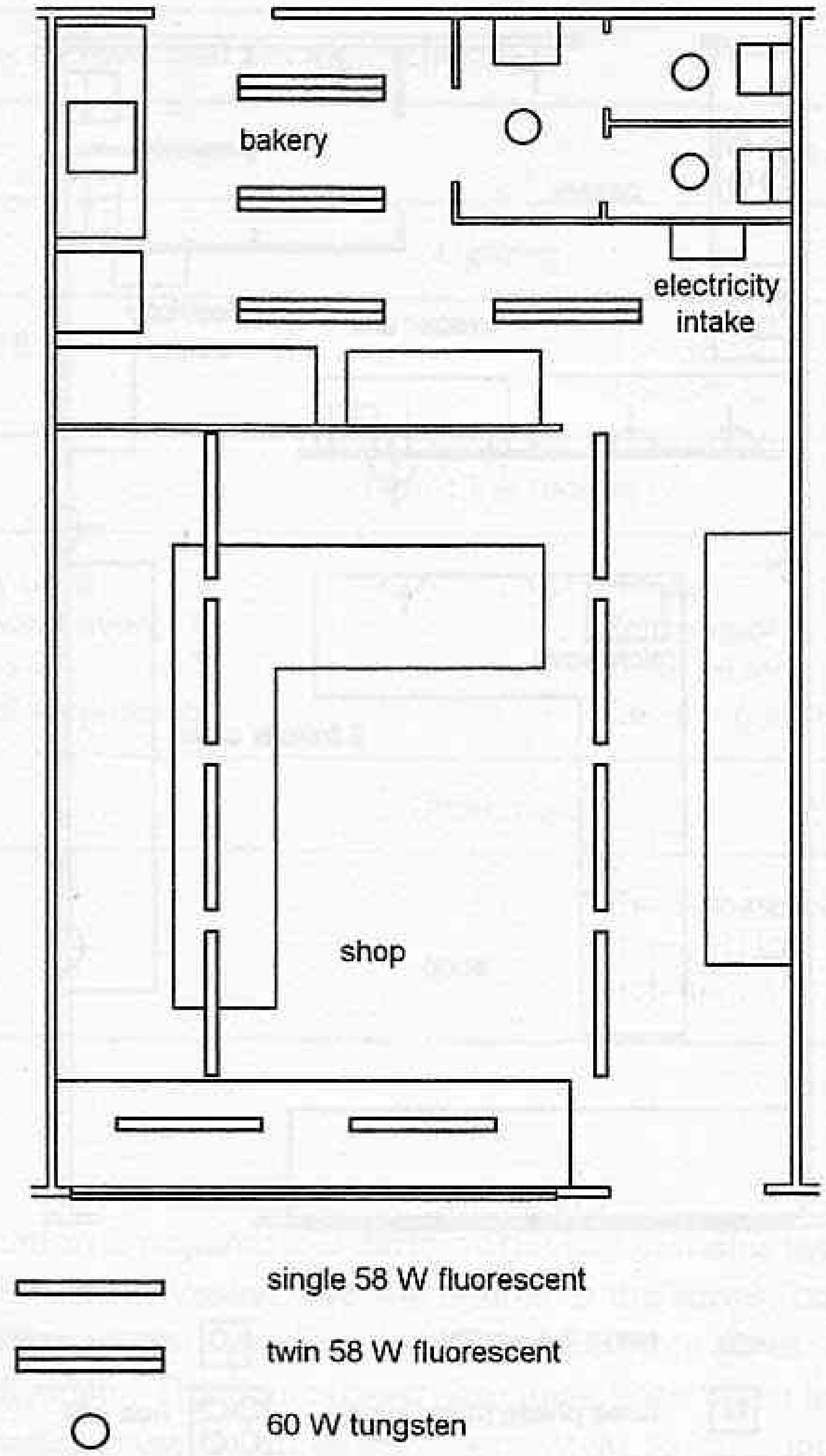

Figure 6.1 **Lighting layout for wiring purposes only.**

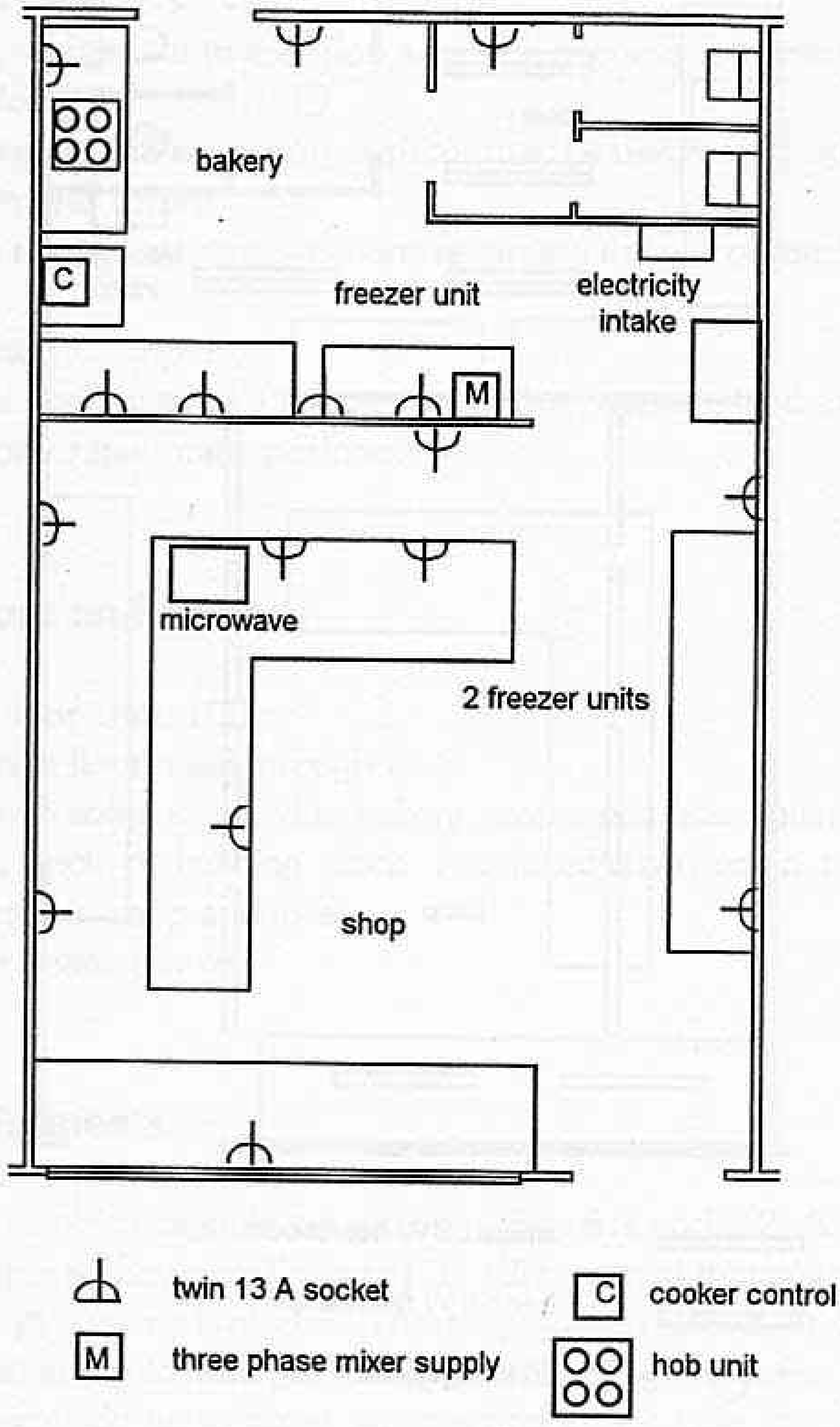

Figure 6.2 **Power outlets in shop.**

Table 6.1 **Provisional electrical schedule.**

Shop		*Bakery*	
Lighting			
10 × 58 W		8 × 58 W 4 × 60 W	
Twin 13 A sockets			
Display units	2	Freezer	1
Microwave oven	1	Refrigerator	1
Freezers	2	Small mixers	2
General purpose	6	General purpose	4
Other loads			
		Three-phase mixer, 750 kW Oven, 10 kW Hob unit, 4 × 1.5 kW	

