DESIGN & INSTALLATION OF ELECTRICAL INSTALLATION COMPLYING WITH CP5 & CP88

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SECTION A - DESIGN AND INSTALLATION OF ELECTRICAL INSTALLATION COMPLYING WITH CP5 & CP88

1 Introduction

Prior to 1977 – There is no mandatory requirement to use any code of practice for the erection of electrical installation.

SS CP5:1977, Code of Practice, Wiring of Electrical Equipment of Building was adopted as a mandatory requirement for the wiring of electrical installation. The CP was based of IEE 14th edition.

SS CP5:1988, Code of Practice for Wiring of Electrical Equipment of Building was adopted and replaced the CP5:1977, which is based on IEE 15th edition.

SS CP5:1998, Code of Practice for Electrical Installation was adopted and replaced the CP5:1988, which is based on IEE 16th edition.

SS CP88: Part I: 2001, Code of Practice for Temporary Electrical Installation at Construction and Building Site was adopted.

SS CP88: Part II: 2001, Code of Practice Temporary Electrical Installations for Festive Lighting, Trade-Fares, Mini-Fares and Exhibition Sites was adopted.

2 Fundamental Requirement for Safety

2.1 Workmanship and Materials

(i) Good workmanship.

(ii) Proper material – comply with relevant Singapore Standard, IEC, BS and other standard if available.

2.2 General

(i) Equipment – Prevent danger

(a) Construction – e.g. IP rating, accessibility to live parts, ingress of water, gas & dust. **[Appendix A/2.2(i)(a)]**

(b) Installation – e.g. Heat dissipation, natural ventilation or refer to the manufacturer's method of installation.

(c) Protection – e.g. non-weather proof equipment installed in weatherproof enclosure.

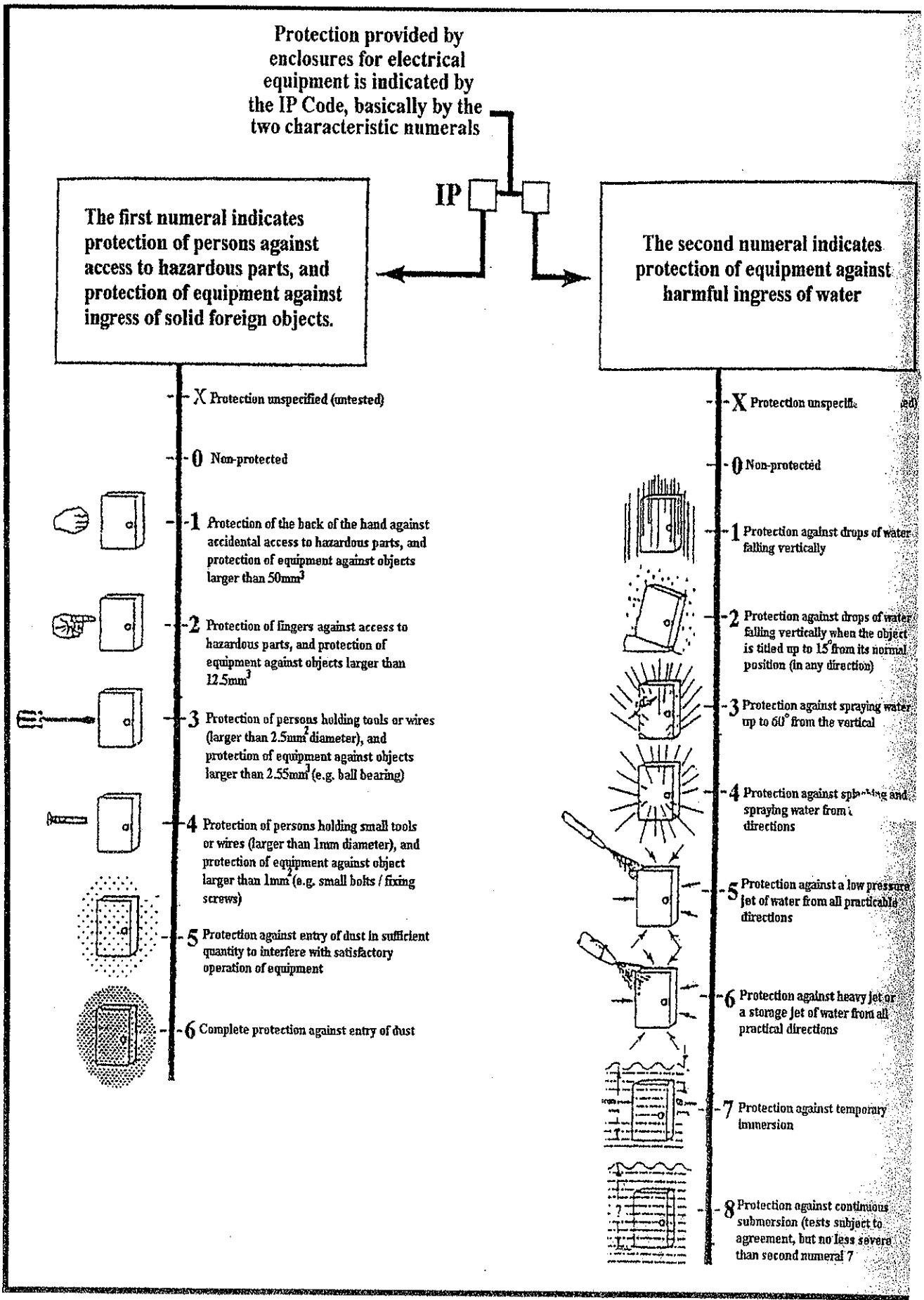


Figure 10. 7 (a) IP Code Chart

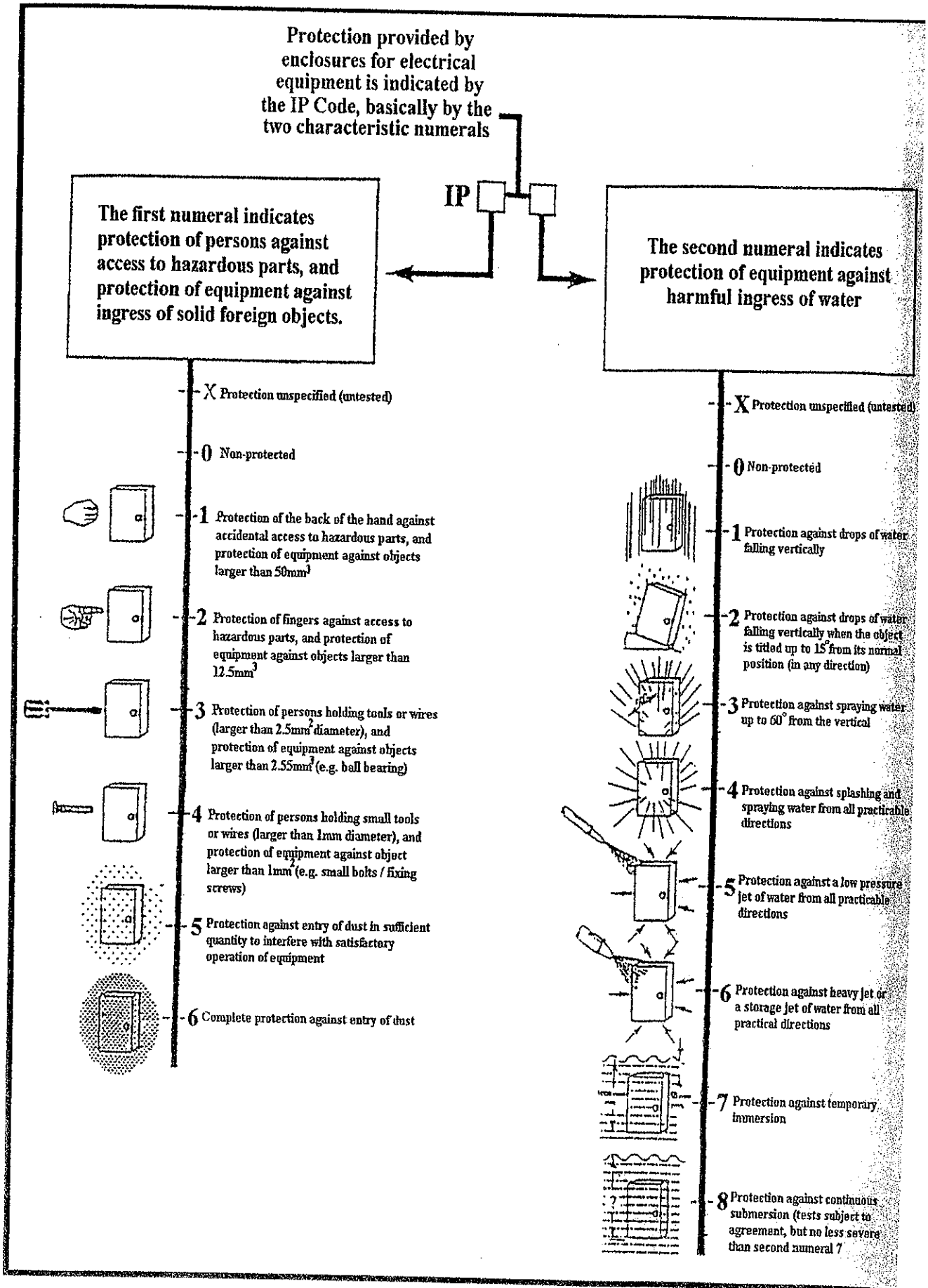
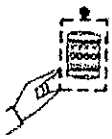
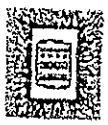
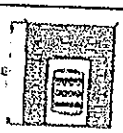


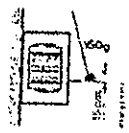
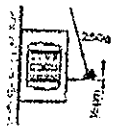
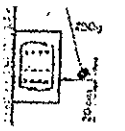
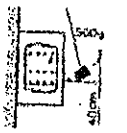
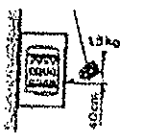
Figure 10. 7 (a) IP Code Chart

Protection Degrees of Enclosures

IP □ □ □

	Protection against solid objects	
0	no protection	
1	protected against solid objects up to 50mm e.g. accidental touch by hands	
2	protected against solid objects up to 12mm e.g. fingers	
3	protected against solid objects over 2.5mm (tools + wires)	
4	protected against solid objects over 1mm (tools + wires + small wires)	
5	protected against dust (no harmful deposing)	
6	total protected against dust	

	Protection against liquid	
0	no protection	
1	protected against vertically falling drops of water (e.g. condesation)	
2	protection against direct sprays of water up to 15° from the vertical	
3	protected against sprays up to 60 from the vertical	
4	protected against water sprayed from all directions	
5	protected against low pressure jets of water from all directions	
6	protected against strong jets of water (e.g. for use on shipdecks)	
7	protected against the effects of immersion between 15cm and 1m	
8	protected against long periods og immersion under pressure	

0	no protection	
1	impact 0.225 joules	
2	impact 0.375 joules	
3	impact 0.500 joules	
5	impact 2 joules	
7	impact 6 joules	
9	impact 20 joules	

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IP □ □ □

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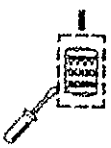
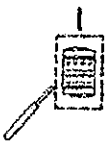
3	protected against solid objects over 2.5mm (tools + wires)	
4	protected against solid objects over 1mm (tools + wires + small wires)	
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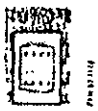
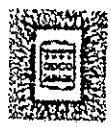
1	protected against vertically falling drops of water (e.g. condesation)	
2	protection against direct sprays of water up to 15° from the vertical	
3	protected against sprays up to 60 from the vertical	
4	protected against water sprayed from all directions	
5	protected against low pressure jets of water from all directions	
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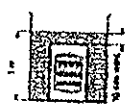
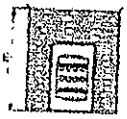
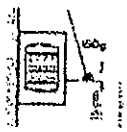
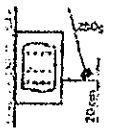
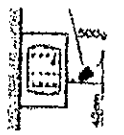
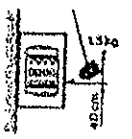
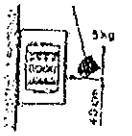
7	protected against the effects of immersion between 15cm and 1m	
8	protected against long periods og immersion under pressure	

0	no protection	
1	impact 0.225 joules	
2	impact 0.375 joules	
3	impact 0.500 joules	
5	impact 2 joules	
7	impact 6 joules	
9	impact 20 joules	

(d) Accessibility - for maintenance, inspection and testing.

(e) Power rating - Suitable for the maximum power demanded by the current using equipment.

Equipment is defined as any item for such purpose as generation, conversion, transmission, distribution or utilisation of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring systems accessories, appliances and luminaries.

Current-using equipment is defined as equipment which converts electrical energy into another form of energy, such as light, heat or motive power.

(ii) Electrical Conductor – Prevent danger

(a) Sufficient current-carrying capacity – continuous current, starting current.

(b) Insulated (where necessary further effectively protected) – e.g. double PVC insulated cable with the inner layer of PVC as basic insulation and the outer layer of PVC provide mechanical protection for the inner layer of PVC.

(c) Placed and safeguarded – installed in conduct, trunking.

(d) EMA reference for conduit wiring in wall

(iii) Electrical joint and connection

(a) Conductance – e.g. Volt drop, I^2R loss give rise to heat & fire hazard.

(b) Insulation – e.g. Voltage & temperature rating. **[Appendix A/2.2(iii)(b)]**

(c) Mechanical Strength – e.g. external pressure, stress.

(d) Protection – e.g. insulated joint enclosed in a weather proof box to prevent ingress of water.

(iv) Over Current Protective Devices

(a) will operate automatically at values of current which are related to the safe current of the circuit.

e.g. Overload current and short circuit current of the circuit conductor and its insulation. Overload current may be due to harmonic currents flowing in the neutral of a three-phase circuit.

(b) adequate breaking capacity (where appropriate, making capacity)

TABLE 52B (Clause 523-01)
Maximum conductor operating temperatures

Conductor material	Insulation material	Conductor operating temperature (°C)	Limiting final temperature (°C)	See Appendix 4 Table
Copper	70°C pvc (general purpose)	70	160/140*	4D 1-2-3 & 4
	60°C rubber	60	200	4H1
	85°C rubber	85	220	4F 1 & 2
	90°C pvc	90	160/140*	
	90°C thermosetting	90	250	4E 1-2-3 & 4
	Impregnated paper	80	160	
Copper	Mineral - plastic covered or exposed to touch	70(sheath)	160	4J1
	- bare and neither exposed to touch nor in contact with combustible materials	105(sheath)	250	4J2
Aluminium	70°C pvc (general purpose)	70	160/140*	4K 1-2-3 & 4
	90°C pvc	90	160/140*	
	60°C rubber	60	200	
	85°C rubber	85	220	
	90°C thermosetting	90	250	4L 1-2-3 & 4
	Impregnated paper	80	160	

*above 300 mm^2

(c) suitably located and are constructed so as to prevent danger from overheating, arcing or the scattering of hot particles, ready restoration of supply. **[Appendix A / 2.2(iv)(c)]**

e.g. Circuit breaker enclosed in a switchboard cubicle.

(v) Earth Leakage and Earth Fault Current

Metalwork of electrical equipment, other than current-carrying conductors, may become charged with electricity in such a manner as to cause danger:

The metalwork shall be connected to earth for safely discharge of electrical energy. The circuits concerned shall be protected against the persistence of an earth fault current by:

(i) an over-current protective devices or a residual current device, or equally effective device (e.g. insulated wall and floor).

(ii) Where substantial exposed metal parts of other services is accessible simultaneously with the metalwork of equipment, then those metal parts of other services shall be effectively connected to the MAIN EARTHING TERMINAL of the installation.

e.g. main equipotential bonding of metallic water pipe, sewage pipe and etc.

(vi) Protective Devices and Switches [Appendix A / 2.2(vi)]

(a) PHASE conductor - A single-pole fuse, switch or circuit breaker shall be inserted in the PHASE conductor.

(b) EARTHED NEUTRAL conductor –

Fuse, single-pole switch or single-pole circuit breaker, CANNOT be inserted in the EARTHED neutral conductor.

Except that LINKED SWITCH or LINKED CIRCUIT-BREAKER can be installed in the earthed-neutral conductor and arrangement shall be made to break all the related phase conductors.

e.g. 4-pole contactor used in a three-phase circuit shall close the neutral first before closing all the R, Y & B phase, and the neutral can be opened only after all the three phases, R, Y & B are opened. So as to prevent floating neutral on the load side which may give rise to high voltage on a particular single-phase, which may caused damaged to any equipment connected to that phase.

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	85°C rubber	85	220	4F 1 & 2
	90°C pvc	90	160/140*	
	90°C thermosetting	90	250	4E 1-2-3 & 4
	Impregnated paper	80	160	
Copper	Mineral - plastic covered or exposed to touch	70(sheath)	160	4J1
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	85°C rubber	85	220	
	90°C thermosetting	90	250	4L 1-2-3 & 4
	Impregnated paper	80	160	

*above 300 mm²

SEGREGATION & COMPARTMENTATION OF SWITCHBOARD

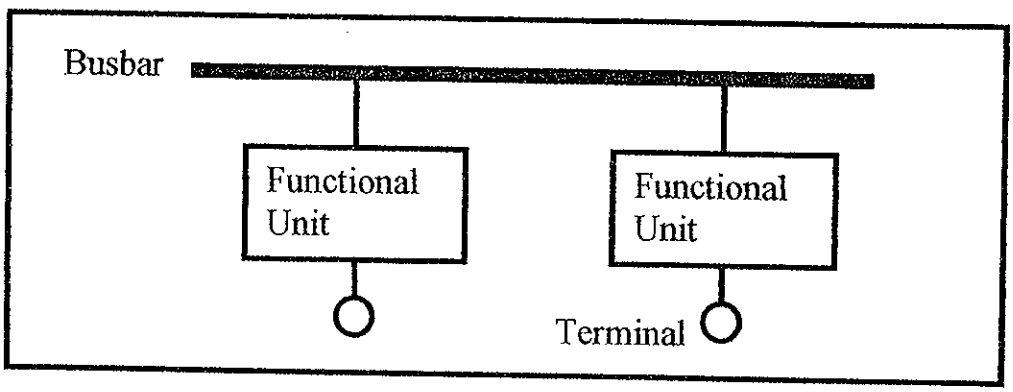
1 Purpose

Electrical faults generates ionised gas which may cause the striking of arc in other healthy live parts, the effect is most onerous in high voltage equipment.

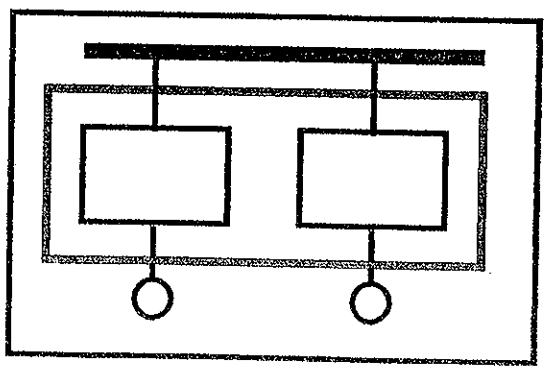
Segregation by barrier between compartment s or between one circuit and the next is essential so that the fault on one circuit may not be developed on other healthy circuits.

SS 482:Part I: 2000 and IEC 439-1 address the specification for LV switchgear and control gear assemblies. There are four distinct forms of physical separation of circuits, classified as Form 1, Form 2, Form 3 and Form 4.

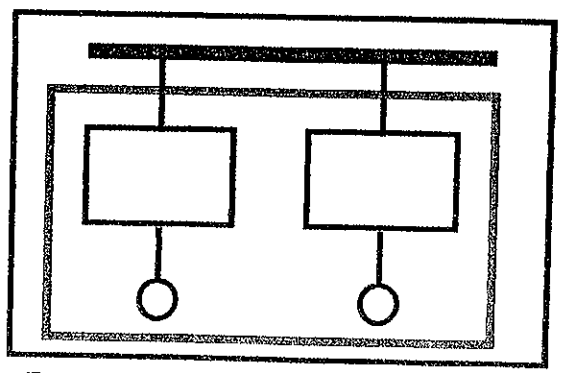
2 Form 1: No internal segregation.



3 Form 2: Segregation of busbars from the functional units, two types.



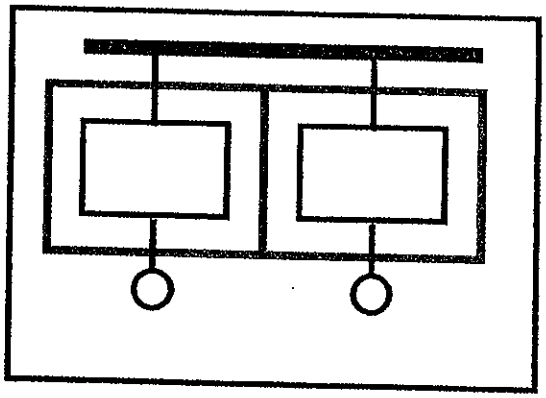
Form 2(a)
Terminals not separate from busbar.