Information is required to determine the size of mains supply. If there is any doubt it is worth showing diversity figures to the supply company.

The IEE Selection and Erection Guidance Note gives some advice about loading diversity. The figures used here have been taken from the Guide, but every project must be considered separately to take into account special factors. This is not an accurate exercise and all figures have been rounded off.

This installation will of necessity be a three-phase load and maximum current per phase is the important calculation.

Lighting

An allowance of 90% diversity is acceptable. For current loading calculations fluorescent lamp ratings must be multiplied by 1.8 to take into account control gear losses.

An assumption of 100 W per outlet is made for tungsten lamps regardless of the specification lamp size. For convenience the bakery shop lighting is spread over two circuits.

Project Specification
BS 7671

High Street Shop

Name...................... Location......................

Reference................ Date.....................

Three phase 240 V 50 Hz. TN-C-S.
Supply fuse 100 A BS 1361 or BS 88

PFC less than 16 kA. Earth loop impedance less than 0.35

100 A TP main switch

Type B distribution board

Circuits	Rating (A)	Cable size (mm^2)	Max length (m)	Lights/points g = gang
1. Sockets shop 1	32	2.5	71	4 x 2g
2. Sockets shop 2	32	2.5	71	5 x 2g
3. Sockets bakery	32	2.5	71	7 x 2g
4. Lights 1	10	1.5	55	11
5. Lights 2	6	1.0	55	13
6. Lights 3	6	1.0	55	10
7. Hob unit	32	6.0	40	
8. Oven	50	10.0	40	
9. Mixer 3-phase	6	1.0	55	

Figure 6.3 **Project specification for shop.**

Shop lighting load

$$= 10 \times 58\text{ W} \times 1.8$$
$$= 1044\text{ W}$$
$$\text{at 90\% diversity} \quad \frac{1044 \times 90\%}{240} = 3.9\text{ A}$$

Bakery lighting

$$= (8 \times 58\text{ W} \times 1.8) + (3 \times 100)$$
$$= 1135\text{ W}$$
$$\text{at 90\% diversity} \quad \frac{1135 \times 90\%}{240} = 4.3\text{ A}$$

Socket outlets

Three circuits would be appropriate. It is customary to put all sockets on one phase. There is no requirement for this in the Regulations but at this stage phase balancing has yet to be considered. Diversity allowances are 100% of first circuit and 40% of all others.

$$30 + 12 + 12\text{ A} = 54\text{ A}$$
$$= 18\text{ A per circuit}$$

Note that this figure is for total load calculations only, not circuit cable sizing.

Other appliances

Mixer, at 50% diversity

$$\frac{750\text{ W} \times 50\%}{240 \times 3} = 0.5\text{ A/phase}$$

Oven, at 100% diversity

$$\frac{10\text{ kW} \times 1000}{240} = 41.6\text{ A}$$

Hob unit, at 80% diversity

$$\frac{6\text{ kW} \times 1000 \times 80\%}{240} = 20\text{ A}$$

Phase balance

It is essential to balance loads across three phases as far as possible. This exercise should consider the diversified current demands to obtain a balance under normal working conditions.

Table 6.2 **Arrangement of loads taking diversity into account.**

Phase		*Amps*
Red	Sockets	54
	Mixer	0.5
		54.5
Yellow	Lights	8.2
	Hob	20
	Mixer	0.5
		28.7
Blue	Oven	41.6
	Mixer	0.5
		42.1

Table 6.2 gives an arrangement which in the circumstances is reasonable but not a good balance. Note that at this stage, this does not necessarily indicate final distribution board particulars. It may be better to put ring circuits on different phases.

Wiring systems

This project is interesting in that, at this early stage, some consideration must be given to the type of wiring systems appropriate to the two main areas, shop and bakery. This is one subject upon which the landlord or insurer may have an interest.

Start by considering cost

From the financial viewpoint it is sensible to consider the most economical wiring system that the Regulations will permit. This is the starting point for design. Changes to more sophisticated methods may be introduced as the situation dictates.

Undoubtedly twin and earth cable is the easiest and cheapest system to install, but the outer sheathing gives only limited mechanical protection. In the
522-06 case of the shop, a certain amount of physical maltreatment should be anticipated.

Shop area

- The public have access and must not be put at risk by their own activities.
- Children will be present and inquisitive fingers can cause damage.
- The shop staff may be heavy-handed in cleaning or careless when handling trays of stock.
- This food shop is subject to hygiene standards which may include frequent washing down.

Surface mounted twin and earth cable is unsuitable for this situation. It would
516–06 be precluded by regulations which specify that the electrical system shall be appropriate to the situation and the method of installation shall take into account the conditions likely to be encountered.

It is acceptable to install unexposed twin and earth cables under plaster or within building voids. This applies on the shop side of this project. Here the concealed cables are deemed to be protected by their location.

Bakery area

Different parts of the bakery area are subject to differing conditions.

- Some general physical abuse can be expected.
- High temperatures will occur in close proximity to the oven and hob units.
- Wall surfaces may be frequently washed down

In these circumstances, the choice of surface wiring systems is one or more of:

- Steel conduit and trunking,
- Plastic conduit and trunking,
- Mineral insulated, copper-sheathed cable (mics) with pvc outersheath,
- Steel wire armoured PVC cable.

Temperature limit of 70°C

A point of interest is that wherever general purpose PVC cable is used, the
523–01 recommended limiting temperature is 70°C. This will apply to all the systems shown above including the mics with PVC outer sheath. Therefore none has any working temperature advantage.

A surface heated to 70°C is very hot and would only exist on an oven casing. The Regulations show 70°C as the limiting temperature for accessible parts of metallic enclosures for electrical equipment. An air temperature in
423–01 excess of 70°C will only be found in the oven or above a hob unit. There would appear to be no problem of cable selection on the basis of temperature alone.

Chapter 7

Earthing and Bonding

The subject of earthing and bonding is complex and raises many controversial issues. The Bill Atkinson rules give only one interpretation of the 16th edition of the Wiring Regulations. These are offered in good faith as a starting point for specifications and contract negotiations.

IEE Guidance Note No.5, *Protection Against Electric Shock*, gives a general interpretation of the Regulations and is a good reference document, but there is no definitive interpretation for every situation. A competent person must be prepared to make a judgement which ultimately may be tested in a court of law.

Customers and specifying engineers are entitled to state special requirements for contracts. Their requirements are often in excess of the Wiring Regulations and there is no harm in this provided that contract documents show what is actually required, and the customer pays for the work. If a project specification only calls for compliance with the Regulations, the contractor may make a judgement as to the minimum requirements. This does not imply a low standard. The Wiring Regulations set a high standard with built-in safety factors.

Ch. 4

This chapter illustrates the use of these minimum requirements by explaining the reasoning behind earthing and bonding principles. These principles form the first line of electrical shock protection. They should be studied carefully.

Take no chances. If in doubt upon earthing requirements, seek advice.

Terminology

Explanations in this chapter stand alone. They are based on the Wiring Regulations but may refer to more than one Regulation Number.

It is important to use the correct Wiring Regulations terminology for earthing, especially if this is different from personally familiar words and phrases. Disputes are sometimes caused by a misunderstanding of IEE definitions. Quite often the result is that participants talk at cross purposes. Confusion is even more significant where the wrong words are used in written documentation, especially when these are contract requirements.

cable are different. XLPE cable has a smaller diameter. The quantity of steel armour is therefore different and these cable types must be considered separately. The Regulations also give different insulation factors. Table 7.2 shows differences for a selection of cables. The table clearly illustrates the problems associated with use of armouring as a cpc without making calculations. The subject is complicated by the different maximum operating temperatures of the two types of insulation. These are 70°C for PVC and 90°C for XLPE.

As a general rule, on the commonly used smaller sizes of PVC swa cable, armouring is acceptable as a cpc. It may also be acceptable for some sizes of XLPE swa cable but calculations need to be carried out. These involve a knowledge of the prospective earth fault current on the project.

Continuity of cable glands

Regardless of any of the above considerations, it is essential to ensure permanent and reliable continuity at terminations of armoured cable. This is

Table 7.2 **Suitability of steel wire armour as a protective conductor.**

Cross sectional area of phase conductor (mm^2)	*No. of cores*	*Actual* (mm^2)	*Cross-sectional area of armouring, minimum acceptable as cpc* (mm^2) OK
PVC insulation			
16	2	47	36 ✔
16	4 =	72	36 ✔
25	2	61	36 ✔
35	2	66	36 ✔
35	4 =	85	36 ✔
50	2	76	56 ✔
95	2	123	107 ✔
95	4 =	160	107 ✔
XLPE insulation			
16	2	41	61 ✘
16	4 =	49	61 ✘
25	2	42	61 ✘
35	2	62	61 ✔
35	4 =	96	61 ✔
50	2	68	95 ✘
95	2	113	180 ✘
95	4 =	140	180 ✘

necessary to carry fault current if the sheath is penetrated and short circuited to the phase conductor.

The continuity of cable gland joints to steel switchgear enclosures is
526–01 notoriously unreliable. Furthermore, enclosure sections fabricated from separate panels increase the chances of a high resistance fault path. To establish good continuity, an earth tag washer should be fitted to the gland and a cable linkage used across to the enclosure earthing terminal.

Information Technology equipment

Sec. 607 The Regulations devote a whole section to earthing arrangements for equipment which has a continuous earth leakage as part of the design.

Information Technology equipment includes most computers, data processing devices and other specialised apparatus such as life support systems in hospitals. For convenience, this chapter will refer to all such equipment as 'computers'.

A common feature of all computer equipment is the sensitivity to supply fluctuations and spikes on the network. These may damage transistorised hardware or corrupt data on software. To ensure a clean supply, computers
545–01 are frequently installed on dedicated 'clean' circuits. They also have inbuilt suppression filtering circuitry. It is these capacitance bridge filters that leak unwanted components of the electricity supply to earth.

On small desktop computers the individual earth leakage is very small and of no great consequence. On large groups of personal computers or single items of mainframe equipment the total leakage may be substantial and introduces a potential hazard to personnel.

With good, reliable earthing on the consumer's installation, the earth leakage is taken away. However, if an open circuit occurs on the system earth, or a high resistance connection arises, everything connected to the faulty earthing system will acquire a potential from the filter circuitry. The fault may not occur suddenly; it may, for example, develop by way of corrosion at a joint.

Many computers have all-insulated enclosures; these would not cause a problem, but the fault potential will be transmitted to equipment with exposed metallic parts such as photocopiers or heating appliances.

Earth leakage currents

The installer will not usually have any information upon computer earth leakage and the supplier may be unhelpful. The Regulations suggest that

607–01 leakage below 3.5 mA may be ignored and a single desktop computer will be below this figure. The normal 13 A plug and socket connection is adequate for a single home computer.

Advice should be sought from the computer manufacturer for larger items of equipment or large office installations. Normal electrical test equipment may not give high frequency readings and cannot be used to measure computer leakage current.

- *Items of stationary equipment*

607–02 Where the leakage is estimated to be between 3.5 mA and 10 mA the equipment should either have a permanent connection to the supply or a BS 4343 'Commando' type plug should be used.

High integrity earthing

For large earth leakage conditions, the Regulations seek 'high integrity' earthing. This may be achieved with a positive earth connection with a minimum size of 10 mm^2. This is shown in Fig. 7.4(a).

The alternative is to supplement the normal cpc with an extra, dedicated, protective conductor.

- Where the item of stationary equipment has an earth leakage in excess of 10 mA the equipment should preferably have a permanent connection to the supply. Alternatively, a BS 4343 plug may be used, provided that the cable green–yellow protective conductor is supplemented by another protective conductor, with a minimum size of 4 mm^2 and connected by way of a separate pin on the plug.

Methods of supplementing the protective conductor are shown in Fig. 7.4(b) and (c). It will be seen that metallic conduit and cable armour or braid may be used, provided that connections are permanent and reliable. The same applies to metallic trunking.

Earth monitoring and isolated supplies

607–02
- An earth monitoring system (see Fig. 7.5) incorporates a second protective conductor. This may be used as the supplementary earth provided that it is of the same standard as Fig. 7.4 methods.
- Where supply is fed from a double wound isolating transformer, a circuit protective conductor for the computer will be taken from the isolated secondary winding of the transformer. This connection should be supplemented to the same standard as Fig. 7.4 methods.