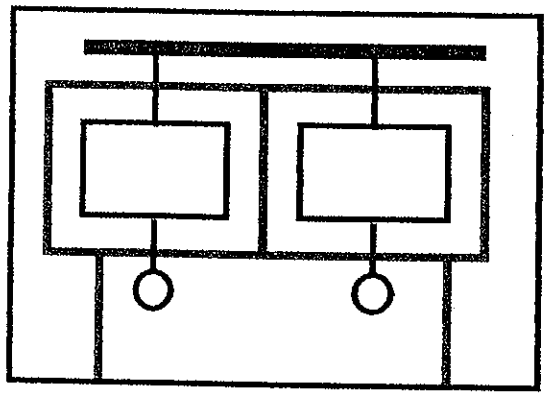
Form 2(b)
Terminals separated from busbar.

4 Form 3:

Segregation of busbars from the functional units, and
segregation of functional units from one another, and
segregation of terminals from functional units.



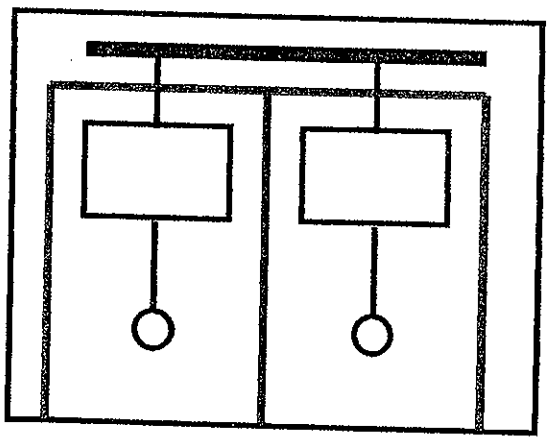
Form 3(a)
Terminals not segregated from busbars.



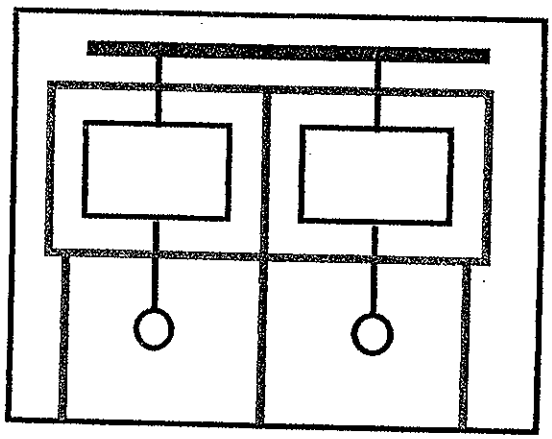
Form 3(b)
Terminals segregated from busbars.

5 Form 4:

Segregation of busbars from the functional units and terminals, and
segregation of functional units from one another, and
segregation of terminals from one another.

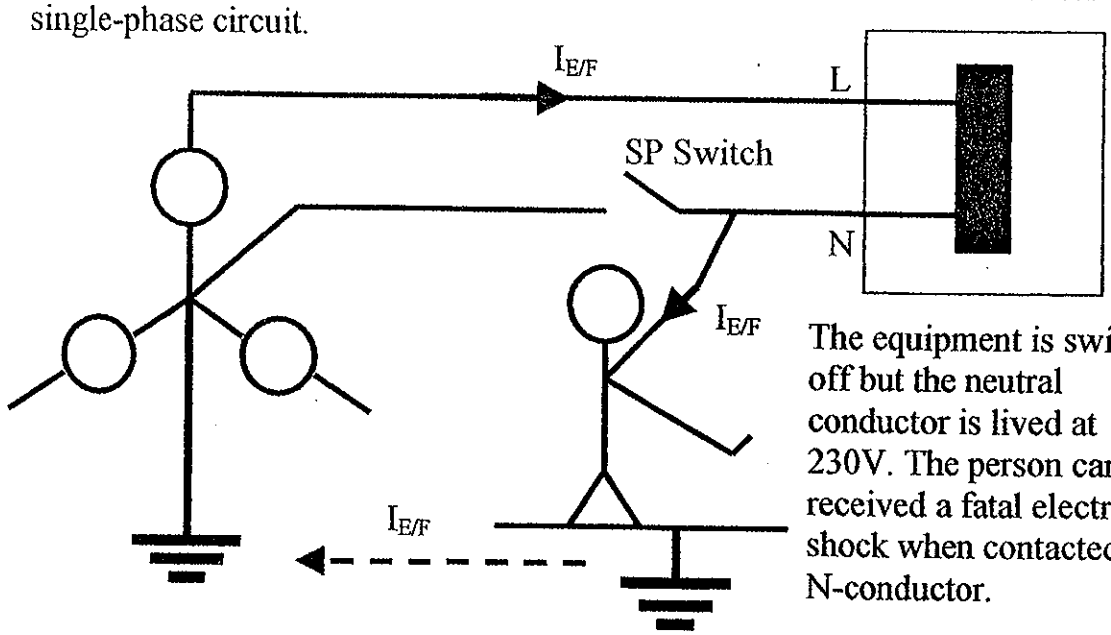


Form 4(a)
Terminals in same compartment as
associated functional unit.



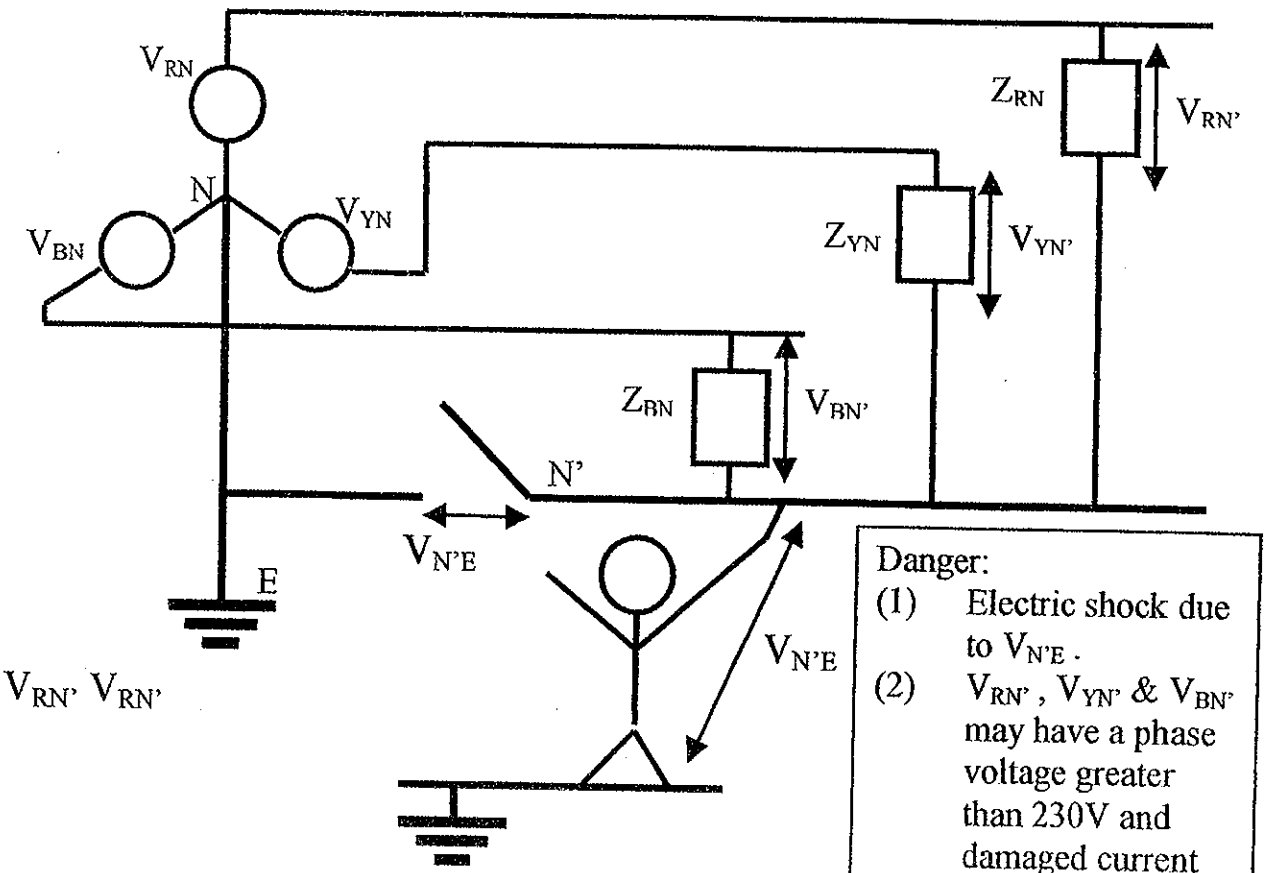
Form 4(b)
Terminals not in same compartment
as associated functional unit.

(1) Danger of single-pole device inserted in the earthed-neutral conductor for single-phase circuit.



The equipment is switched off but the neutral conductor is lived at 230V. The person can received a fatal electric shock when contacted the N-conductor.

(2) Danger in a three-phase circuit consist of unbalanced single-phase load when there is a broken neutral.



Danger:
(1) Electric shock due to $V_{N'E}$.
(2) $V_{RN'}$, $V_{YN'}$ & $V_{BN'}$ may have a phase voltage greater than 230V and damaged current using equipment.

(c) suitably located and are constructed so as to prevent danger from overheating, arcing or the scattering of hot particles, ready restoration of supply. **[Appendix A / 2.2(iv)(c)]**

e.g. Circuit breaker enclosed in a switchboard cubicle.

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The metalwork shall be connected to earth for safely discharge of electrical energy. The circuits concerned shall be protected against the persistence of an earth fault current by:

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(ii) Where substantial exposed metal parts of other services is accessible simultaneously with the metalwork of equipment, then those metal parts of other services shall be effectively connected to the MAIN EARTHING TERMINAL of the installation.

e.g. main equipotential bonding of metallic water pipe, sewage pipe and etc.

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e.g. 4-pole contactor used in a three-phase circuit shall close the neutral first before closing all the R, Y & B phase, and the neutral can be opened only after all the three phases, R, Y & B are opened. So as to prevent floating neutral on the load side which may give rise to high voltage on a particular single-phase, which may caused damaged to any equipment connected to that phase.

(vii) Isolation and Switching

To prevent or remove danger.

(a) Use effective means – Isolator, emergence switch, switch for functional-switching.

(b) Suitably placed for ready operation.

(c) All voltages may be cut off from every installation, from every circuit thereof and from all equipment.

Every fixed electric motor shall be provided with an efficient means of switching off, readily accessible, easily operated and so placed to prevent danger.

(viii) Accessibility of Equipment

For operation and maintenance shall provide ADEQUATE and SAFE MEANS of

- Access
- Working Space.

(ix) Precaution in Adverse Conditions

(a) To prevent danger, all equipment shall be suitably constructed or protected when it is likely to be exposed to

- Weather,
- corrosive atmospheres,
- other adverse conditions.

(d) All equipment in surroundings susceptible to risk of fire or explosion shall be

- suitably constructed or protected, and
- such other special precautions shall be taken.

(x) Additions and Alteration to an Installation

Be it temporary or permanent, designer shall ascertained the following condition,

(a) Existing equipment – Adequate rating and their condition shall be suitable for any altered circumstances.

(b) Earthing arrangement – Adequately size.

(xi) Inspection and Testing

Finally, appropriate inspection and tests shall be made, to verify so far as reasonably practicable that the requirement of this whole paragraph 2 has been met.

TABLE 4B

Allowances for diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies	Type of premises *		
	Individual household installations, including individual dwellings of a block	Small shops, stores, offices and business premises	Small hotels, boarding houses, guest houses, etc.
1. Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2. Heating and power (but see 3 to 8 below)	100% of total current demand up to 10 amperes + 50% of any current demand in excess of 10 amperes	100% f.l. of largest appliance + 75% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
3. Cooking appliances	10 amperes + 30% f.l. of connected cooking appliances in excess of 10 amperes + 5 amperes if socket-outlet incorporated in unit	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
4. Motors (other than lift motors which are subject to special consideration)		100% f.l. of largest motor + 80 f.l. of 2nd largest motor + 60% f.l. of remaining motors	100% f.l. of largest motor + 50% f.l. of remaining motors
5. Water-heaters (instantaneous type)*	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances
6. Water-heaters (thermostatically controlled)	no diversity allowable †		
7. Floor warming installations	*(Reseved for future use)*		
8. Thermal storage space heating installations	*(Reserved for future use)*		
9. Standard arrangements of final circuits in accordance with Appendix 5	100% of current demand of largest circuit + 40% of current demand of every other circuit	100% of current demand of largest circuit + 50% of current demand of every other circuit	
10. Socket outlets other than those included in 9 above and stationary equipment other than those listed above	100% of current demand of largest point of utilisation + 40% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every point in main rooms (dining rooms, etc) + 40% of current demand of every other point of utilisation

Section B - ASSESSMENT OF GENERAL CHARACTERISTICS

1 General

Assessment of the of the characteristic of the installation shall consist of:

(a) Purpose, Supplies and Structure, and

(b) External Influences, and

(c) Compatibility, and

(d) Maintainability.

These characteristics shall be taken into account in the choice of

(i) Method of Protection for Safety, and

(ii) Selection and Erection of Equipment.

2 Purpose, Supplies and Structure

(a) Maximum Demand **[Ref Appendix B/2(a)]**

Rated in unit Amperes. Diversity may be taken into consideration.

(b) Number and Type of Live Conductors

To be determine for the Source of Supply and for each circuit to be used within the installation. e.g.

(i) Single-phase 2 wire a.c.
(ii) 3-phase 4 wires a.c. consist of R, Y, B & N conductors.
(iii) 3-phase 3 wires a.c. consist of R, Y & B conductor. (for balance 3-phase motor)

(c) Type of Earthing Arrangement **[ref Appendix B/2(c)]**

In Singapore only TN-S and TT system for installation taking electricity supply from SP Asset Transmission and Distribution Network.

(d) Nature of Supply

Determine the characteristics of the source of supply or supplies by calculation, measurement, enquiry or inspection.

TABLE 4B

Allowances for diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies	Type of premises *		
	Individual household installations, including individual dwellings of a block	Small shops, stores, offices and business premises	Small hotels, boarding houses, guest houses, etc.
1. Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2. Heating and power (but see 3 to 8 below)	100% of total current demand up to 10 amperes + 50% of any current demand in excess of 10 amperes	100% f.l. of largest appliance + 75% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
3. Cooking appliances	10 amperes + 30% f.l. of connected cooking appliances in excess of 10 amperes + 5 amperes if socket-outlet incorporated in unit	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
4. Motors (other than lift motors which are subject to special consideration)		100% f.l. of largest motor + 80 f.l. of 2nd largest motor + 60% f.l. of remaining motors	100% f.l. of largest motor + 50% f.l. of remaining motors
5. Water-heaters (instantaneous type)*	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances
6. Water-heaters (thermostatically controlled)	no diversity allowable †		
7. Floor warming installations	*(Reseved for future use)*		
8. Thermal storage space heating installations	*(Reserved for future use)*		
9. Standard arrangements of final circuits in accordance with Appendix 5	100% of current demand of largest circuit + 40% of current demand of every other circuit	100% of current demand of largest circuit + 50% of current demand of every other circuit	
10. Socket outlets other than those included in 9 above and stationary equipment other than those listed above	100% of current demand of largest point of utilisation + 40% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every point in main rooms (dining rooms, etc) + 40% of current demand of every other point of utilisation

This Appendix gives some information on the determination of the maximum demand for an installation and includes the current demand to be assumed for commonly used equipment. It also includes some notes on the application of allowances for diversity.

The information and values given in this Appendix are intended only for guidance because it is impossible to specify the appropriate allowances for diversity for every type of installation and such allowances call for special knowledge and experience. The figures given in Table 4B, therefore, may be increased or decreased as decided by the engineer responsible for the design of the installation concerned.

The current demand of a final circuit is determined by summating the current demands of all points of utilisation and equipment in the circuit and, where appropriate, making an allowance for diversity. Typical current demands to be used for this summation are given in Table 4A. For the standard circuits using BS 1363 socket outlets, detailed in Appendix 5, an allowance for diversity has been taken into account and no further diversity should be applied.

The current demand of a circuit supplying a number of final circuits may be assessed by using the allowances for diversity given in Table 4B which are applied to the total current demand of all the equipment supplied by that circuit and not by summating the current demands of the individual final circuits obtained as outlined above. In Table 4B the allowances are expressed either as percentages of the current demand or, where followed by the letters f.l., as percentages of the rated full load current of the current-using equipment. The current demand for any final circuit which is a standard circuit arrangement complying with Appendix 5 is the rated current of the overcurrent protective device of that circuit.

An alternative method of assessing the current demand of a circuit supplying a number of final circuits is to summate the diversified current demands of the individual circuits and then apply a further allowance for diversity but in this method the allowances given in Table 4B are not to be used, the values to be chosen being the responsibility of the designer of the installation.

The use of other methods of determining maximum demand is not precluded where specified by a suitably qualified electrical engineer.

After the design currents for all the circuits have been determined, enabling the conductor sizes to be chosen, it is necessary to check that the limitation on voltage drop is met.

TABLE 4A

Current demand to be assumed for points of utilisation and current-using equipment

Point of utilisation or current-using equipment	Current demand to be assumed
Socket outlets other than 2A socket outlets	Rated current
2A socket outlets	at least 0.5A
Lighting outlet*	Current equivalent to the connected load, with a minimum of 100W per lampholder
Electric clock, electric shaver supply unit (complying with BS 3052), shaver socket outlet (complying with BS 4573), bell transformer, and current-using equipment of a rating not greater than 5VA	May be neglected
Household cooking appliance	The first 10A of the rated current plus 30% of the remainder of the rated current plus 5A if a socket outlet is incorporated in the control unit
All other stationary equipment	Rated current

*NOTE. Final circuits for discharge lighting are arranged so as to be capable of carrying the total steady current, viz. that of the lamp(s) and any associated gear and also their harmonic currents. Where more exact information is not available, the demand in volt-amperes is taken as the rated lamp watts multiplied by not less than 1.8. This multiplier is based upon the assumption that the circuit is corrected to a power factor of not less than 0.85 lagging, and takes into account control gear losses and harmonic currents.

+ For blocks of residential dwelling, large hotels, large commercial premises, and factories, the allowances are to be assessed by a competent person.

* For the purpose of this Table an instantaneous water-heater is deemed to be a water-heater which heats water only while the tap is turned on and therefore uses electricity intermittenly.