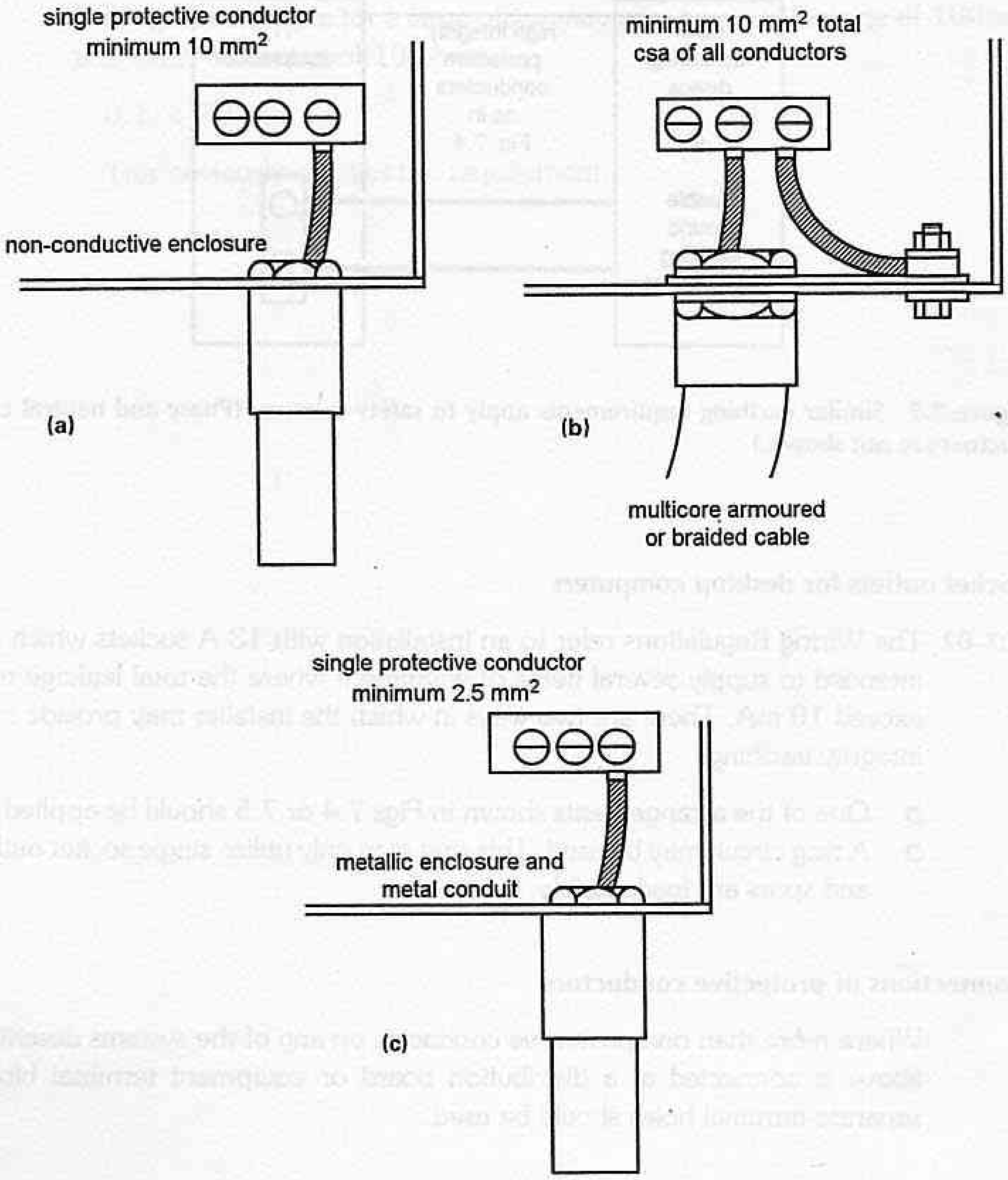

Figure 7.4 **High integrity earthing for computerized systems. (Phase and neutral conductors not shown.)**

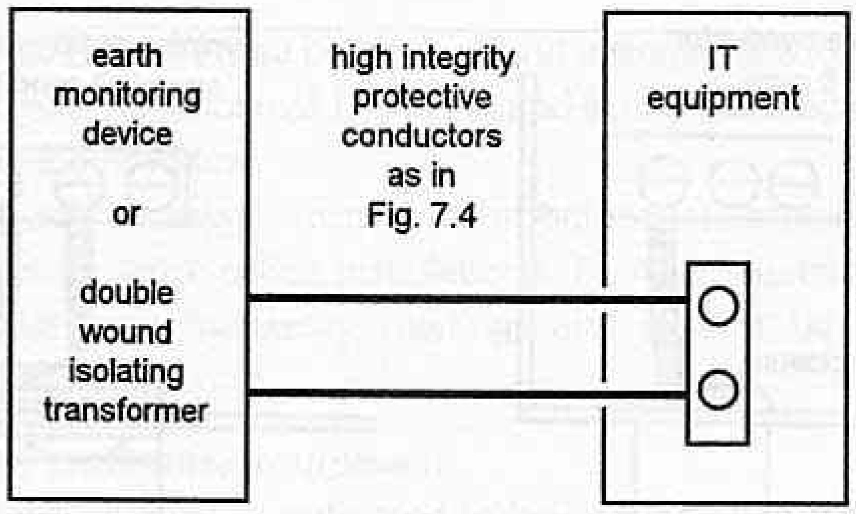

Figure 7.5 **Similar earthing requirements apply to safety systems. (Phase and neutral conductors are not shown.)**

Socket outlets for desktop computers

607–02 The Wiring Regulations refer to an installation with 13 A sockets which are intended to supply several items of equipment where the total leakage may exceed 10 mA. There are two ways in which the installer may provide high integrity earthing:

- One of the arrangements shown in Figs 7.4 or 7.5 should be applied, or
- A ring circuit may be used. This ring may only utilize single socket outlets and spurs are inadmissible.

Connections of protective conductors

Where more than one protective conductor on any of the systems described above is connected at a distribution board or equipment terminal block, separate terminal holes should be used.

Residual current devices

To avoid the loss of data from nuisance tripping, it is not advisable to apply residual current devices to computer circuits. Where these are specified for safety reasons, for example in schools, the total normal earth leakage of the equipment should not exceed 25% of the operating current rating of the rcd.

607–03 The Regulations require that TT installations incorporate a residual current device and the above requirement should be noted.

For TT installations it is also necessary to satisfy a formula which is intended to limit dangerous voltages arising on exposed conductive parts in normal service: *2 × earth leakage current (amps) × earth electrode resistance (ohms) must be less than 50.*

A typical example for a large office may give an earth leakage of 100 mA and earth resistance of 10 ohms.

$0.1 \times 20 = 2$

This obviously satisfies the requirement.

Unfortunately the definitions of many words have changed in order to give internationally harmonized meanings. We must all learn the new language. We may be convinced that our own long-established usage is better than the official interpretation, but a court or tribunal will not settle a claim on personal whims.

Definitions

This is one occasion when it may help to give some actual definitions from the Wiring Regulations:

- *Earthing*
  The act of connecting exposed conductive parts of an installation to the main earthing terminal of the installation.
- *Earthing conductor*
  A protective conductor connecting the main earthing terminal of an installation to an earth electrode or to other means of earthing.
- *Equipotential bonding*
  Electrical connection maintaining various exposed conductive parts and extraneous conductive parts at substantially the same potential.
- *Bonding conductor*
  A protective conductor providing equipotential bonding.

Green and yellow conductors

The most important conclusion to be made from the definitions is that the words *earthing* and *bonding* are not synonymous or interchange-
514–03 able. The correct group term for green and yellow cables is *protective conductors*.

A protective conductor may be:

- The *main earthing conductor* for the installation. This connects the consumer's main earthing terminal (met) with the supply earth.
- *A main bonding conductor*. This connects the met to extraneous conductive parts, e.g. water and gas mains.
- *Supplementary bonding*. This is not normally required except in special locations where there is increased shock risk.
- *Circuit protective conductors*. These are the connections to exposed conductive parts and include the metallic parts of an electrical system and appliances frames.