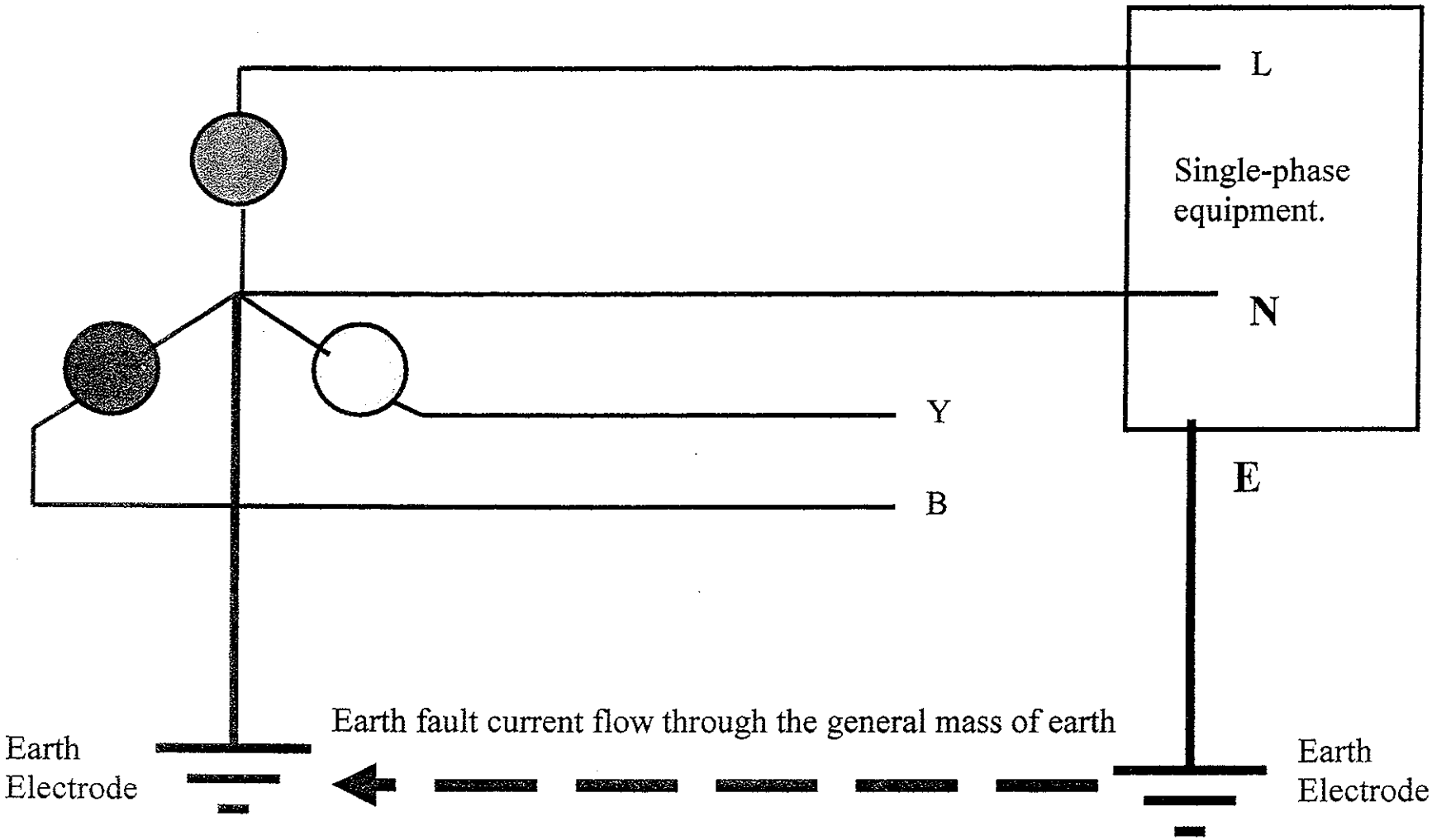
† It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

Example of Standard Connection Charge

Load		Standard Connection Charge $
16-45 kVA	63A 1-phase 63A 3-phase	5,300.00
46-75 kVA	66 – 108A 3-phase	8,800.00
76-140 kVA	109 – 202A 3-phase	16,700.00
141-180kVA	203 – 260A 3-phase	22,000.00
181-230 kVA	261 – 332A 3-phase	28,700.00
231-280 kVA	333 – 404A 3-phase	34,400.00

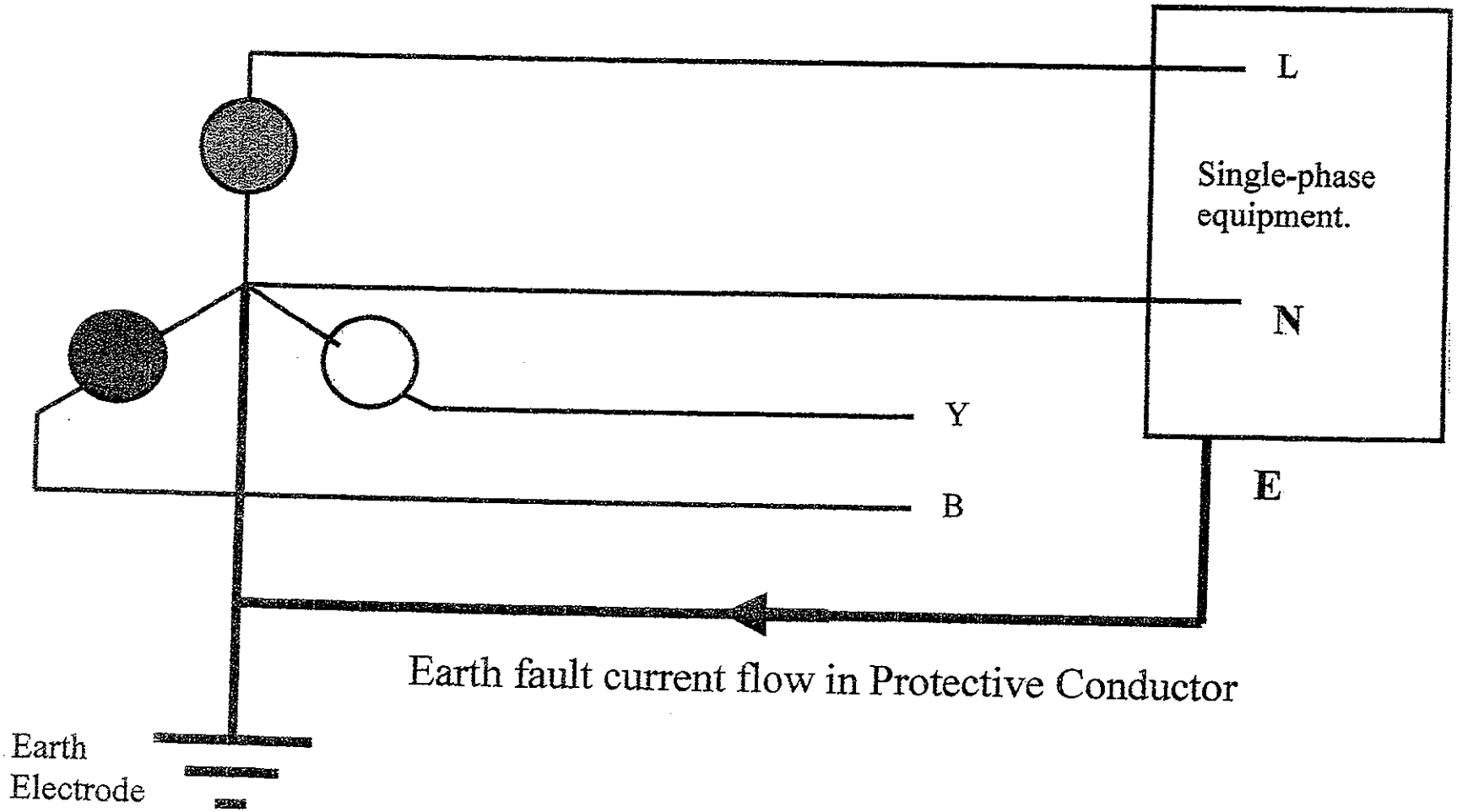
Appendix B / 2(c)

Fig (2) Earthing System - TT



Appendix B / 2(c)

Fig (1) Earthing System - TNS



(i) Nominal voltages. (e.g. Distribution Voltages may vary within ±6% are 230V, 400V, 22kV, and Transmission Voltages are 66kV and 230kV)

(ii) Nature of current and Frequency. (Supply frequency of Public supply network is 50Hz)

(iii) Prospective short-circuit current at the origin of the installation.

(a) Supply taken from SP Asset Transmission and Distribution Network:

Voltage	Supply Capacity	Short-Time Withstand Current Rating of Switchgear
22kV, 3-phase	-	25kA, 3 sec
6.6kV, 3-phase	-	20kA, 3 sec
400V, 3-phase	>180kVA	36kA, 3 sec
400V, 3-phase	>75kVA and ≤180kVA	25kA, 3 sec
400V, 3-phase	≤75kVA	9kA
230V, 1-phase	>15kVA and ≤23kVA	9kA
230V, 1-phase	≤15kVA	6kA

(b) For electrical installations taking electricity supply from the landlord's or management corporation's electrical installations, the LEW in-charge must ensure that the customer's main supply incoming switchgear is capable of withstanding the prospective short-circuit current at the connection point.

(iv) Earth fault loop impedance (Z_e) of that part of the system external to the installation.

e.g. For electrical installation taking electricity supply from the landlord's or management corporation's electrical installations, the LEW in-charge shall measure the external earth fault loop impedance at the supply take off point e.g. at the electrical riser.

(v) Suitability for the requirements of the installation, including the maximum demand. e.g.

- standby generators: automatic cut in after lost of supply source and autom
- standby generator connected permanently in parallel with the supply source. Consult the electricity supplier on the requirement of reverse power protection if any, metering requirement on maximum demand if any.

(vi) Type and rating of the overcurrent protective devices acting at the origin of the installation.

- DTL relay
- IDMTL relay (consist of three different type, namely Standard, Very Inverse and Extremely Inverse)
- Fuse

(e) Supplies for Safety Services and Standby Purpose **[Appendix B/2(e)]**

(i) Such supplies (e.g. standby generator) shall have,

- Adequate capacity.
- Reliability.
- Rating.
- Appropriate changeover time for the operation specified.

(ii) Where the normal source of supply is to be provided by an electricity supplier, the supplier shall be consulted regarding switching arrangements or parallel operation.

(iii) Supplies for safety services shall comply with the requirement of Chapter 56 of CP5: 1998.

(iv) A source for safety services shall be classified as either automatic (continuously available) or non-automatic (available within a stated time delay).

(f) Installation Circuit Arrangement

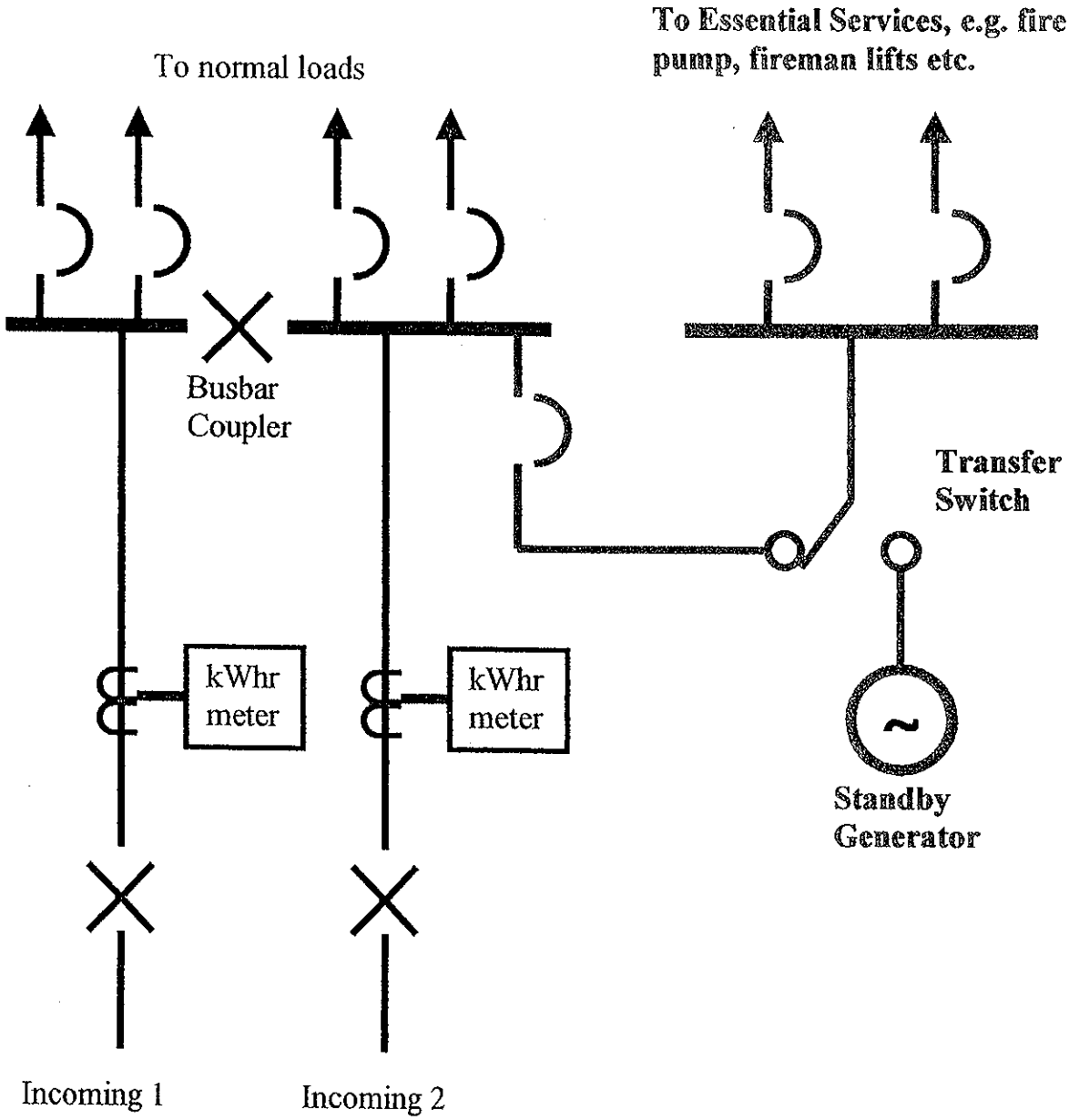
(i) Division of circuit so as to:

- avoid danger and minimise inconvenience in the event of a fault, and
- facilitate safe operation, inspection, testing, and maintenance.

(ii) Separation of circuit

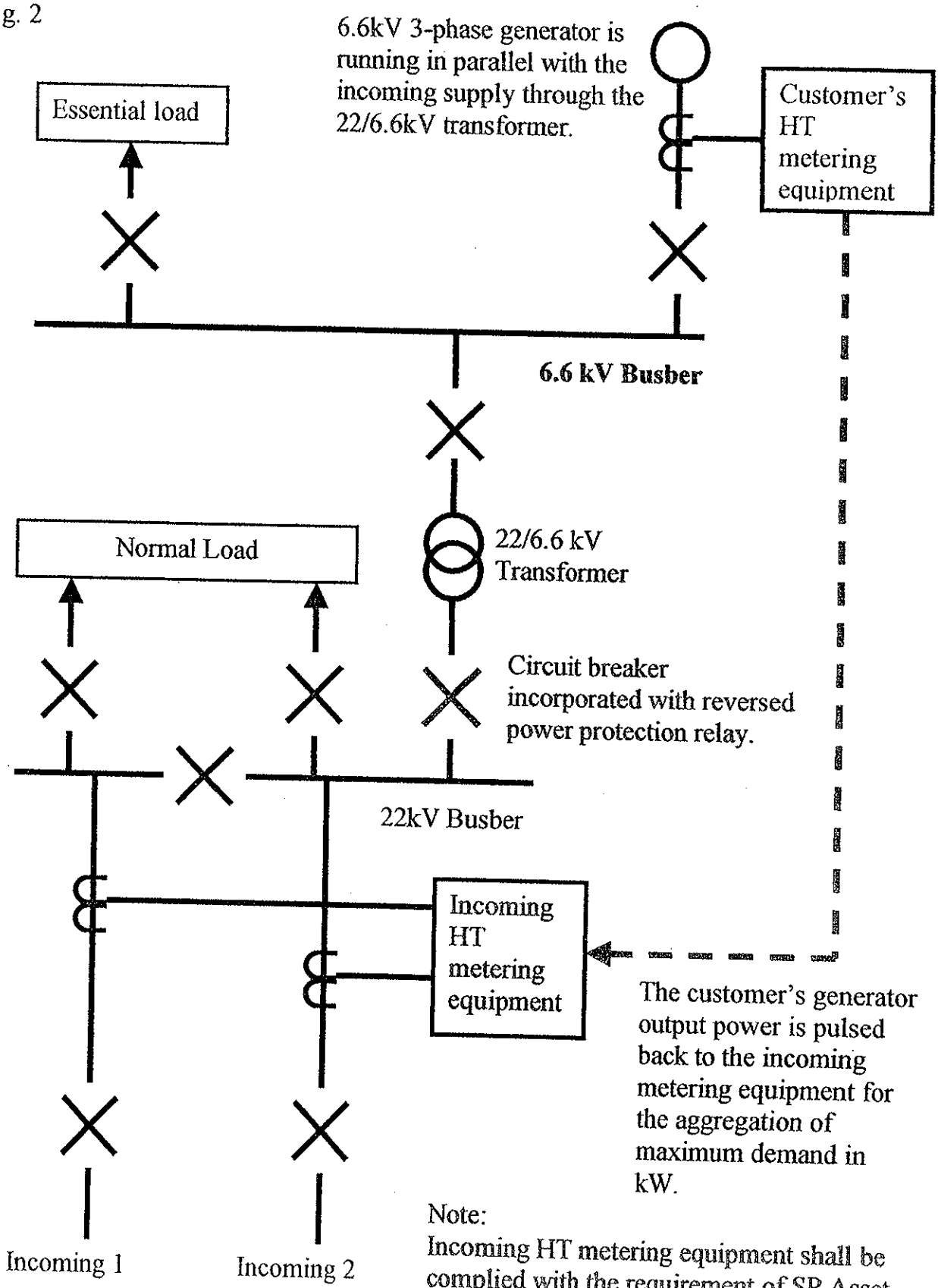
- A separate circuit shall be provided for each part of the installation which needs to be separately controlled for
  - compliance with CP5, or
  - prevent danger.

e.g. 1



The standby generator is never connected in parallel with the incoming supply.

e.g. 2



Note:
Incoming HT metering equipment shall be complied with the requirement of SP Asset Transmission and Distribution Network.

- The number of final circuits required, and the number of points supplied by any final circuit, shall be such as to facilitate compliance with the requirements for

  • overcurrent protection, and

  • isolation and switching, and

  • current carrying capacity of conductors.

- Distribution Board comprises more than one final circuit, each final circuit shall be connected to a separate way in a distribution board.

  The wiring of each final circuit shall be electrically separate from that of every other circuit, so as to prevent indirect energising of a final circuit intended to be isolated.

3 External Influences

"External influences" signifies influences from sources external to the installation which may be affect the design and safe operation of the installation.

The IEC classification corresponding to Appendix 5 of CP5 is adopted for this Code together with the proposed IEC requirements for its application.

4 Compatibility

(a) An assessment shall be made of any characteristics of equipment likely to have harmful effects upon other electrical equipment or other services, or likely to impair the supply.

These characteristics include, e.g.

(i) Transient overvoltages (produce steep rise high voltage which may damage other electrical equipment or electronic component)

(ii) Rapidly fluctuating loads (produce fluctuating voltage in the supply line which may behave as electrical noise for electronic equipment),

(iii) Starting current (give rise to voltage deep),

(iv) Harmonic currents (such as flourescent lighting loads and thyristor drives, e.g. third harmonic current of R, Y and B phase will be in phase in the neutral conductor which may cause overloading of the neutral conductor. e.g. I_{R3} = 10A, I_{Y3} = 15A, I_{B3} = 17.5A, then

the neutral current $I_{N3} = I_{R3} + I_{Y3} + I_{B3} = 10 + 15 + 17.5 = 42.5A$.)

(v) Mutual inductance,

(vi) d.c. feedback,

(vii) High frequency oscillations,

(viii) Earth leakage current,

(ix) Any need for additional connections to Earth (e.g. for equipment needing a connection with Earth independent of the main means of earthing of the electrical installation, for the avoidance of interference with its operation).

(b) For an installation taking electricity from an electricity supplier, the supplier shall be consulted regarding any equipment of the installation having characteristics likely to have significant influence on the supply network. [e.g. refer to SP PowerGrid Ltd's handbook on "**how to apply for electricity connection**".

5 Maintainability (clause under ref SS 538 : 2008)

An assessment shall be made for the installation on the following:

(i) frequency and quality of maintenance, and

(ii) any periodic inspection, testing, maintenance and repair likely to be necessary can be readily and safely carried out, and

(iii) any protective measures for safety remains effective, and

(iv) the reliability of equipment is sustained.