Equipotential bonding

413–02 The standard UK system of shock protection is earthed equipotential bonding and automatic disconnection of supply (eebads). The principle is used to satisfy one or both of the basic international safety requirements to reduce the intensity or duration of an electric shock.

Bonding connections sometimes carry substantial network current – even with the local supply isolated.Always take care when disconnecting a bonding conductor for testing or service alterations.

The purpose of equipotential bonding is to maintain all simultaneously accessible parts within a zone at the same potential. It is not intended to carry fault current although it may well do so. Fault disconnection is achieved by earthing and that is a separate part of the exercise and normally relies upon circuit protective conductors.

Protective multiple earthing

Why earth at all?

A public electrical distribution system in the UK is earthed at the local transformer. If the supply was not earthed, it would eventually acquire a connection to earth at some stage by a fault on a consumer's installation. This would be harmless and might go undetected.

However, the system would now be earthed.

Subsequently a second fault to earth could arise on another installation. Current would immediately flow between the two independent earth connections and could cause fires at both places.

By making a positive earth connection at the transformer the supplier ensures that all earth faults can be detected and made safe by the operation of protective fuses, circuit-breakers or residual current devices.

Reliability of the earth–neutral path

Over the years, distribution networks and installations have become more complex, and with complexity there are increased chances of faults and open circuits. It therefore became technically expedient to earth the neutral conductor at different places around the network. This is protective multiple earthing.

The principle of pme is shown in Fig. 7.1. For clarity this is a simplified
Defs single-phase system. The Wiring Regulations designate an installation using an earth derived from a pme network as TN-C-S. It is usually the consumer's

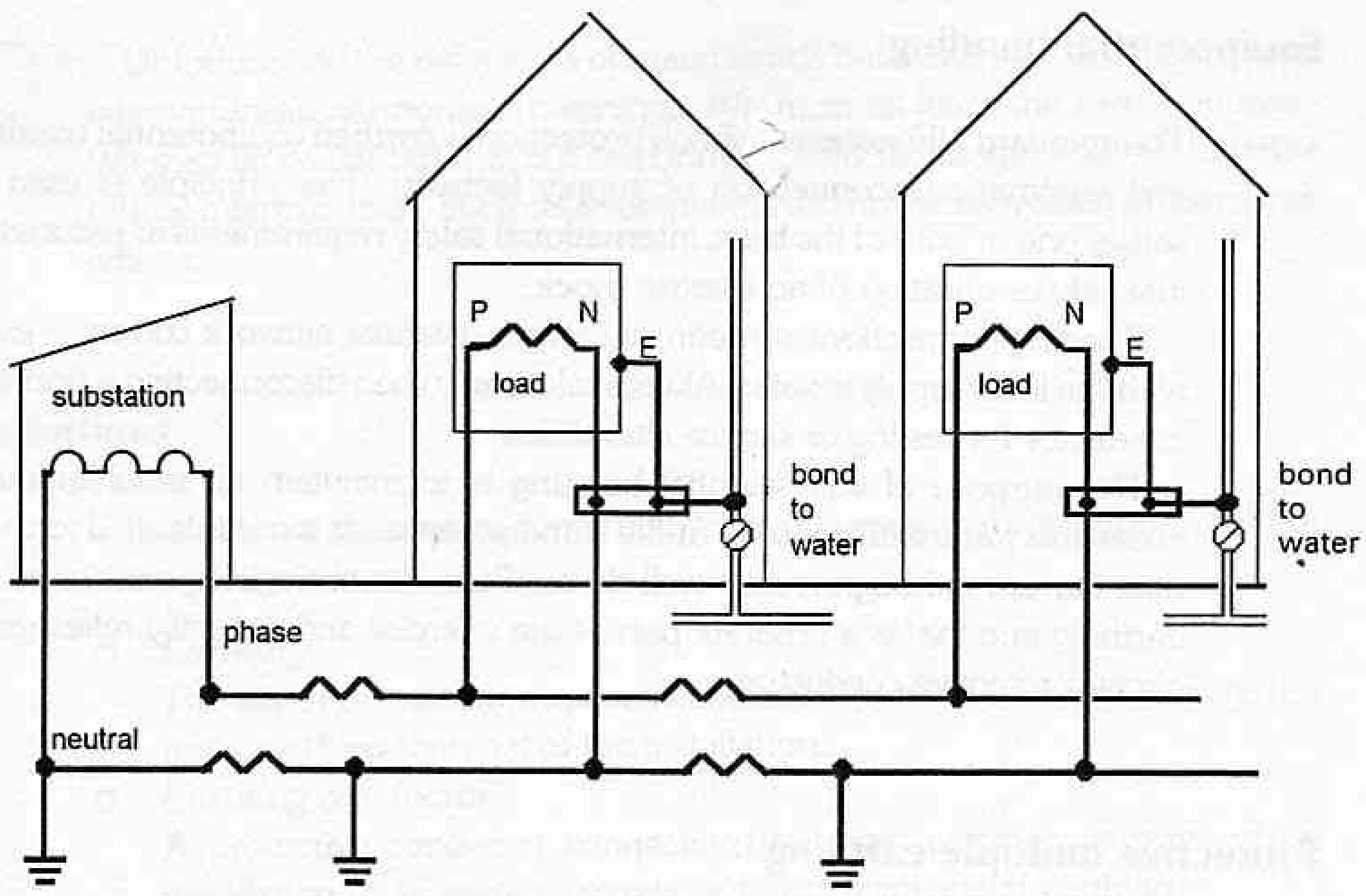

Figure 7.1 **The principle of pme.**

decision to use this earth. If the consumer prefers to use an earth electrode instead of the pme earth, the instalation is designated as TT.

Note the multiple earthing, and the fact that this may only be carried out on the supply network. The consumer is given three terminals: phase, neutral and earth. Within the installation the neutral and earth should *never* be interconnected. This is dangerous, contrary to the Supply Regulations and therefore illegal. If neutral and earth are accidentally or deliberately joined, an indeterminate current will flow which may be related to network conditions, not just the situation within the particular installation.

It will also be seen that all network conductors, including earth, have resistance. When current flows, resistance produces voltage drop. In the case of the soil, there will exist a potential gradient between earth electrodes. There could be a difference of a few volts between different 'earths' on the system. This is the reason why the introduction of 'earthy' extraneous conductive parts into an existing equipotential zone may create hazardous, or inconvenient, touch voltages.

Defs Equipotential bonding of all services and extraneous conductive parts creates an electrical zone where everything within reach is effectively at the same potential. Isolated metalwork by definition is insulated from earth and is not an extraneous part. Isolated metalwork carries no potential and should not be bonded.

The equipotential zone may be extended to other related areas with the use of equipotential main bonding conductors.

Main bonding

Metalwork entering the zone from another area is sometimes already con-
547–02 nected to the earthing on a different system. This could bring in a different earth potential. This metalwork must therefore be bonded locally to maintain the equipotential characteristics of the zone. Metalwork or other conductive media entirely within the zone is no problem.

Most of these items within the zone need not be bonded:

- Door handles,
- Window frames,
- Stainless steel sinks with plastic drainpipes,
- Suspended ceiling grids,
- Free standing steel tables or benches,
- Steel cupboards, shelving or racks.

Because of the use or proximity of electrical appliances or luminaires, it may be decided to *earth* some of the above excluded items. This is a subjective safety judgement and not considered to be an equipotential bonding issue.

Metallic water, gas and oil pipes entering a building must have a main bonding connection within 600 mm of the point of entry (see Fig. 7.2). In

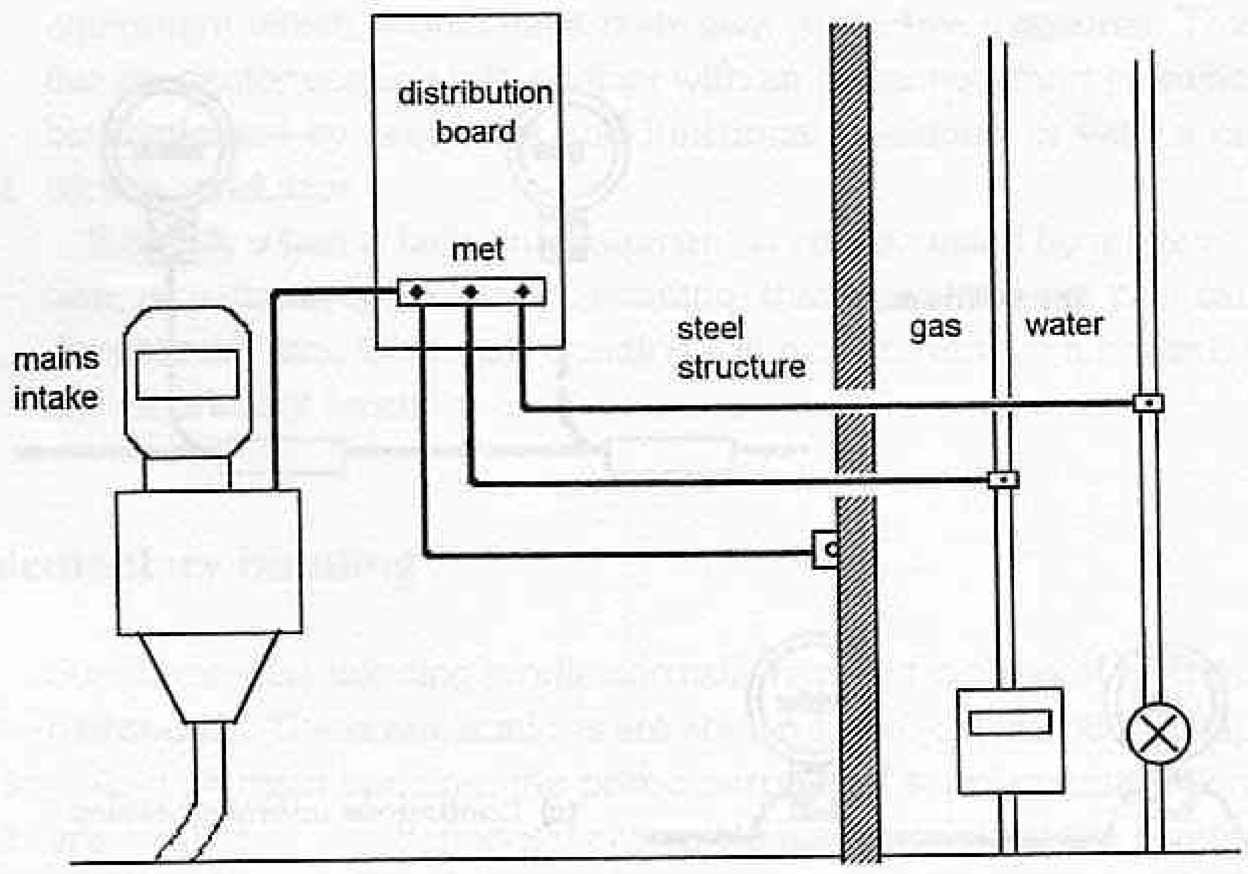

Figure 7.2 **Connections at main earthing terminal (met) must be accessible for testing.**

some cases it may be convenient to run one main bonding conductor for more
526–01 than one bonding connection. This is permissible provided that it is possible to disconnect any single service without interfering with the bonding to other services (Fig. 7.3).

Other items requiring a main equipotential bond are structural steelwork and lightning conductors. A central heating system entering the building, or a rising main would also need to be considered.

According to the Regulations, a bonding conductor need not always be a
543–02 cable. Some extraneous conductive parts could possibly be used. These must have continuity that is permanent and reliable and have an appropriate copper equivalent cross-sectional area. Suitable structural steelwork and pipework may be used but not gas or oil pipes.

The use of extraneous metalwork for main bonding involves examination of on-site conditions and an understanding electricity company inspector. Only main bonding utilising cables is considered on the projects in this book.