Example of Standard Connection Charge

Load		Standard Connection Charge $
16-45 kVA	63A 1-phase 63A 3-phase	5,300.00
46-75 kVA	66 – 108A 3-phase	8,800.00
76-140 kVA	109 – 202A 3-phase	16,700.00
141-180kVA	203 – 260A 3-phase	22,000.00
181-230 kVA	261 – 332A 3-phase	28,700.00
231-280 kVA	333 – 404A 3-phase	34,400.00

SECTION C – TURN ON ELECRICITY SUPPLY AND METERING ARRANGEMENT

1 Application of Load

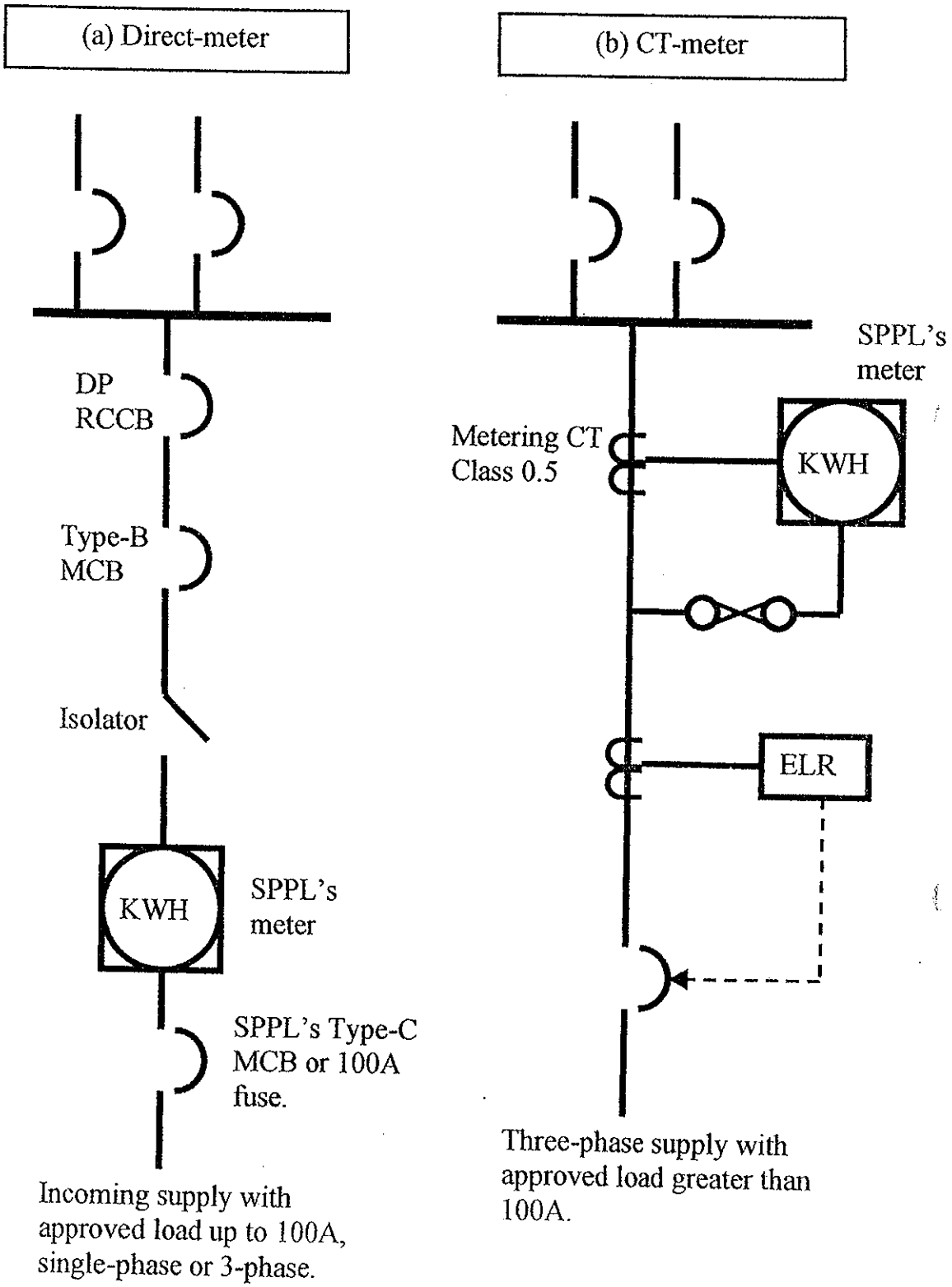
The procedure of application of load approval to turn on of electricity supply will vary according to the electricity supplier.

Take for example a bungalow is taking 400V/100A 3-phase supply directly from SP Asset Transmission and Distribution Network which is the property of SP PowerGrid Ltd (SPPL) and the utility account is opened under SP Services Ltd (SPSL). The following process is the arrangement for supply application till turn on of electricity supply:

S/No.	Action by LEW / Customer	Action by SPSL /SPPL
1	Submit Application Form for load approval. **[Appendix C/1]**	
2		Letter of Quotation for load approval. **[Appendix C/2]**
3	Customer to make payment for the service connection charge.	
4	LEW erection of electrical installation.	SPPL will installed the service cable upon received payment.
5	Customer to open electricity account with SPSL. **[Appendix C/3]**	
6	LEW to check with SPPL that the installed service cable is ready to be energised with electricity, then make appointment with SPSL for supply turn on and SPPL for installation of meter. **[Appendix C/4, C/4a, C/5 & C/6]**	
7	LEW ensure SPPL has installed the electricity meter prior to the confirmed turn on appointment.	SPPL to installed electricity meter at least one day prior to the turn on appointment.
8	LEW shall ensure the customer or his representative with letter of authorisation to attend the turn on appointment.	
8	On supply turn on date, LEW submit COC and COR and an endorsed copy of the incoming SLD to SPPL officer.	SPPL turn on electricity supply to the customer's main intake switchboard and issue Statement of Turn-on of Electricity. **[Appendix C/7]**
9	LEW to assist the SPSL officer to inspect and test the customer's electrical installation.	SPSL officer will inspect and test the installation and all the outlet points of the customer's electrical installation. Issue Electrical Installation Test Report. **[Appendix C/8]**

2 Metering Arrangement

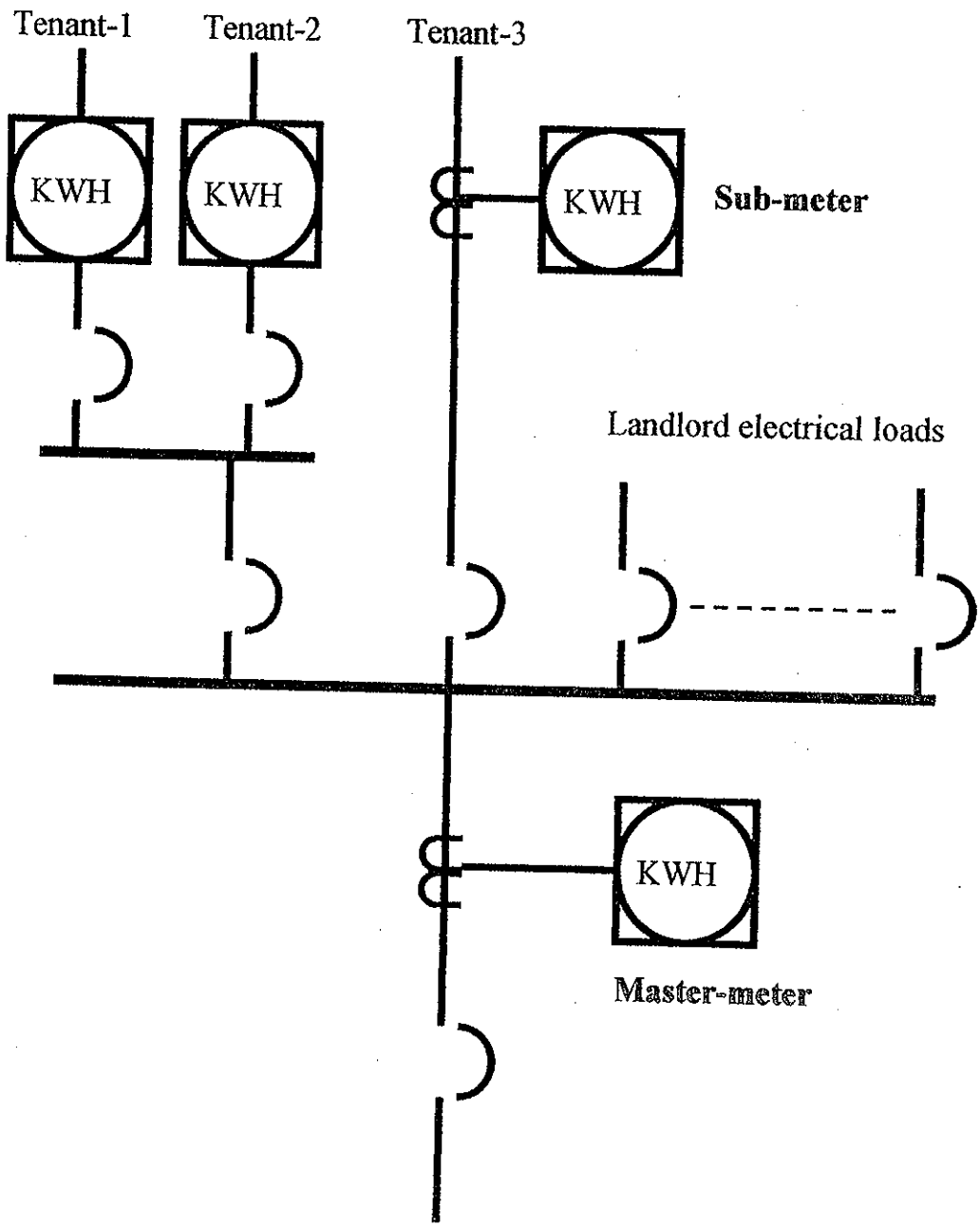
2.1 Single customer



2.2 Multi-tenanted Premises

(a) Master and Sub-Metering Scheme

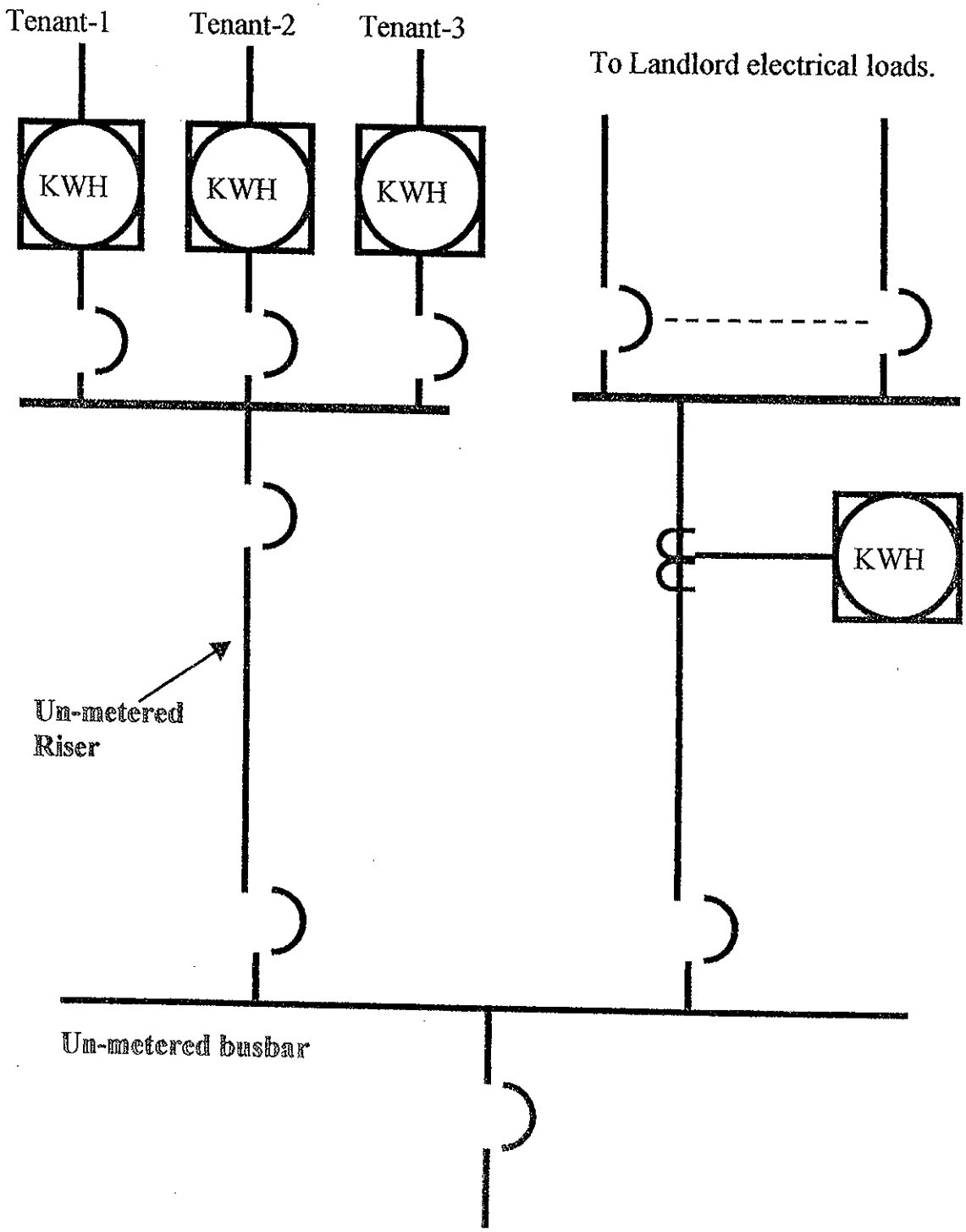
This metering scheme will be applicable to newly developed multi-tenanted premises. The landlord or owner will pay the amount electricity representing the difference between the amount of electricity consumed and registered by the Master-meter and the aggregate of the amount of electricity consumed by the occupants of the individual units within the premises.

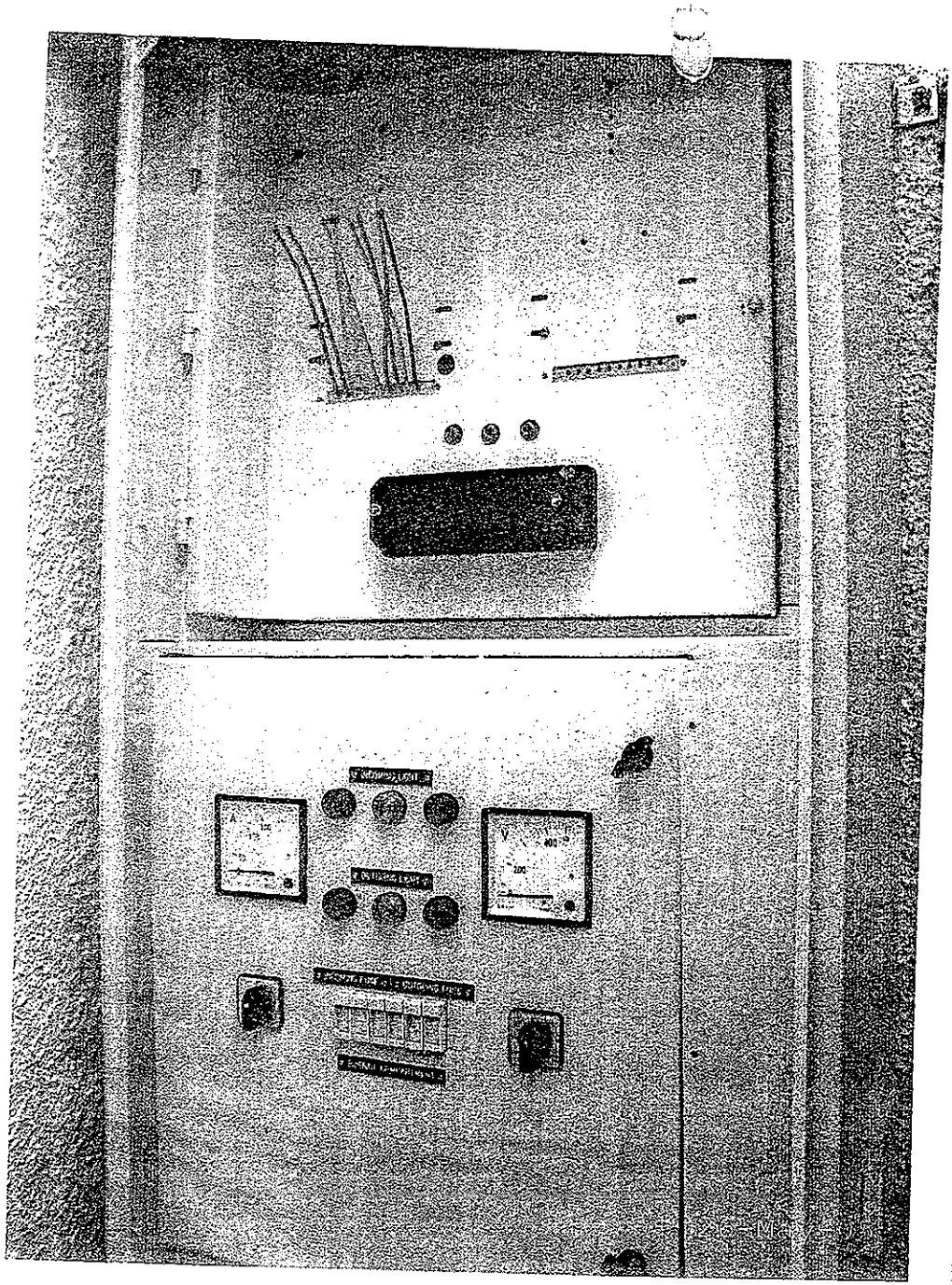


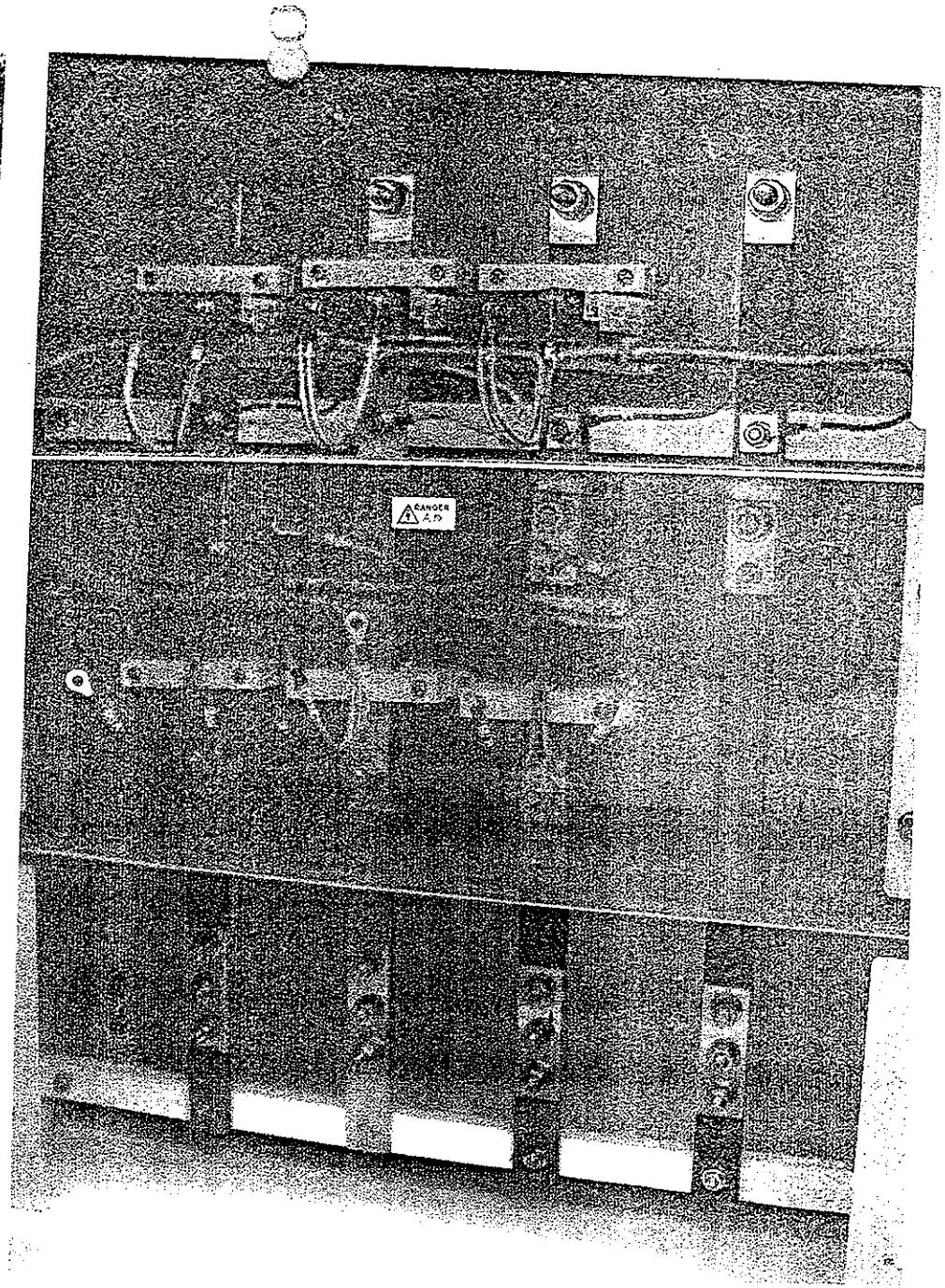
(b) Metered and Unmetered Scheme

This metering scheme may be installed in some of the existing multi-tenanted premises.

Electricity consumed by landlord and tenants will be registered by their meter directly.