Although the Regulations give minimum copper equivalent sizes of main

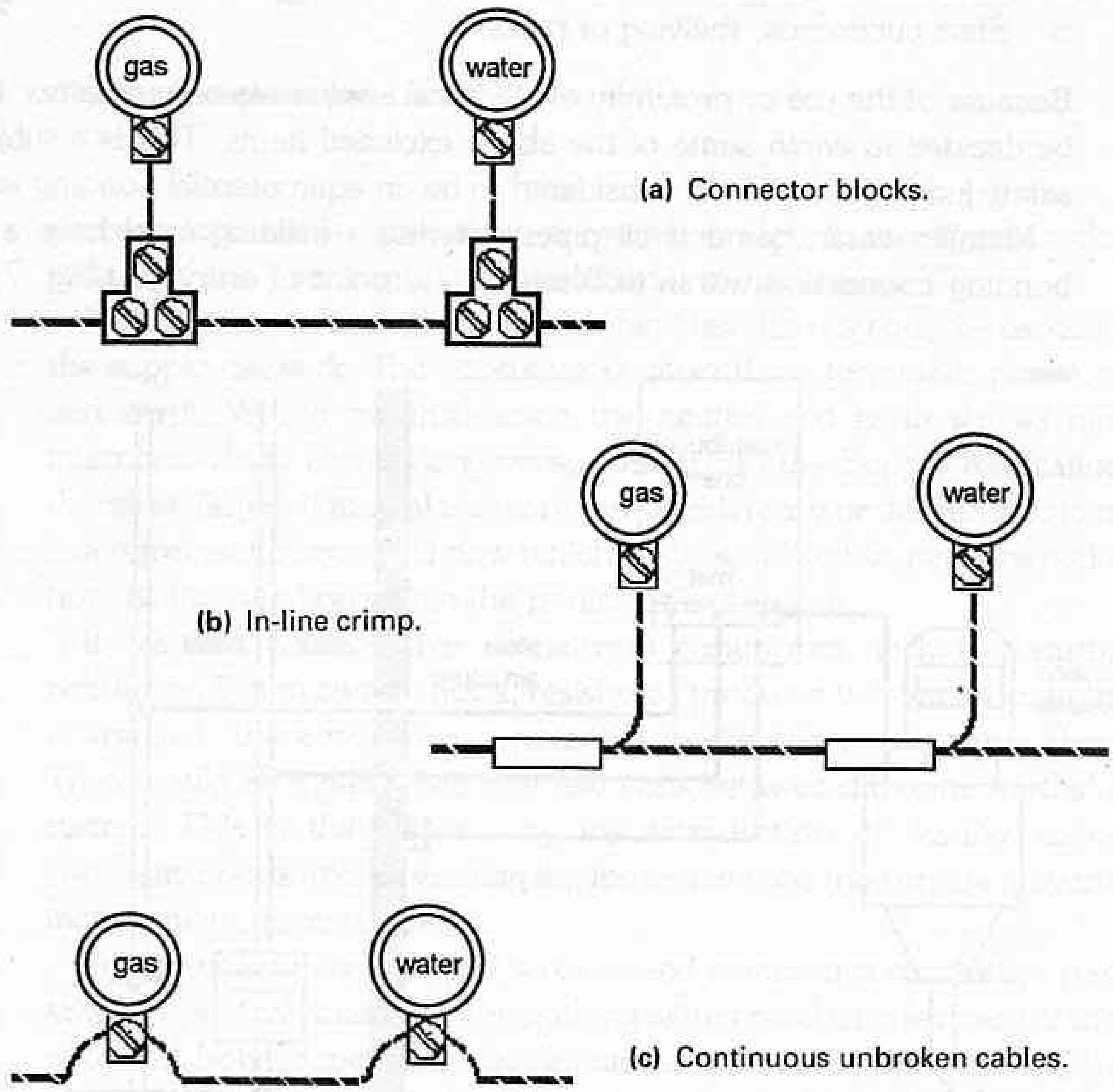

Figure 7.3 **Three bonding methods using a single cable.**

Table 7.1 **Minimum size of pme main bonding conductors.**

Copper equivalent cross-sectional area of supply neutral conductor (mm^2)	*Minimum copper equivalent, cross sectional area of main bonding conductor* (mm^2)
35 or less	10
35 up to 50	16
50 up to 95	25
95 up to 150	35
150	50

bonding conductors for pme systems as shown in Table 7.1, the local supply
547–02 authority may have special requirements for main bonding.

Smaller sizes would be acceptable for TT and TN-S systems but as most installations will eventually be connected to a pme network it is suggested that the table should be used for all situations.

Single fault condition

An important factor to be considered is that the Regulations only consider a single fault condition. Bonding does not exist to clear faults on unrelated equipment which should have their own protective measures. The risk of a live conductor coming into contact with an extraneous part elsewhere should be eliminated by protective and functional insulation or with a circuit pro-
413–02 tective conductor.

It is only when a fault on equipment is compounded by a failure of insulation, or a circuit-breaker not operating, that an extraneous part can become dangerously live. Obviously bonding will help to remove a hazard, but this is not its primary function.

Supplementary bonding

Supplementary bonding is only normally required in areas of high risk, such as bathrooms. These applications are shown in projects in other chapters.

547–03 As with main bonding, the prime purpose of supplementary bonding is to
413–02 ensure that all simultaneously accessible metalwork is at the same potential.

The Wiring Regulations give the opportunity to use supplementary bonding elsewhere where earth loop impedance is high. The condition rarely applies in small installations and requires special study, it is only mentioned in passing here. Nevertheless it is a good idea to supplement bonding wherever possible, for example by cross-connecting structural steel with a metallic switchgear. This will lower the total earth loop impedance.

It is not such a good idea to cross-bond to isolated metalwork such as windows or doors set in timber frames. Under certain conditions this bonding may transmit a potential to an otherwise safe component.

Circuit protective conductors

The subject changes now from bonding to earthing. This may be academic in that electric current will not take note of labels and differentiate between green–yellow cable routes, plumbing or structural metalwork. Fault current will be divided across all available paths in proportion to relative resistances in accordance with Ohm's Law.

Circuit protective conductors are the green/yellow wires connected to appliances or taken through conduits to outlets. It would be incorrect to call
543–01 them 'earth wires'. A cpc must be sized and installed to ensure that any earth fault current will operate the appropriate protective device safely and speedily.

Sizing of cpcs is related to:

- The size of live circuit conductors (i.e. phase and neutral),
- The rating of the protective device,
- Rapid disconnection within a designated time,
- The prospective fault current.

Note that the above does not include the normal load current. This will have been taken into account when selecting the phase and neutral cables and the associated protective devices.

This book does not enter into calculations for protective conductor sizes. The projects shown have been designed with suitable circuit protective conductors which will conveniently fulfil the requirements of the Regulations. In some circumstances the result is over-engineering and the designer may find commercial advantages in making different arrangements.

Steel conduit and trunking

Undoubtedly conduit has sufficient conductivity to be an effective circuit protective conductor. Unfortunately a problem arises regarding continuity at
543–02 joints, particularly where a coupler and bush is used at knock-out holes in sheet metal enclosures. It would be difficult to assert that every joint will give

permanent and reliable continuity over the course of the subsequent five years or more. Additionally, in the absence of definitive information, a full continuity calculation would need to be carried out for every joint in the installation.

In the circumstances, for the purpose of the projects in this book, it is recommended that a green–yellow insulated copper conductor be pulled into all conduits. The conductor should be the same size as the largest phase conductor in the conduit.

It is important to remember that this does not reduce the responsibility to ensure the continuity of the conduit system. This is necessary to earth the
526–01 conduit itself and constitutes a good reason to use insulated plastic conduit.

Steel trunking can be considered in the same light as conduit. Effective continuity is as good as the worst joint. If permanent and reliable continuity can be assured, there is no reason why the trunking should not be used as the sole circuit protective conductor. However, the designer must be assured that the cross-sectional area at joints corresponds to the formula given in the Regulations.

An easier and possibly more reliable solution is to install a separate copper circuit protective conductor.

Note that it is acceptable to use just one cpc and/or bonding conductor for a group of circuits. This conductor should be sized appropriate to the largest
543–01 circuit or bonding requirement. Tee-off connections should be made in a manner that allows modifications and disconnections to be carried out without breaking the continuity to other equipment. In-line crimped joints are recommended.

Steel wire armoured cable

Is the armouring on a cable adequate for 'earthing' purposes? This is a matter of terminology and, as will be seen, the armouring is never suitable as a main bonding conductor, but may be satisfactory as a cpc.

There are two methods of determining the size of a cpc:

543–01
- Using the adiabatic formula in the Regulations, or
- Using the table of acceptable sizes.

Once again the issue of calculations is avoided in this book and only the second option is considered here. It must be emphasized that this method is probably unduly pessimistic and a more economical solution may result from detailed calculations.

Comparison of PVC and XLPE armoured cable

The physical sizes of insulation around similar conductor size PVC and XLPE

On this project it is unlikely that the estimated maximum demand figure will ever occur for more than a few minutes. This information will be used to determine the size of the mains supply. If there is any doubt, it is worth showing the figures to the electricity company.

A 100 A three-phase supply will be suitable for this load.

What about a sub-main?

When the above data are studied it will be seen that the major loads are located some distance from the mains intake position. Long runs of steel wire armoured cables will be necessary for the spray area and the compressor. The cooker could also create cable sizing problems using PVC insulated and sheathed cable.

There are at least three technical and commercial disadvantages in running long final circuits:

- *Voltage drop*
525–01 This is usually the deciding factor for cable sizing.
- *Diversity*
This cannot be applied to final circuit cables which are selected with reference to the full load current and rating of the protective device. It may be acceptable to apply diversity to sub-main cables carrying several loads provided that the protective device is suitable.
- *Earth loop impedance*
The impedance along an extended small sub-circuit cable may exceed the limits for fault protection.

All three of the above factors apply to this scheme. The extreme example is the cable run to the compressor, a distance of some 50 m.

A convenient position for local sub-distribution is where it had been intended to locate a supply for the spray area requirements. A three-phase distribution board at this point will carry the circuits shown in Table 8.3.

Wiring systems

The workshop can be considered separately from the office situation.

Workshop

A layout such as this lends itself to a plastic conduit and trunking installation. These systems are easy to install but must be carefully located to avoid
522–06 physical damage. If this was a light industrial application, for example a

Table 8.3 **Phase balance at sub-distribution board B.**

Phase		*Amps*
Red	Spray area	20
	Compressor	10.4
	Office lights	9
		39.4 (Total)
Yellow	Spray area	20
	Compressor	10.4
	13 A Sockets	20
		50.4 (Total)
Blue	Spray area	20
	Compressor	10.4
	Cooker	25
		55.4 (Total)

Diversified loading figures have been taken from Table 8.2. The phase balance at the mains distribution would be unchanged.

clothes manufacturing workshop, non-metallic wiring systems would have advantages and would have been recommended. With this current project, electrical safety relies upon protection of cables in extreme circumstances. Guidance Note PM 37 recommends the use of steel conduit and trunking or swa cables for places where motor vehicles are serviced. It would be irresponsible to ignore this guidance.

Steel conduit and trunking

Trunking is suggested for major groups of cables for lighting and sockets around the building. A suitable clear route will usually be found on the walls at
528–01 about 3–4 m above floor level; 415 V, 240 V and 110 V single-core cables may be mixed, provided that standard 300/500 V minimum rated cables are used.

In the workshop location, ambient conditions will always be reasonable;
523–04 therefore, if cable runs are surface mounted and never buried in any form of thermal insulation, there will be no temperature or insulation derating factors to be applied. The sizes given in Table 8.4 have a good margin of tolerance in sizing to the point that grouping factors may also be discounted.

471–15 - Other portable electric tools should operate on a 110 V centre tap earth system. The use of reduced low voltage is no protection against fire and explosion from flammable vapours.
- Compressed air portable tools are preferable to electric tools.
- Industrial 230 V plugs and sockets to BS 4343 (BS EN 60309-2) are more suitable than domestic BS 1363 types.

The installer should advise the client on the H & SE recommendation for 'Commando' type plugs. There is frequently user resistance to BS 4343 plugs and sockets for 240 V equipment.

(This scheme is based on BS 1363 13 A plugs with the BS 4343 alternative as an option.)

Wiring Regulations

- Every item of equipment must be of a design appropriate to the situation
512–06 in which it is to be used. The electrical installation must be of an industrial nature and, where appropriate, suitable for wet conditions.
- Any socket outlet which may reasonably be expected to supply portable equipment out of doors must have 30 mA rcd protection. Only the socket adjacent to the front roller shutter door is in this category but it would be a wise precaution to give rcd protection to all sockets..

Load assessment and maximum demand

After full consultations, a provisional list of electrical equipment has been drawn up in Table 8.1. A suitable format for a Project Specification is shown in Fig. 8.3.

Maximum demand load and diversity

This project calls for special consideration in terms of total maximum
313–01 demand. There is no relevant guidance. The designer must obtain manufacturer's data and rely upon experience.

Calculations and phase balancing figures for diversity will be approximate. Numbers have been rounded off.

Lighting

For current loading calculations, discharge lamp ratings must be multiplied by 1.8 to take into account control gear losses. An assumption of 100 W per outlet is made for tungsten lamps regardless of specification lamp size.

In the absence of other information, no diversity is being considered on discharge lighting and the tungsten load is discounted.

Table 8.1 Schedule of equipment for garage workshop.

Offices	*Workshop*
Lighting Fluorescent 8 × twin 75 W	 7 × single 75 W (benches) 4 × single 65 W (pit)
4 × 100 W tungsten	6 × 250 W SON (low-bay)
13 A 240 V sockets 8 × twin	 6 × single 1 × single with rcd
16 A 110 V sockets (yellow)	4 × single
415 V welder (red), single phase and neutral	1 × 32 A single
Roller shutters, gas blowers and ramps, 3-phase and neutral	8 × 6 A
Cooker and gas boiler supply, single phase	1 × 6 A 1 × 32 A
Provision for spray area, 3-phase and neutral	1 × 32 A
Compressor, 3-phase and neutral	1 × 16 A

Office lighting load

$$= 8 \times 2 \times 75\ \text{W} \times 1.8$$
$$= 2160\ \text{W}$$

This will be on one phase $= 9\ \text{A}$

Workshop lighting load

Benches $= 7 \times 75\ \text{W} \times 1.8$
$= 945\ \text{W}$

plus pit	=	$4 \times 65\ W \times 1.8$
	=	468 W
plus low-bay	=	$6 \times 250\ W \times 1.8$
	=	2700 W
Total lighting load	=	4113 W

Assume that this will be spread approximately equally across three phases

$$\frac{4113}{240 \times 3} = 5.7\ \text{A/phase}$$

Welder

415 V 10 kVA rating. Full load must be anticipated across two phases

= 24 A

Compressor

This runs on low load most of the time. 50% diversity can be allowed.

$$\frac{15\ \text{kW} \times 50\%}{240 \times 3} = 10.4\ \text{A/phase}$$

Gas blowers

$2 \times$ three-phase 0.75 kW fan motors. Full load must be anticipated.

= 2 A/phase

Provision for spray area

In the absence of other information a maximum demand load has been assumed

= 30 A/phase

Phase balance

It is essential to balance loads across three phases as far as possible. This exercise should consider the diversified current demands to obtain a balance on normal working conditions.

Table 8.2 gives a suitable arrangement. Note that at this stage, this does not necessarily indicate distribution board particulars.

Table 8.2 **Proposed balance across phases using diversified load figures.**

Phase		*Amps*
Red	Welder	24
	Office lights	9
	Works lights	5.7
	13 A sockets	20
	Gas blowers	2
	Spray area	20
	Compressor	10.4
	Ramp/hoists	—
	Roller shutters	—
		91.1 (Total)
Yellow	Welder	24
	Works lights	5.7
	13 A sockets	20
	Gas blowers	2
	Spray area	20
	Compressor	10.4
	110 V transformer	—
	Ramp/hoists	—
	Roller shutters	—
		82.1 (Total)
Blue	Works lights	5.7
	13 A sockets	20
	Gas blowers	2
	Spray area	20
	Compressor	10.4
	Gas boiler	—
	Ramp/hoists	—
	Roller shutters	—
	Cooker	25
		83.1 (Total)

Estimate of maximum demand

It will be seen that the estimate of maximum demand is very much a matter of experience. There is a tendency to overestimate high fixed loads which in practice only occur for short periods of time. Compressor and fan motors run
311-01 on low load most of the time and heaters have thermostatic regulation. The cooker is an unknown quantity, as are sundry kettles and room heaters.