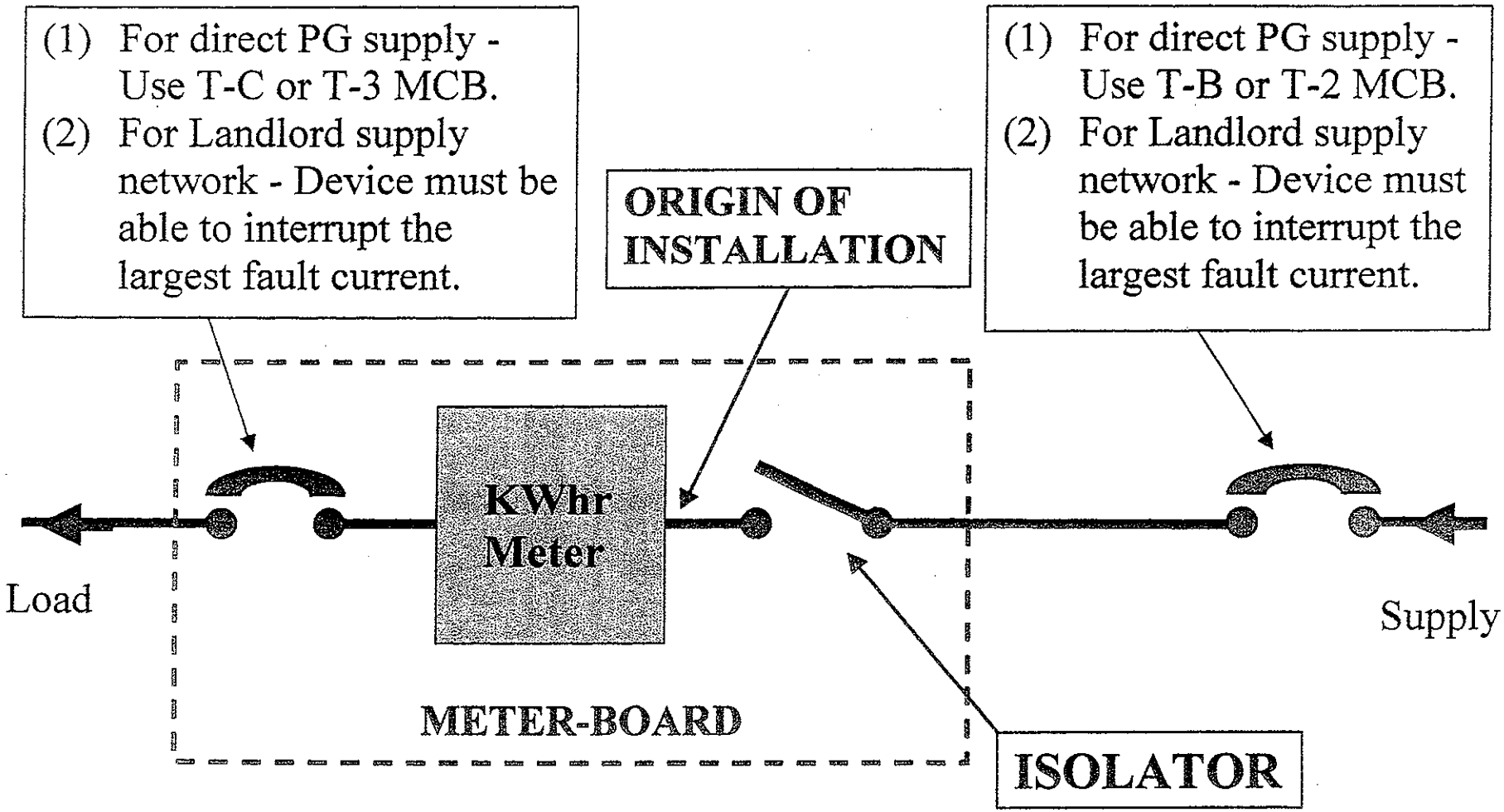


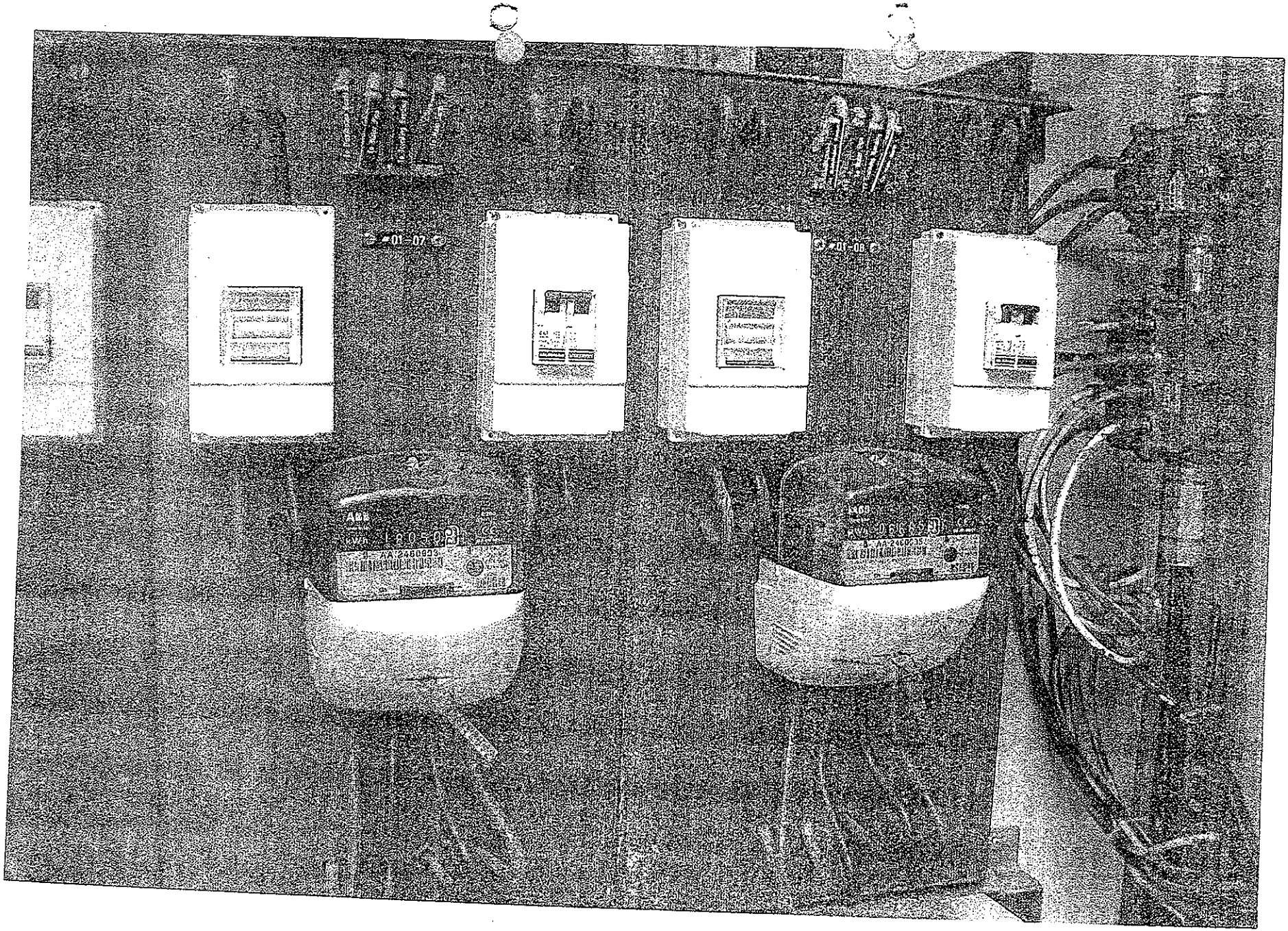



DANGER

2016-0

SEGUENCE OF CONTROL GEARS AT THE METER-BOARD FOR APPROVED LOAD UP TO 100A 3-PHASE 400V WITH DIRECT-METERING ARRANGEMENT





Appendix C/1

APPLICATION FORM
FOR CONNECTION TO SP POWERASSETS
TRANSMISSION SYSTEM

For official use only	
Application Number. :	
Date Received :	

To : SP Services Ltd
111 Somerset Road #06-05
Singapore Power Building
Singapore 238164

PART 1 APPLICANT'S DETAILS

Sub-metered customers (tenants) are not eligible for this application. All tenants in multi-metered premises are required to obtain supply from their landlord/MCST or HDB for HDB premises.

I request you to provide/upgrade the load connection service to my premises as given in Part II by my Licensed Electrical Worker undertaking the project

Name of Company/Applicant*: _____ ROC/NRIC No: _____

Name of Authorised Person & Designation* _____

Forwarding Address : _____ Postal Code : Singapore _____

Tel : _____ Fax : _____ Mobile Phone : _____ Pager _____

Email : _____ Signature of Applicant : _____ Date : _____

PART 2 INSTALLATION DETAILS – (To be completed by LEW)

Project Description : _____

Site Address : _____ Postal Code : Singapore _____

Utility Account No (existing) : _____ Existing Approved Load : _____ kVA/kW*

Any previous Consultation? Yes / No* If Yes, please provide Consultation No : _____

TYPE OF CONNECTION (Please tick appropriate box)

☐ New Connection ☐ Temporary Connection ☐ Change of connection pt

☐ Upgrade existing connection pt ☐ Upgrade with new connection pt

☐ Others (please specify: _____

TYPE OF DEVELOPMENT (Please tick appropriate box)

☐ Industrial ☐ Commercial ☐ Residential

☐ Others (Please specify) : _____

Type of Business Activity (Brief Description) : _____ Voltage Sensitive? Yes / No *

LOAD REQUIREMENT (One intake connection point per premises)

Total load requirement (to include existing load, if any)

☐ 30A/60A/100A* 230V single-phase ☐ 30A/60A/100A* 400V three-phase ☐ _____ kVA at 400V three-phase

☐ 22kV (min 1,700kW for 2 HV services, min 12,750 kW for 4 HV services) ☐ 66kV/230kV* (min 25.5MW for 66kV, min 85MW for 230kV)

Total Contracted Capacity of _____ kW at _____ kV via _____ service cable(s).

Initial Contracted Capacity of _____ kW (shall not be less than ¼ of the Contracted Capacity) for _____ months (not exceeding 12 months)

Landlord's Contracted Capacity (minimum 1700kW) : _____ kW (for multi-metered premises only)

Initial Landlord's Contracted Capacity : _____ kW (shall not be less than ¼ of the Landlord's Contracted Capacity)

For multi-tenanted installation with the exception of HDB residential installation, the metering scheme shall be designed as Master/Sub-metering scheme.

Target date of Energisation : _____/_____/_____ **Estimated ultimate load** _____ kVA/kW*

Contd. Appendix C/1.

EXISTING TYPE OF PREMISES (Please tick appropriate box)

☐ Single user premises ☐ Multi-tenanted Master-sub premises ☐ Multi-tenanted premises

TYPE OF METERING SCHEME

Please specify the metering scheme : *Master / Normal

Any change in metering scheme? *Yes / No . If yes, please specify _____.

TO BE COMPLETED FOR INSTALLATION EXCEEDING 45kVA

Total Land Area : _____ m^2 Gross Floor Area : _____ m^2

PLANS AND DETAILS (Mandatory)

☐ 2 copies of Architect's site and location plan
☐ 2 copies of plan showing proposed customer's intake connection point and the existing intake point (if applicable)
☐ Details of the type, floor area & designed load of individual premises for multi-metered premises

PART 3 LEW DETAILS

I confirm that the above information is correct and agree to advise SP Services should there be subsequent changes.

Name of Authorised LEW : _____ Licence Number: _____

Registered Forwarding Address : _____

_____ Postal Code : Singapore _____

Tel : _____ Fax : _____ Mobile Phone _____ Pager _____

Email : _____

Signature of Authorised LEW _____ Date _____

* Delete where not applicable

SP SERVICES
A subsidiary of Singapore Power Group

Appendix C/2

TAX INVOICE
GST Reg. No.: M2-89209204

SP Services Ltd • 111 Somerset Road #06-01 Singapore 238164 Tel: 6823 8888
Co. Registration No.: 199504470N

22-Jun-2005

QUOTATION FOR ELECTRICITY SUPPLY CONNECTION

Singapore 576855

Quotation No:
Application No:
Connection Charge: $ 8000.00
5% GST: $ 400
Previous Payment: $
Amount Payable: $ 8400
Expiry Date: 22-Dec-2005

RESIDENCE

SERVICE ID	APPROVED LOAD	FINAL SERVICE SIZE
DIRECT SC	69 KVA	35mm2/4C Cu/XLPE

Total Service Connection Charge including GST: $ 8400

NOTE

1. THE ABOVE IS A FIRM QUOTATION VALID FOR PAYMENT BEFORE THE EXPIRY DATE INDICATED.
2. YOU ARE REQUIRED TO ATTACH THE RIGHT HAND PORTION AND MAIL IT WITH YOUR CROSSED CHEQUE TO SP SERVICES LTD, ORCHARD P. O. BOX 341 SINGAPORE 912312. THE UPPER PORTION WITH MACHINE PRINTED PAYMENT REFERENCE WILL BE RETURNED TO YOU AS RECEIPT. OTHERWISE, THE CHEQUE WILL BE AUTOMATICALLY CREDITED TO YOUR EXISTING UTILITIES ACCOUNT OF OUR CHOICE TO OFFSET YOUR CURRENT CHARGES. YOU'LL BE REQUIRED TO DRAW ANOTHER CHEQUE FOR PAYMENT.
3. PLEASE WRITE THE APPLICATION NUMBER ON THE REVERSE SIDE OF YOUR CHEQUE.
4. PAYMENT CAN ONLY BE MADE BY CASH OR CHEQUE AT OUR CUSTOMER SERVICES CENTRE, 111 SOMERSET ROAD #01-10.
5. THE INVOICE IS FOR SERVICE CONNECTION WORK TO BE CARRIED OUT BY SP POWERGRID LTD (GST REG NO : M2-8920919-X). THE ORIGINAL TAX INVOICE IS NOT VALID FOR CLAIMING INPUT TAX UNLESS IT BEARS THE MACHINE-PRINTED RECEIPT.
6. **FOR CONTESTABLE CONSUMERS, YOU ARE REQUIRED TO ACTIVATE AND SUBSCRIBE A TELEPHONE LINE FOR EACH METER PANEL FOR REMOTE METER READING PURPOSES BEFORE ARRANGING FOR THE INSTALLATION OF METERS.**

LEW'S COPY (NOT TO BE USED FOR PAYMENT)

CO:PS BUSINESS:K TXN:3
APPLICATION NO:
QUOTATION NO:
AMOUNT PAYABLE: $ 8400

Contd Appendix C/2.

officers at 6823 8287/8340.

Email Address:
install@singaporepower.com.sg

Singapore

Mon-Fri: 8am-5pm

22-Jun-2005

Dear Sir/Madam,

ELECTRICITY CONNECTION TO

RESIDENCE

We are pleased to inform you that we can provide the electricity connection service requested. The quotation for the work to be done is given in the right-hand portion of this letter.

Please detach the right-hand portion of this letter and forward it together with your payment. Upon your payment, an officer from SP PowerGrid Ltd will liaise with your Licensed Electrical Worker/Contractor for implementation. We have also enclosed a copy of the customer guide on obtaining electricity connection for your use.

Please note the conditions of electricity connection stated overleaf and the following:

Applicant to provide a 100mm diameter cable entry pipe and meter compartment to be sited at the front gate / perimeter wall.

Applicant to provide cable entry pipe up to roadside drain.

Yours sincerely,

Rick Lim
Assistant Manager, Electricity Supply Application
Customer Services Branch

cc:

Attn:

This is a computer generated letter which requires no signature.

APPENDIX C/3

SP SERVICES LTD

Contact Log Ref:

(Acting for itself and as agent for and on behalf of Public Utilities Board and City Gas Pte Ltd for the supply of utilities)

APPLICATION FOR WATER, ELECTRICITY AND/OR GAS

(Co. Registration No. 199504470N)

Name of Applicant/Company: _____ ("the Consumer")

NRIC/FIN/Employment Pass/Co Reg no. : _____ Co Reg Date (for application in Co. name): _____

Tel No. _____ Fax No. : _____

Handphone No. _____ E-mail address: _____

Contact No. regarding your supplies (if different from above) _____ Contact Person (for application in Co.name) _____

Declaration (For Application in personal name)

☐ Please check here if you are an undischarged bankrupt. Bankruptcy number: _____

Details of Premises

a. Address of Premises where supplies are required _____ S _____ ("the Premises")

b. ☐ Owner ☐ Tenant

c. ☐ Residential Use ☐ Business Use

d. Mailing Address (if different from Premises) _____ S _____

e. For application made in person before 3pm at our services centers, supplies to your premises will be turned on the next business day (subject to availability of appointment). As for application submitted by fax or mail, supplies to your premises will be turned on in 4 working days. Alternatively you may indicate the turned-on date, subjected to availability of appointment.

Preferred Date of Turn on of Supplies : _____

Express Turn-on of supplies is subjected to the availability of appointments and an express charge.
***Next Day turn on/Express Service does not apply for premises without meters or requiring a Licensed Electrical Installation.**
****Please note that supplies will not be turned on if our technician found that the meter is not connected to the electrical installation or has been rewired at your premises.**

I/We make application(s) for the following utilities:

☐ Gas supply from City Gas Pte Ltd ☐ Electricity supply from SP Services Ltd ☐ Water supply from the Public Utilities Board

For Gas Turn-on / Installation, please call City Gas at 1800-555 1651 for an appointment.
Refuse collection charges (if applicable) will start with effect from the opening of account.

* For Non-Domestic Application (please indicate): ☐ Temp Supply ☐ Permanent Supply

1. I / We agree that each application for a utility, when accepted, will constitute a binding contract between myself / ourselves and Public Utilities Board / SP Services Ltd / City Gas Pte Ltd (as the case may be) and I / We agree that such contract shall be separate and independent from each other and shall be separately enforceable.
2. In the event that I / We make an application for gas at a later date, I / We agree to be bound by the terms and conditions for supply of gas set out in Part III overleaf and such other terms and conditions which City Gas Pte Ltd may, at its absolute discretion, notify and impose. I / We understand that nothing herein shall be constructed as an offer by City Gas Pte Ltd to supply gas to me / us and that City Gas Pte Ltd has the absolute discretion to reject my application for gas supply for any reason.
3. I / We agree to be bound by the terms and conditions specified by each supplier as set out in Part I (Water Supply) / Part II (Electricity Supply) / Part III (Gas Supply) overleaf.

_____ Consumer's Signature / Date
Co Stamp (Where applicable)

_____ Name, Designation & NRIC / FIN No. of Person signing for the Company

For Official Use

Utility A/C No: _____

Application Collected by: _____

Date of Application received: _____

Deposit $ _____ ☐ **Billed** ☐ **Collected (cash/cheque #** _____)

Request for Giro Form ☐ **Yes** ☐ **No**

Appt Date and Time Scheduled: _____

Remarks: _____

SP SERVICES LTD

(Acting for itself and as agent for and on behalf of Public Utilities Board and City Gas Pte Ltd for the supply of utilities)

PART I

Terms and Conditions of the Contract for the Supply of Water by The Public Utilities Board ("PUB")

1 The Consumer shall pay an initial deposit and maintain it at an amount not less than one and a half times the monthly charges. For non-Singaporeans and non-permanent residents an amount not less than 3 times the monthly charges.
2 The Consumer shall accept liability for this account.
3 Either party may give 4 working days' notice in writing to the other party to terminate this agreement.
4 If the water meter does not in the opinion of PUB correctly register the amount of water supplied to the Premises, PUB shall be entitled to charge such sum as it shall assess and the Consumer shall accept such assessment as final and conclusive.
5 The Consumer shall pay for the water supplied to the Premises at the appropriate water tariff according to the use of the Premises. The Consumer shall notify PUB of the change of use of the Premises within 7 days of such change.
6 The Consumer shall pay a fee on every reminder issued to the Consumer for failure to make payment in accordance with a bill sent to the Consumer.
7 The Consumer shall pay a late payment charge on any outstanding amount owed by the Consumer.
8 PUB shall not be liable for any failure or inconsistency in the water supply to the Premises howsoever and whatsoever caused.

PART II

Terms and Conditions of the Contract for the Supply of Electricity by SP Services Ltd ("SP Services")

1 The Consumer shall pay an initial deposit and maintain it at an amount not less than one and a half times the monthly charges. For non-Singaporeans and non-permanent residents an amount not less than 3 times the monthly charges.
2 The Consumer shall accept liability for this account.
3 Either party may give 4 working days' notice in writing to the other party to terminate this agreement.
4 If the electricity meter does not in the opinion of SP Services correctly register the amount of electricity supplied to the Premises, SP Services shall be entitled to charge such sum as it shall assess.
5 The Consumer shall pay for the electricity supplied to the Premises at such rates of electricity tariffs for the appropriate category of consumer as is fixed by SP Services from time to time.
6 The Consumer shall pay a fee, as is fixed by SP Services from time to time, for every reminder issued to the Consumer for failure to make payment in accordance with a bill sent to the Consumer.
7 The Consumer shall pay a late payment charge of 1% on any outstanding amount owed by the Consumer.
8 SP Services shall not be liable for any failure or defect in the supply of electricity to the Premises howsoever and whatsoever caused.

PART III

Terms and Conditions of the Contract for the Supply of Gas by City Gas Pte Ltd ("City Gas")

1 City Gas has appointed SP Services Ltd to be its agent for the opening and termination of this gas supply account, and the billing, collection and settlement of all charges under this account.
2 The Consumer shall pay an initial deposit and maintain it at an amount not less than one and a half times the monthly charges. For non-Singaporeans and non-permanent residents an amount not less than 3 times the monthly charges.
3 The Consumer shall accept liability for this account.
4 Either party may give 4 working days' notice in writing to the other party to terminate this agreement.
5 If the gas meter does not in the opinion of City Gas correctly register the amount of gas supplied to the Premises, City Gas shall be entitled to charge such sum as it shall assess.
6 The Consumer shall pay for the gas supplied to the Premises at such rates of gas tariffs for the appropriate category of consumer as is fixed by City Gas from time to time. The Consumer shall notify SP Services Ltd of the change of use of the Premises within 7 days of such change.
7 The Consumer shall pay a fee, as is fixed by City Gas from time to time, for every reminder issued to the Consumer for failure to make payment in accordance with a bill sent to the Consumer.
8 The Consumer shall pay a late payment charge of 1% on any outstanding amount owed by the Consumer.
9 City Gas shall not be liable for any failure or defect in the supply of gas to the Premises howsoever and whatsoever caused.

Appendix C/4

APPLICATION FOR APPOINTMENT FOR ENERGISATION OF SERVICE CONNECTION BY FAX

FACSIMILE TRANSMITTAL SHEET **Total No. of Pages (including this page): [ ]**

To:	Manager, Installation Branch	From [Name of LEW]:	
Company:	SP Services Ltd	Company:	
Fax No.:	62777044	Fax No.:	
Date:		Office Telephone No.:	
Application No.:		Pager/Handphone No.:	
MSS A/C No.:		Approved Load:	

I would like to make an appointment for energisation of service connection to _____

_____.
(site address)

The following documents are faxed together with this application.

Documents	Tick if applicable
1) Opening of Account with SP Services Ltd	
2) Opening of Account with Electricity Retailer (for contestable consumer)	
3) Confirmation of meters already fixed (for contestable consumer)	
4) Electrical Installation Licence issued by EMA	
5) Certificate of Compliance (original to be submitted to SPPG's project officer)	
6) Letter from IRAS confirming official address	

I will submit the Certificate of Readiness on site, failing which service connection shall not be energised and SPPG & SPPA shall not be liable for any loss arising therefrom.

I understand that the date of appointment is subject to confirmation by SP Services Ltd and the appointment date shall not be earlier than 4 business days from this fax date. The preferred appointment dates are as follows:

1st choice: Date: _____ Time: Morning / Afternoon*

2nd choice: Date: _____ Time: Morning / Afternoon*

3rd choice: Date: _____ Time: Morning / Afternoon*

(*delete whichever not applicable)

_____ _____
Name & Signature of LEW Licence No.

FOR OFFICIAL USE

The appointment for energisation of service connection is fixed on _____ at _____.
(date) *(time)*

Please liaise with Meter Section of SPPG for the fixing of revenue meter before the energisation.

For clarification, please contact _____ at Telephone No.: 627770 _____.

NEW.

Appendix C/4b.

METER DECLARATION REPORT

APC: _____ Turn-on Date: _____

Site Address: _____

PART I

To: Manager (Installation Branch), SP Services Ltd

Please select one:

- ☐ I will remove and return the following meters to SP PowerGrid Ltd (Meter Section).
- ☐ I will inform SP PowerGrid Ltd (Meter Section) to remove the following meters.
- ☐ The following meters were found missing.

Date for meters to be returned by: _____ (within 2 weeks from turn-on date unless with valid reason).

- Meter no: _____ Meter no: _____

Reason: _____

Please take note that if the old meters are not returned, the account holder shall bear the consequences of any issue that may arise.

Name & Signature of LEW / Date	Licence No.	Tel No.

I concur with the above statement.

Name & Signature of Account Holder / Date

PART II

To: Deputy Director (Meter), SP PowerGrid Ltd

For your record and necessary action.

Name & Signature of Officer-in-charge for Manager (Installation Branch) SP Services Ltd	Tel No.	Date

Appendix C/4a.

FORM E

CERTIFICATE OF FITNESS OF RESIDENTIAL UNIT

Application No. _____

To: Manager, Installation Branch
SP Services Ltd
111 Somerset Road #06-05
Singapore Power Building
Singapore 238164

PROJECT: _____

_____

AT APARTMENT BLOCK No. _____ STREET NAME: _____

DATE OF INSPECTION: _____ POSTAL DISTRICT: _____

Type/Total No. of Units		/(units)	/(units)
Others	MCB Rating		
	MCB Type (Before & after Revenue Meter)		
	Service Cable Size		
	RCCB Rating / Sensitivity		
Details of Electrical Installation	Cooker / Oven Point		
	Water Heater Point		
	15A Socket Outlet		
	13A Socket Outlet		
	Fan Point		
	Lamp Point		
	20A isolator SPN		
	20A isolator TPN		
	30A isolator SPN		
	30A isolator TPN		
	Others		
Unit Nos.			

I hereby declare that I have supervised the installation, inspected and tested the electrical installation of the residential unit(s) in accordance with the relevant Regulations and Code of Practice.

I hereby certify that the electrical installation of the residential unit(s) has been designed in accordance with the relevant Regulations and Code of Practice.

_____
Signature/Name/Licence No. of LEW responsible for electrical installation work*

_____
Signature/Name/Licence No. of LEW responsible for design of electrical installation*

* The same LEW may perform both design and installation work for the electrical installation.

Appendix C/5

CERTIFICATE OF COMPLIANCE

Particulars of Electrical Installation

Name of Consumer: _____

Address of Installation: _____

_____

Electrical Installation Licence No. _____ MSS Account No. _____

Approved load & Supply Voltage: _____ kW _____ Volts

Generator(s) Installed: ☐ Operated in parallel with PowerGrid's network.
No. of generator: _____ Rating: _____ kVA
☐ Standby generator.
No. of generator: _____ Rating: _____ kVA
☐ Not applicable

Electrical Installation Design Certification

I certify that the design of the above-mentioned electrical installation complies with the requirements of the Electricity (Electrical Installations) Regulations 2002 and the relevant Singapore Standard Code of Practice. With the certification of compliance by the LEW responsible for the installation work as shown below, I hereby request for the energisation of the supply line to the said electrical installation on _____ (date).

_____ _____ _____
Name & Signature of LEW responsible for design of electrical installation* **Licence No.** **Date**

Electrical Installation Inspection Certification

I have supervised the work of the above-mentioned electrical installation and hereby certify that the electrical installation complies with the requirements of the Electricity (Electrical Installations) Regulations 2002 and the relevant Singapore Standard Code of Practice. I further certify that the technical requirements as stipulated by the person responsible for turning on the switchgear which controls the supply of electricity to the said electrical installation have been complied with.

_____ _____ _____
Name & Signature of LEW responsible for electrical installation work* **Licence No.** **Date**

* The same LEW may perform both design and installation work for the electrical installation.

Copy to:

Market Support Services Licensee

REF: E(EI)Reg5(2)

Appendix C/6

CERTIFICATE OF READINESS
FOR THE ENERGISATION OF SERVICE CONNECTION

Name of Customer Installation: _____

Address: _____

Customer Installation Licence No/Expiry Date: _____

Connection Voltage: _____

Approved Load: _____

Name of Connection Cable(s): _____
Owned by Connection Applicant (Yes / No)

MSS Account No: _____

Name of Retailer: _____

_____

Certification By LEW

I, _____(name) the undersigned LEW, hereby certify that the service connection*, the equipment and works at the above installation (Licence No: _____) are now ready and fit for energisation with effect from the date and time specified below.

Date: _____

Time: _____

I certify that:

a. protection details are as follows**:

CT Ratio: _____ /1A or 5A*

Short-Time Withstand Current Ratings of Main Supply Incoming Switchgear_____KA for 3 sec

Main 1 Type: _____

Main 2 Type*: _____ Direct Acting Tripping Setting: _____

O/C Type: _____ Setting: _____

E/F Type: _____ Setting: _____

b. the switching equipment/transformer/service connection* and all associated apparatus related to the service connection have been tested and checked by me and they have passed the pre-commissioning checks and tests in compliance with the Market Rules, Transmission Code, Handbook on How to Apply for Electricity Connection, Connection Agreement, all other applicable standards, and the associated protection systems have all been proven effective.

c. The main protection schemes for the service connection have been commissioned by load simulation method on date: _____**

d. *for multi-metered installation with the exception of HDB residential installation, the metering scheme has been designed as master/sub-metering scheme.

* Delete where not applicable
** To indicate NA where protection scheme is not applicable

Appendix C/7

STATEMENT OF TURN-ON OF ELECTRICITY
Regulation 5(3) of the Electricity (Electrical Installations) Regulations 2002

Electricity supply to : _____
(Name of Applicant)

at _____
(Address of Installation)

_____

_____

Electrical Installation Licence No* : _____

I agree that the above-mentioned electrical installation is suitable for connection to the electrical system. I certify that the supply line to the installation has been energised on _____ (date) at _____ (time) .

_____ Name & Signature of PowerGrid's officer

_____ NRIC No.

_____ Date

I acknowledge that the supply line has been energised on the date and time indicated above.

_____ Name & Signature of LEW responsible for the design & installation of the electrical installation

_____ Licence No.

_____ Date

I acknowledge that the supply line has been energised on the date and time indicated above and confirm that I will be responsible for the operation of this electrical installation hereafter.

_____ Name & Signature of LEW responsible for the operation of the electrical installation*

_____ Licence No.

_____ Date

I acknowledge that the supply line has been energised on the date and time indicated above.

_____ Name & Signature of Applicant or his representative

_____ NRIC / Passport No.

_____ Date

* Not Applicable for an electrical installation that is exempted from licensing

Appendix C/8

SP SERVICES
A member of Singapore Power Group

ELECTRICAL INSTALLATION INSPECTION REPO

SP Services Ltd
111 Somerset Road #06-05 Singapore Power Building Singapore 238164 Tel: 6823
Co. Registration No: 199504470N

Tester: TESTER
Appln. Ref. No.:
Customer:
Proj Description:
Site Address: ZP

Date: 07-Dec-2005 09:01:59 Page: 40
Account No.:
Tel No:
Premise No :
Installation No :
M-Inst No : None

Approved Load: 69 KVA
Customer Code: OOO
Supply Voltage: 400 V
Type of Appln: Rewiring/Upgrading

Installation Items Details:

Description	Qty	Description	Qty	Description	Qty
20A SPN/DP ISO	~~12~~ 14	30A TPN ISO	2	Water Heater Point	~~6~~ 7
Lamp Point	~~150~~ 153	13A SSO	~~38~~ 53	cooker	1
				connection units	5
				shaver	4

Previous Inspection - Remarks

Not Applicable

Meter Reqt	Meter No	Meter Reading	Exist Meter No.	Meter Count
N		15		

Meter Scheme	: NORMAL	Phase to Phase Insulation	: 2	M ohms
Rate Type	: ELECDOM	Phase to Earth Insulation	: 19	M ohms
Final Serv Size	: 35mm²/4c cu	Neutral to Earth Insulation	: 1	M ohms
CB/CUT Out Size	: 100A HRC fuse	ELR/ELCB Test Satisfactory	: YES / ~~NO~~	
Line/Earth Z	: 0.74Ω	Polarity Check Satisfactory	: YES / ~~NO~~	

Inspection Result: PASSED / ~~FAILED~~ / ~~NOT TESTED~~

~~installation~~ does not comply with requirements due to the following ~~items~~ (see overleaf for explanation). A re-inspection is required:

Remarks :

Inspection Date/Time[12]: 09.12.2005 14:00:00 Tester: Signature:

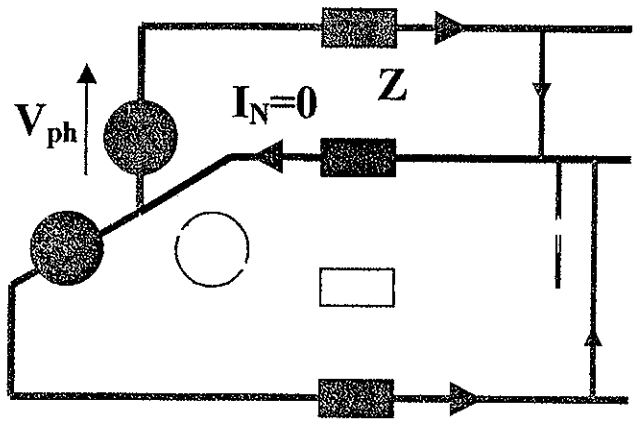
Customer Rep: I/C No: Signature:

I, WANG HEE WENG ,hereby certify that I have supervised the work on the above electrical installation and that to the best of my knowledge and belief the electrical installation is in accordance with the Singapore Standard CP5 and the relevant regulations .I further certify that I have inspected and tested the said electrical installation and it is safe for turn-on.

Name : Licence No. : Signature:

Comparison of the magnitude of the prospective short circuit current for a three phase supply system

1 Symmetrical 3-Phase Fault:



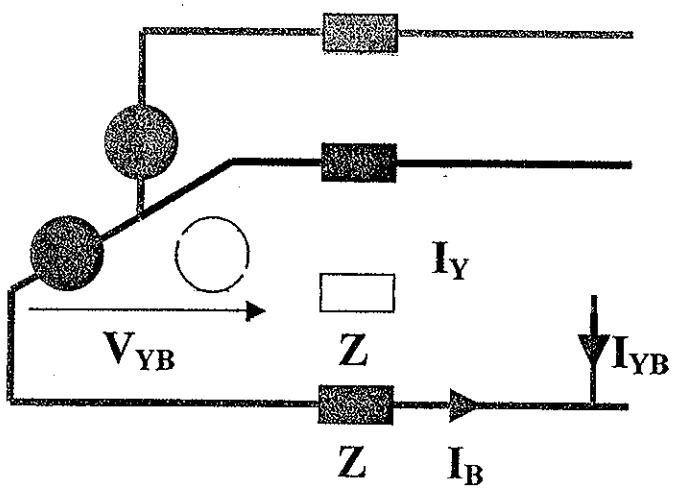
$I_N = I_R + I_Y + I_B = 0$ (A)

There is no voltage drop across the impedance of the N-line. The **"magnitude"** of the line current,

$I_{sym} = I_R = I_Y = I_B = (V_{ph} / Z)$

$I_{sym} = (V_{ph} / Z)$

2 Line to Line Fault:



The prospective short circuit current,

$I_{YB} = I_Y = (-I_B)$

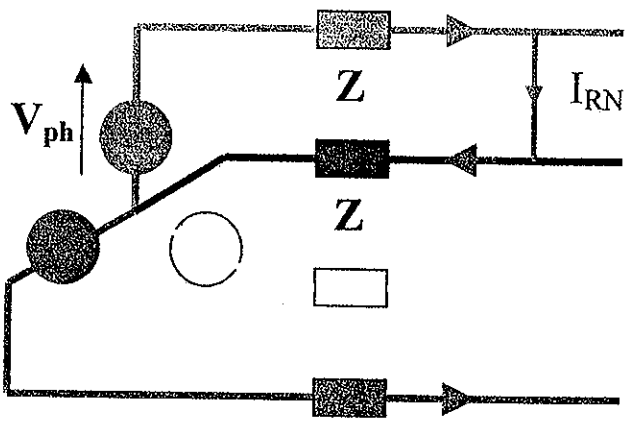
$= V_{YB} / (2Z)$

$= (V_L)/Z$

$= (\sqrt{3})V_{ph} / 2Z$

$= 0.866(V_{ph}/Z)$

3 Line to Neutral Fault:

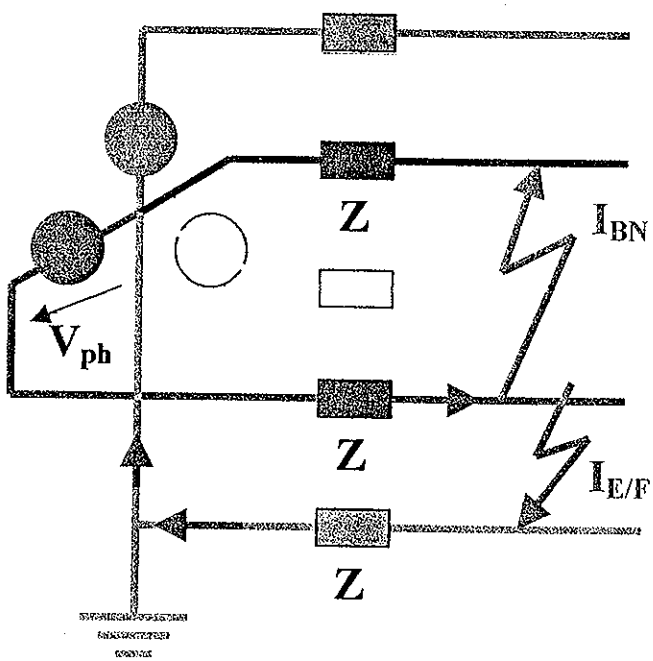


$I_{RN} = V_{ph} / 2Z$

$= 0.5\ (V_{ph}/Z)$

4 Line to Earth Fault:

(a) TN-S system

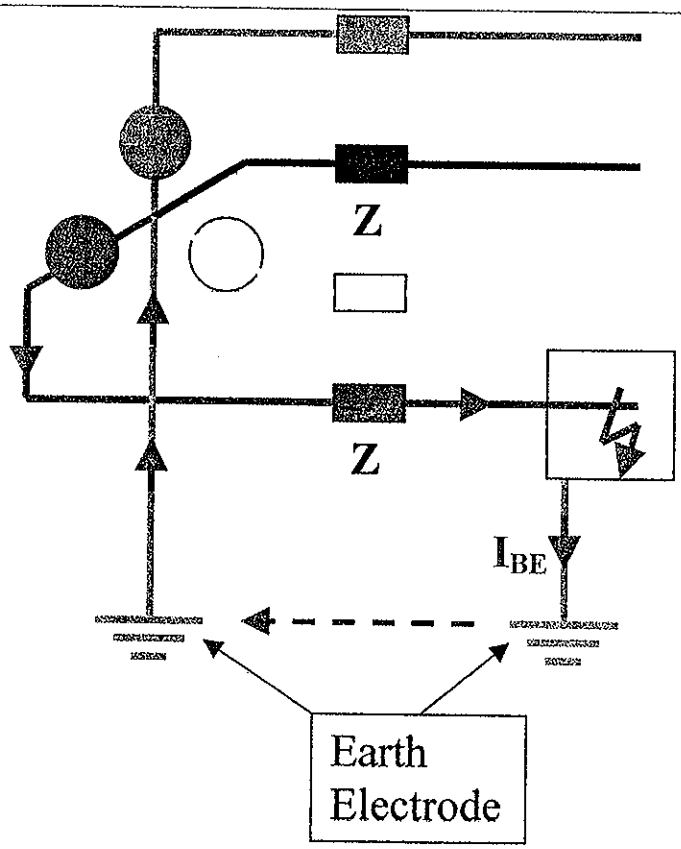


Assuming the CPC is of the same size as the N-conductor.

$I_{E/F} = I_{BN} = V_{ph} / (2Z)$

$= 0.5(V_{ph}/Z)$

(b) TT-System

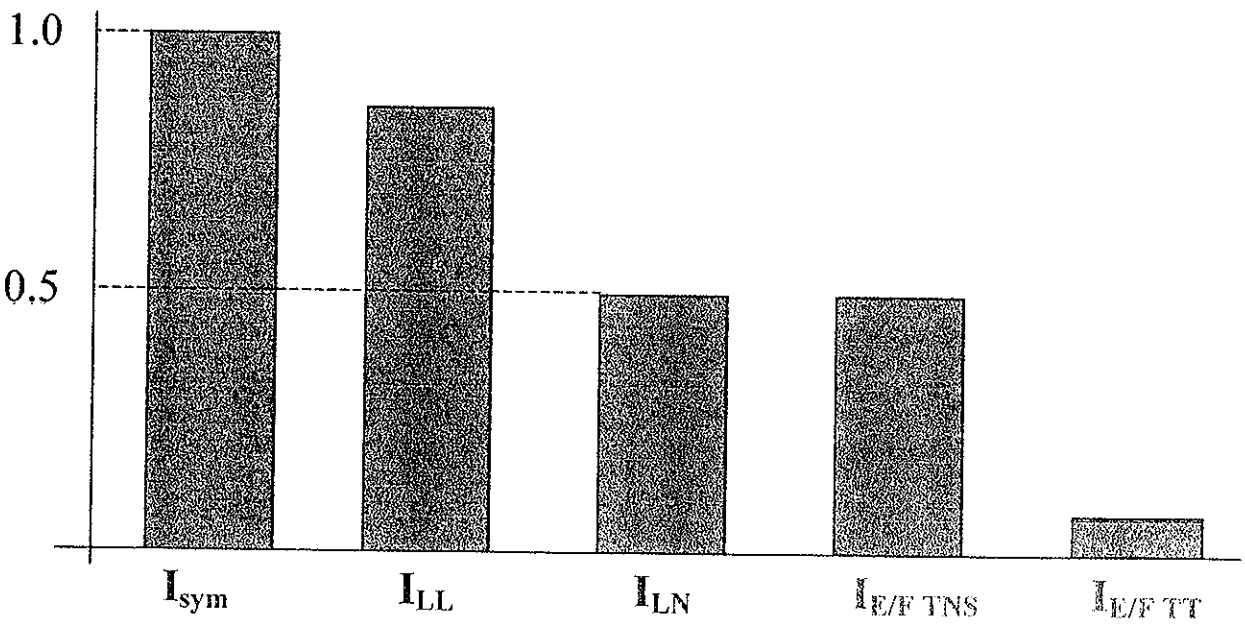


The prospective earth fault current $I_{E/F} = I_{BE}$

$= V_{ph} / (Z + Z_{electrodes})$

Usually the earth electrode resistance, $Z_{electrodes}$ is much more larger than the overall circuit conductor's impedance, Z. Let assume $Z_{electrodes} = 7Z$, then

$I_{E/F} = V_{ph} / (Z + 7Z)$
$= \mathbf{0.125}\ (V_{ph} / Z)$



PROTECTION AGAINST THERMAL EFFECTS

1 Purpose

Person fixed equipment and fixed materials adjacent to electrical equipment (Heat source) shall be protected against harmful effects of heat.

2 Propagation of heat -

By Conduction / Radiation.

3 Thermal Effects

(i) Combustion, ignition or degradation of materials.

(ii) Risk of burns.

(iii) Impairment of the safe function of installed equipment.

4 Protection Against Fire and Harmful Thermal Effects

4.1 Does not cause danger or harmful effects to adjacent fixed material by

(a) Correct selection and erection of Fixed electrical equipment.

(b) Manufacturer's installation instruction.

4.2 In the presence of risk of fire or harmful effects to adjacent materials:

(i) Mounting on support (with low thermal conductance) or within an enclosure which will withstand such temperature. Or

(ii) Screening by material which can withstand the heat emission. Or

(iii) Mounting to allow safe dissipation of heat and at a sufficient distance from adjacent materials.

4.3 Fixed equipment that can emit arc or high temperature particles:

(i) Total enclosure in arc-resistant material. and/or

(ii) Screening by arc-resistant material. And/or

(iii) Mounting so as to allow safe extinction of the emission at a sufficient distance.

4.4 Every termination of live conductors or joint shall be contained within an enclosure

(i) Accessory to SS, IEC or BS.

(ii) Enclosure to SS, IEC or BS.

(iii) Enclosure of material complying with glow wire test requirement of IEC 695-2-1.

(iv) Enclosure formed or completed with building material tested to BS 476 Part 4.

(v) Enclosure formed or completed by part of building structure, having the ignitability characteristic "P" as specified in BS 476 Part 5.

4.5 Electrical equipment in a single location contains, in total, flammable liquid in excess of 25 litres:

Prevent the spread of burning liquid, flame and the products of combustion.

4.6 Fixed equipment causing a focusing or concentration of heat :

Installed at a sufficient distance from any fixed object or building element.

4.7 Materials used for the construction of enclosure shall comply with the resistance to heat and fire requirements in an appropriate product standard.

No product standard exists - materials used shall withstand the highest temperature in normal use.

5 Protection against Burns

The temperature limit under normal load conditions for an accessible part of equipment within arm's reach		
Part	Material of accessible surface	Maximum temperature (°C)
A hand-held means of operation	Metallic	55
	Non-metallic	65
A part intended to be touched but not hand-held.	Metallic	70
	Non-metallic	80
A part which need not be touched for normal operation	Metallic	80
	Non-metallic	90

6 Protection Against Overheating

6.1 Forced Air Heating System
(Not central-storage heater):-

Electric element -

(a) Cannot be activated until the prescribed air flow has been established.

(b) Deactivated when the air flow is reduced or stopped.

(c) Two temperature limiting devices independent of each other which prevent permissible temperature from being exceeded in air ducts.

(d) Frame and enclosure of electric element - Non-ignitable material.

6.2 Appliances Producing Hot Water or Steam

(i) Protected against overheating in all service conditions -

By design or method of erection.

(ii) Type of protective device -

Non-self-resetting device, functioning independently of the thermostat.

(iii) Appliance has no free water outlet -

Use device to limit water pressure.

PROTECTION AGAINST UNDERVOLTAGE

1 Precaution & Danger

Where a reduction in voltage, or loss and subsequent restoration of voltage, could cause danger - then take precautions.

2 Damaged Without Danger

"Current-using equipment" or "part of installation" may be damaged by a drop in voltage and it is verified that such damage is unlikely to cause danger, one of the following arrangement shall be adopted:

(i) Take suitable precautions against the damage foreseen, or

(ii) confirm that the damage foreseen is an acceptable risk.

3 Time Delay Without Danger

If the operation of the equipment allows without danger a "brief reduction" or "loss" of voltage -

(i) then undervoltage protective device shall incorporate a "suitable time delay".

(ii) Any delay in the opening or reclosing of a contactor shall not impede instantaneous disconnection by a control device or a protective device.

4 Characteristic of Undervoltage Protective Device

It shall be compatible with the requirements for starting and use of the equipment.

5 Dangerous Reclosure

The reclosure shall not be automatic.

OVERCURRENT PROTECTION

1 Definition

(1) Overcurrent – A current value exceeding the rated value.

(2) Overload current – An overcurrent occurring in a circuit which is electrically sound.

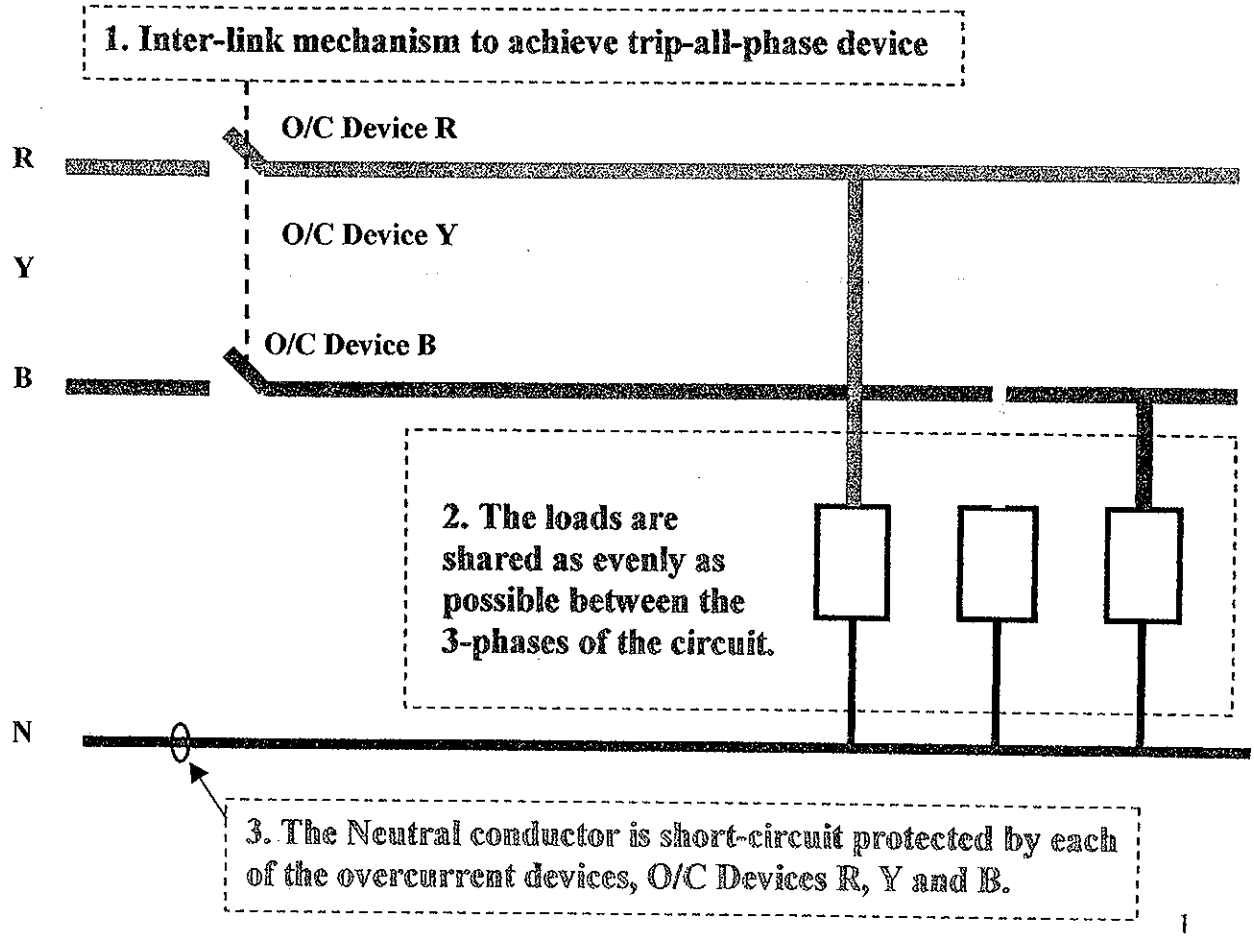
(3) Short-circuit current – An overcurrent resulting from negligible impedance between live conductors.

2 What is Overcurrent Protection

All live conductors (phase red, yellow, blue and neutral) shall be protected by one or more devices for **automatic interruption** of the supply in the event of **overload** and **short-circuit**.

2.1 Overcurrent protection of Neutral Conductor

If the cross-sectional area of the Neutral conductor is less than that of the phase conductor, all of the following 3 conditions must satisfied:



Q1 Why is that a trip-all-phase device is required for a 3-phase circuit?

Q2 Why the loads are shared as evenly as possible for the 3 different phases?

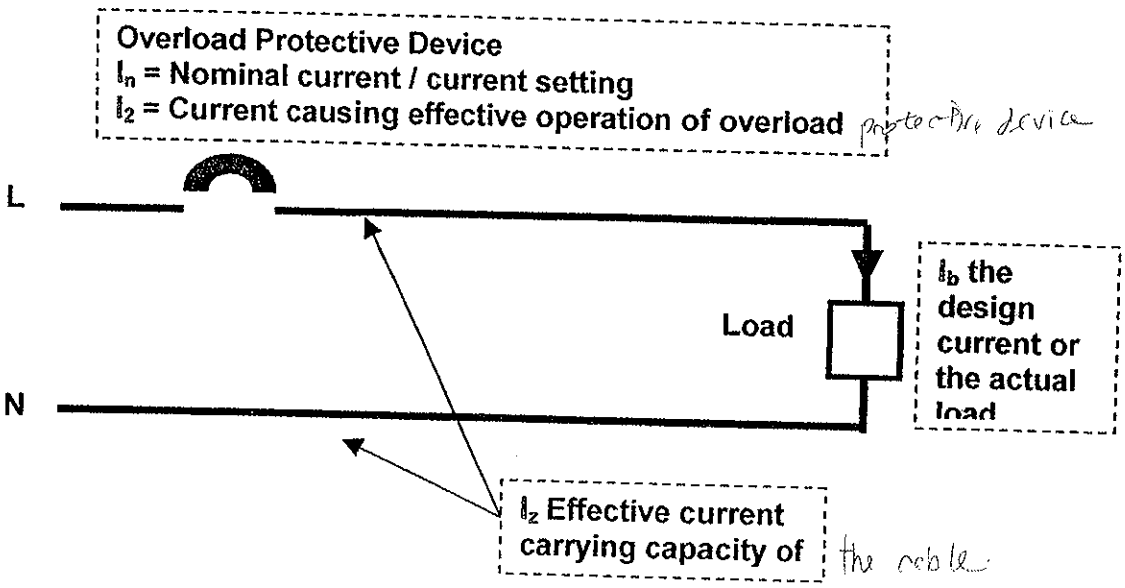
Q3 Why the Neutral conductor must be short-circuit protected by each of the short-circuit protective device installed in each of the phase conductor?

3 Requirement for Overload Protection

The requirements of overload protection are:

(i) Co-ordination with conductor
(ii) Co-ordination with short-circuit protective device installed at the source side.

(i) Co-ordination between Conductor and Overload Protective Devices



Must satisfy with the following 3-conditions.

(i) $I_b \leq I_n$ .....(1)

(ii) $I_n \leq I_z$ .....(2)

(iii) $I_2 \leq 1.45 I_z$ .....(3)

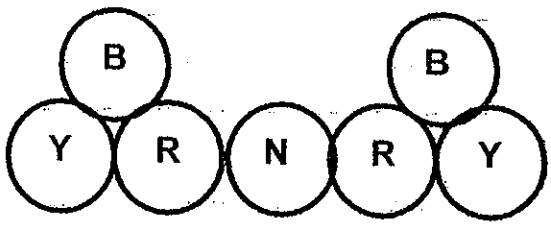
If a single protective device is used to protect several conductors connected in parallel, the value of I_Z is the sum of the effective current-carrying capacities of those conductors, provided that those conductors

- are of the same type, cross-sectional area, length and disposition, and
- have no branch circuits throughout their length, and
- are arranged so as to carry substantially equal current.

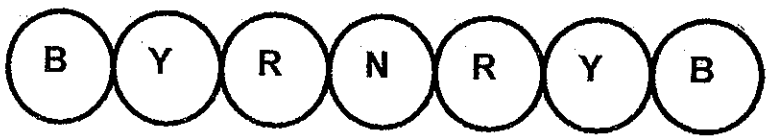
e.g. Installation of 7x500 mm^2 single core cables:–

Due to magnetic coupling effect, the inductance of a core is affected by the currents in the neighbouring conductors. Differential inductance can lead to uneven current distribution of the current in each of the multiple cores of the same phase. To minimise such uneven distribution of currents, it is desirable to install sets of 7x500 mm^2 single core cables in such a manner that the two cores of the same phase are symmetrical in respect to the neutral. Two examples of acceptable arrangement are depicted below. For long route length, sets of such service cables shall also be physically segregated.

Configuration No. 1



Configuration No. 2



(ii) Co-ordination with Short Circuit Protective Devices

Overload protective devices may have a breaking capacity below the value of the prospective short circuit current at the point where the devices are installed.

In that case, the characteristic of the overload protective devices shall be co-ordinated with those short circuit protective devices so that the energy let-through by the short circuit protective devices dose not exceed that which can be withstand without damage by the overload protective device.

3.1 Selection of Overload Protective Devices

Note: The cable shall be selected in accordance with the relevant standard of SS or BS or IEC.

(1) Select devices such as:

(a) (i) fuse to "BS 88 Part 2", "BS 88 Part 6", "BS 1361" or

(ii) circuit breaker to "SS359", "BS 3871 Part 1", "IEC 60947-2"

then $I_b \leq I_n \leq I_z$

(b) Semi-enclosed fuse to BS 3036 (or re-wirable fuse), then

$I_b \leq I_n$

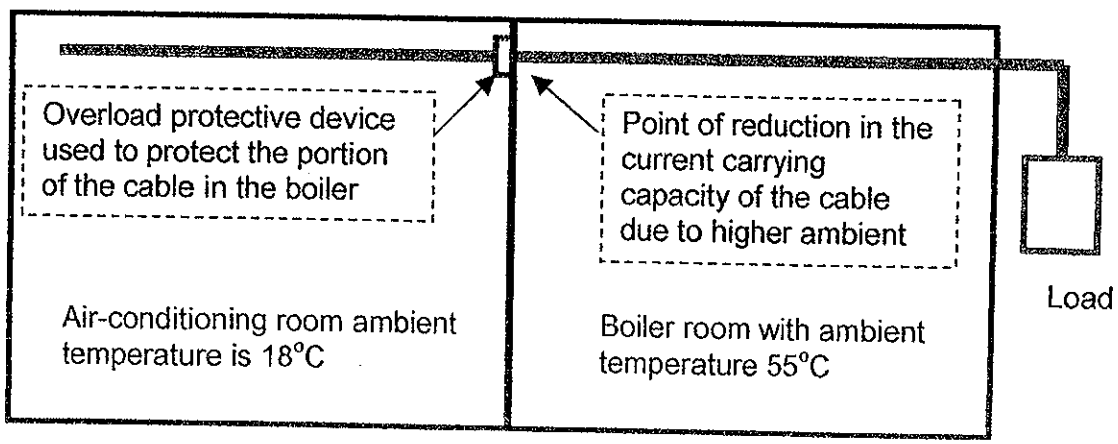
$I_n \leq 0.725 I_z$

3.2 Position of Overload Protective Devices

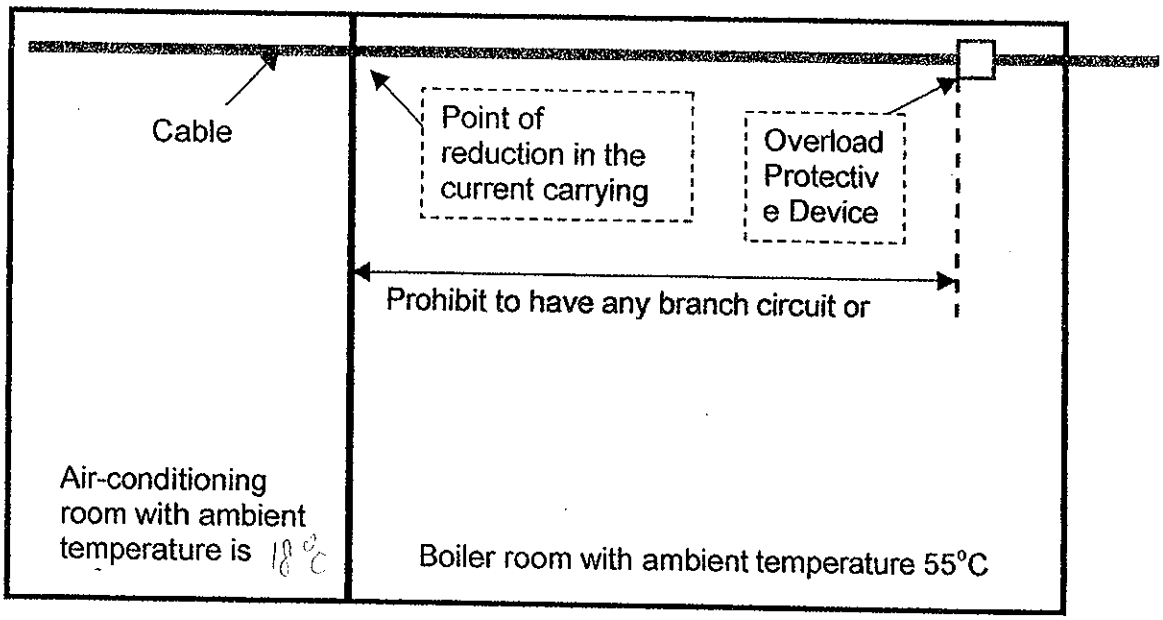
The effective current carrying capacity of a conductor can be affected by

(1) ambient temperature
(2) grouping
(3) thermal insulation
(4) operating temperature of cable

(a) Can be installed at a point where a reduction occurs in the value of the current carrying capacity of the conductors. e.g.



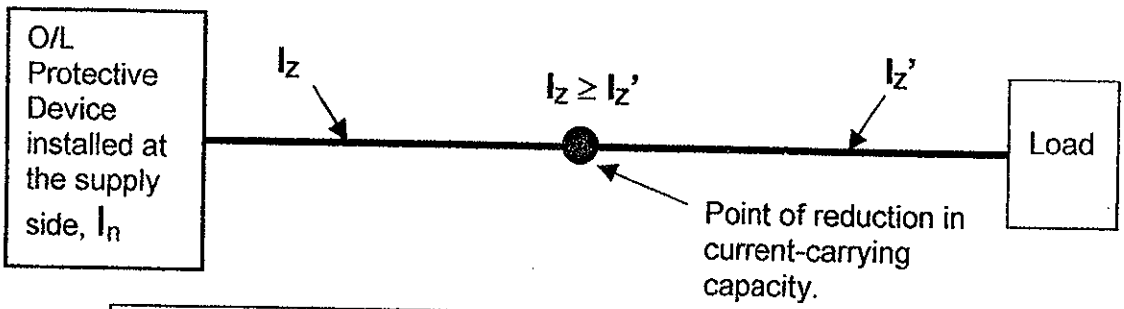
(b) Can be installed away from the point of reduction in the current carrying capacity towards the load side, provided there is no branch circuit or outlet between the point of reduction and the point of installed device. e.g.



3.3 Omission of Overload Protective Device

Conductors need not be provided with overload protective devices under the following 4 conditions:

(1) Conductors situated on the load side of the point where a reduction occurs in the value of the current-carrying capacity, the conductors are effectively protected against overload by a protective device placed on the supply side of hat point.



I_n shall comply with the following condition:

$$I_b \leq I_n \leq I_z'$$

$$I_2 \leq 1.45\, I_z'$$

(2) The characteristics of the load are not likely to cause an overload current to flow. E.g. fixed heating appliance.

(3) Circuit supply equipment where unexpected opening of the circuit could cause a greater danger than an overload condition. E.g. supply circuit of lifting magnet, excitor circuit of ratating machine.

(4) Secondary circuits of current transformer.

3.4 Selection of Overload Protective Devices

Overload protective devices can be:

(i) Fuse to "BS 88 Part 2", "BS 88 Part 6", "BS 1361" or

(ii) Circuit breaker to "SS359", "BS 3871 Part 1", "IEC 60947-2"

4 Protection Against Short Circuit

A short circuit current can cause danger due to thermal and magnetic effects it produces in conductors.

Temperature rise in a conductor is proportional to the thermal energy I^2t. Cable's insulation can be permanently damaged due to excessive temperature rise in the conductor.

To protect the insulation of the conductor, the thermal energy of the short circuit current I^2t produced shall not brings the cable conductor to exceed the admissible limiting temperature.

(1) Thermal capacity of a cable under short circuit condition is K^2S^2.

K is a value depending on the conductor and insulation material, which can be obtained from CP5:1998 Table 43A, 54B(L), 54C(L), 54D and 54F(L).

S is the cross-sectional area of conductors in mm^2

(2) Temperature rise in the conductor is proportional to the thermal energy I^2t.

(3) To protect the insulation of the cable, let the thermal energy generated in the conductor reach the thermal capacity of the cable.

$$I^2t \leq K^2S^2$$

or $t \leq K^2S^2/I^2$ **Note: The time, t cannot exceed 5sec.**

Short circuit protection is achieved by the protective device which can interrupt the short circuit current, I, within the time duration t. Note that, t, cannot exceed 5 seconds, because the equation $I^2t \leq K^2S^2$ is an approximate equation which is derived with assumption based on thermal engineering.

(4) Where the short circuit protective device has current limiting characteristic or the operation time, t <0.1 second. The term I^2t shall be replace by the **let-through energy** as quoted by the manufacturer of the device.

(5) The breaking capacity rating of the short circuit protective device shall be not less than the prospective short circuit current at the point at which the device is installed.

A lower breaking is permitted if another short circuit protective device having the necessary breaking capacity is installed on the supply side. In that case, the characteristic of the devices shall be co-ordinate so that the let-through energy of the supply side device does not exceed that which can be withstood without damaged by the device on the load side and the conductors protected by these devices.

4.1 Selection of Short Circuit Protective Devices

Short circuit protective devices can be:

(i) Fuse to "BS 88 Part 2", "BS 88 Part 6", "BS 1361" or

(ii) Circuit breaker to "SS359", "BS 3871 Part 1", "IEC 60947-2"

4.2 Selection of Protective Device Against Both Overload and Short Circuit

Select an overload protective device based on paragraph 3.4 and also ensure that the device has a rated breaking capacity not less than the value of the prospective fault current at its point of installation. This is the most common method to achieve protection against over-current.

4.3 Position of Short Circuit Protective Device

(a) at the point where a reduction a reduction occur in the value of the current carrying capacity of the conductor.

(b) at a point along the run of those conductor, provided that the part of run between the point where the value of current carrying capacity is reduced and the position of protective device , each conductor shall:

(i) not exceed 3 m in length, and

(ii) be erected in such a manner as to reduce to a minimum the risk of fault current, and

(iii) be erected in such a manner as to reduce to a minimum the risk of fire or danger to persons.

4.4 Omission of Short Circuit Protection

Short circuit protection need not be provided for:

(1) Conductors connecting generators, transformers, rectifiers, or batteries, provided that short circuit protective devices are provided on their control panel.

(2) certain measuring circuit.

(3) Circuit supplying equipment when unexpected opening of the circuit could cause a greater danger than short circuit condition.

(4) Secondary circuit of current transformer.

4.5 Time / Current Curve of a Cable

The equation, $I^2t \leq K^2S^2$ can be used to construct a straight-line curve on a log-log graph paper. The curve is called the "adiabatic line" or "maximum fault current line" of a conductor.

The adiabatic line of any cable can be superimposed onto the characteristic curve of various protective devices and examine their co-ordination. As a general rule, if the adiabatic line of a cable is located on the right side of the characteristic curve of the protective device and doses not cross it; the cable will be protected against short circuit by this device.

e.g. Construct the adiabatic line of a PVC insulated cable with copper conductor of cross sectional area $4mm^2$.

4.6 Discrimination Between Fuses for Short Circuit Protection

There are two phases of operation of a fuse.

(1) The first period is called the **Pre-arcing time**, I^2t energy is absorbed to melt the fuse element.

(2) The second period is called the **arcing time** during which the arc is being extinguished.

Selection of fuse:

(1) It must have a rating higher than the load current and must be capable of dealing with normal over-load current, such as starting of a motor, without being stressed.

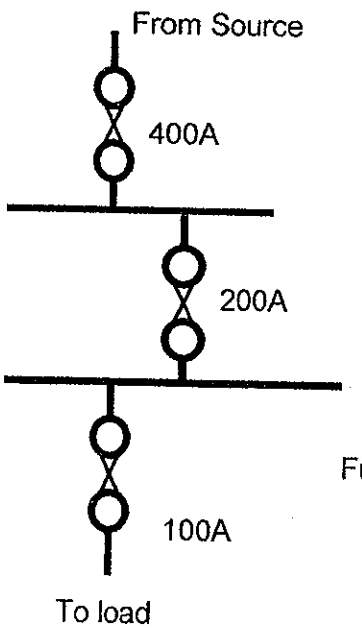
(2) It must have sufficient breaking capacity at its point of installation in order to interrupt the short circuit current.

(3) Try to achieve discrimination between fuses connected in cascading when subjected to short circuit current.

Discrimination between fuses in cascading:

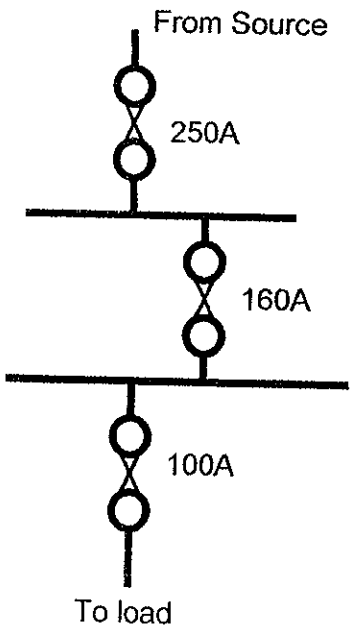
(1) Double the nominal current rating of the fuse. Or

(2) Base on the total I^2t value of the smaller fuse does not exceed the pre-arcing I^2t value of the larger fuse.



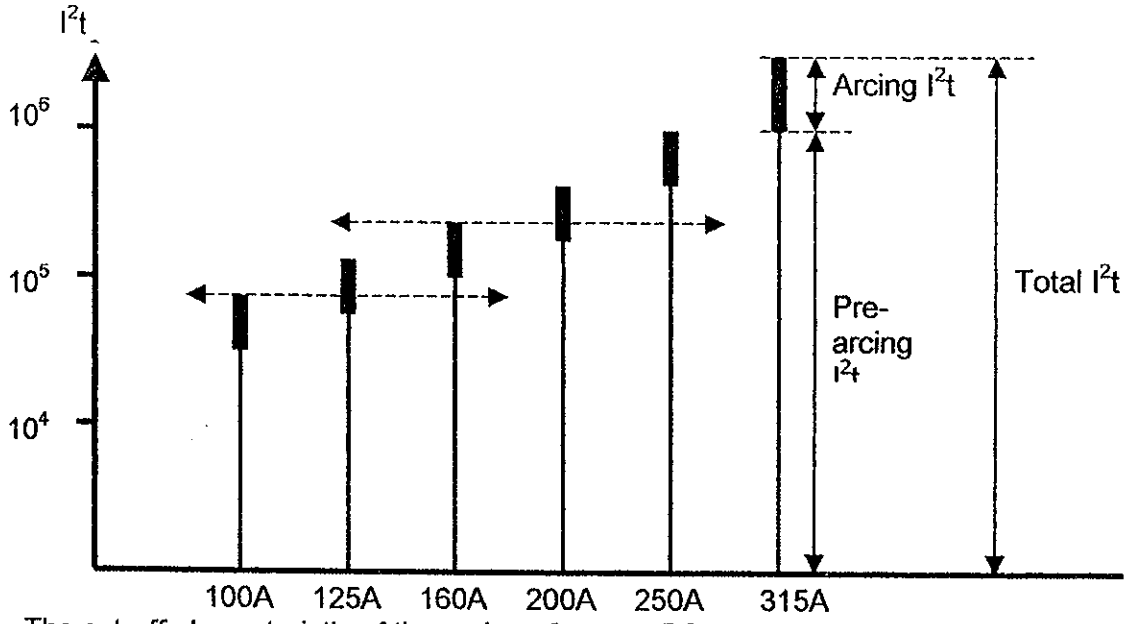
Discrimination by Double rating

Fuses are BS 88

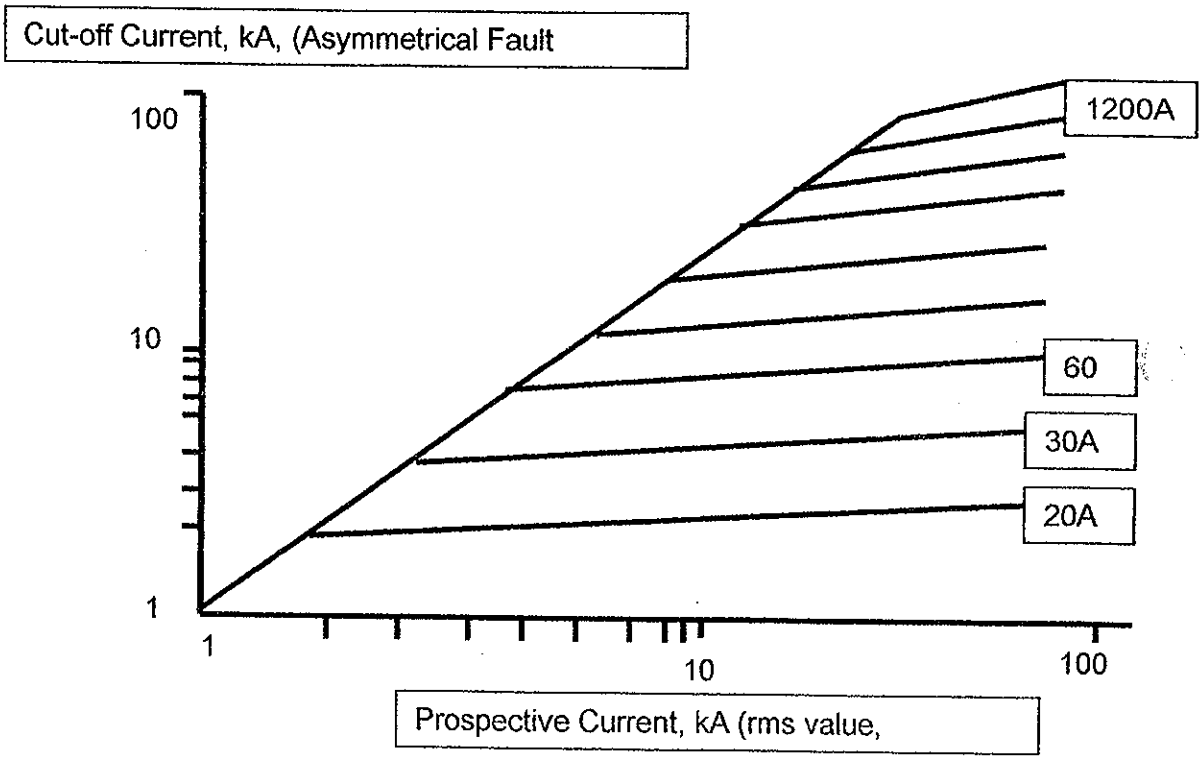


Discrimination based on I^2t value

The fuse I^2t characteristic as shown below.



The cut-off characteristic of the various fuses to BS 88 are as shown below.



4.7 Resistance of Copper and Aluminum Conductor under Fault Conditions

The equation, $t \leq K^2S^2/I^2$, has been based on the assumption of a constant value of effective short circuit current I. But in practice, this short circuit current I changes during the period of short circuit due to the rise in temperature the conductor resistance increases.

A practical and sufficiently accurate method which make use of the "average temperature" attained by the conductor is used to calculate the "average impedance" of the conductors during the short circuit duration t. Table 17A provide the resistance of copper and aluminum conductor at 20°C and Table 17B provide the multiplier. The product of the appropriate multiplier and the resistance will give the average fault resistance.

TABLE 17B
Multiplier to be applied to Table 17A

Insulation Material	p.v.c.	85°C Rubber	90°C Thermosetting
Multiplier	1.38 (1.30)	1.53 (1.42)	1.60 (1.48)

Note: The values in brackets are applicable to the resistance of circuit protective conductors where Table 54B applies.

TABLE 17A

Values of resistance/metre for copper and aluminum conductors and of ($R_1 + R_2$)/metre at 20°C in milliohms/metre

Cross-sectional area mm²		Resistance/metre or ($R_1 + R_2$)/metre	
Phase Conductor	Protective Conductor	Plain Copper	Aluminum
1	-	18.10	
1	1	36.20	
1.5	-	12.10	
1.5	1	30.20	
1.5	1.5	24.20	
2.5	-	7.41	
2.5	1	25.51	
2.5	1.5	19.51	
2.5	2.5	14.82	
4	-	4.61	
4	1.5	16.71	
4	2.5	12.02	
4	4	9.22	
6	-	3.08	
6	2.5	10.49	
6	4	7.69	
6	6	6.16	
10	-	1.83	
10	4	6.44	
10	6	4.91	
10	10	3.66	
16	-	1.15	1.91
16	6	4.23	-
16	10	2.98	-
16	16	2.30	3.82
25	-	0.727	1.2
25	10	2.557	-
25	16	1.877	-
25	25	1.454	2.4
35	-	0.524	0.868
35	16	1.674	2.778
35	25	1.251	2.068
35	35	1.048	1.736

e.g. The external earth-fault loop impedance at the DB is 0.6 Ohm. A 20A MCB is used control a final circuit with a 20A isolator. The final circuit consists of 3 number of 2.5mm^2 copper conductors with single PVC insulated cables and laid in PVC trunking. Find the short circuit current for a short circuit between live and earth terminal at the isolator. The final circuit is about 10 metre long.

4.8 **Time/Current Curve of a Cable**

The equation, $t \leq K^2S^2/I^2$, can be used to construct a straight-line curve on log-log graph paper. The curve is called the "adiabatic line" or "maximum fault current line" of the conductor. The value of K can be obtained from Table 43A depending on the type of conductor materials and insulation.

Conductor material	Insulation material	Assumed initial temperature (°C)	Limiting final temperature (°C)	K
COPPER	70°C pvc (general purpose)	70	160 / 140 *	115 / 103 *
	90°C pvc	90	160 / 140 *	100 / 86 *
	60°C rubber	60	200	141
	85°C rubber	85	220	134
	90°C thermosetting	90	250	143
	Impregnated paper	80	160	108
COPPER	Mineral: - plastic covered or exposed to touch. - bare and neither exposed to touch nor in contact with combustible materials	70 (sheath) 105 (sheath)	160 250	115 135
Aluminum	70°C pvc (general purpose)	70	160 / 140 *	76 / 68 *
	90°C pvc	90	160 / 140 *	66 / 57 *
	60°C rubber	60	200	93
	85°C rubber	85	220	89
	90°C thermosetting	90	250	9471
	Impregnated paper	80	160	

4.9 Application of Time/Current Curve of Cable

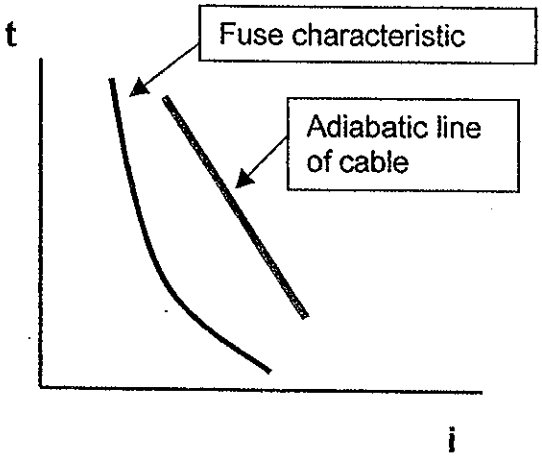
The short circuit duration t (also called disconnection time for protection) corresponds to a short circuit current I can be determined from the curve.

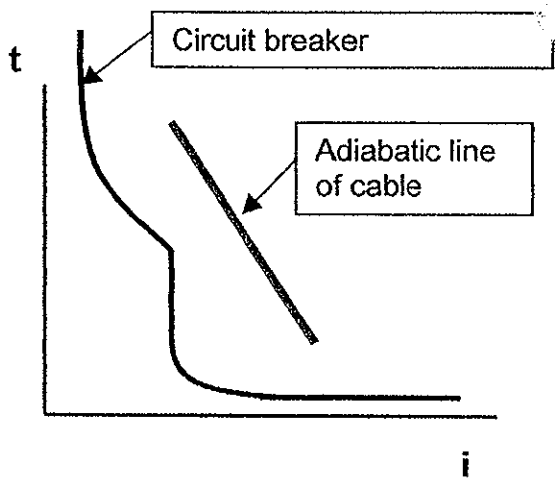
e.g. For a short circuit current of I = 1000A, t = 0.2 sec;

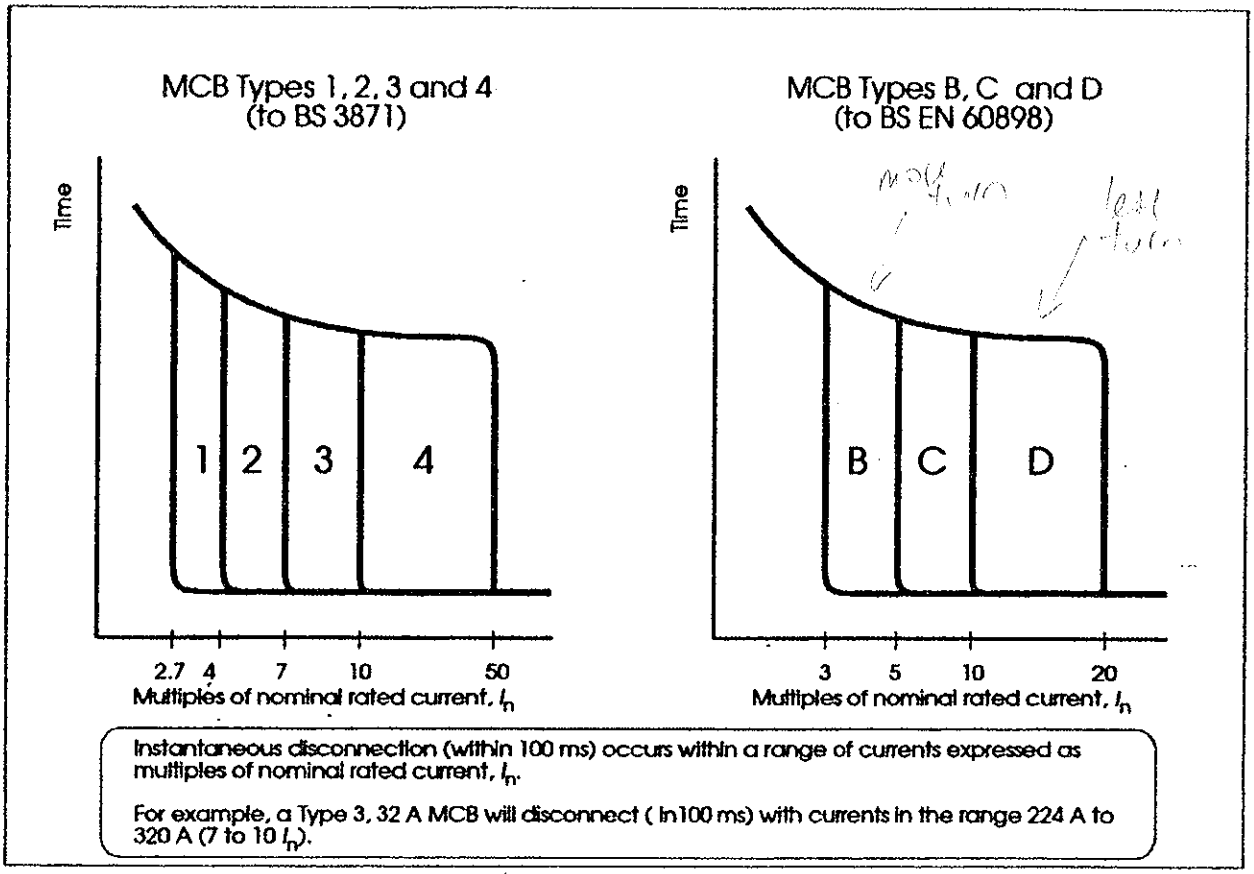
For I = 2000A, t = 0.05 sec.

The adiabatic line of the cable can be superimposed onto the characteristic curve of protective device and examine their co-ordination. i.e. It indicates whether the protective device will disconnect the faulty circuit.

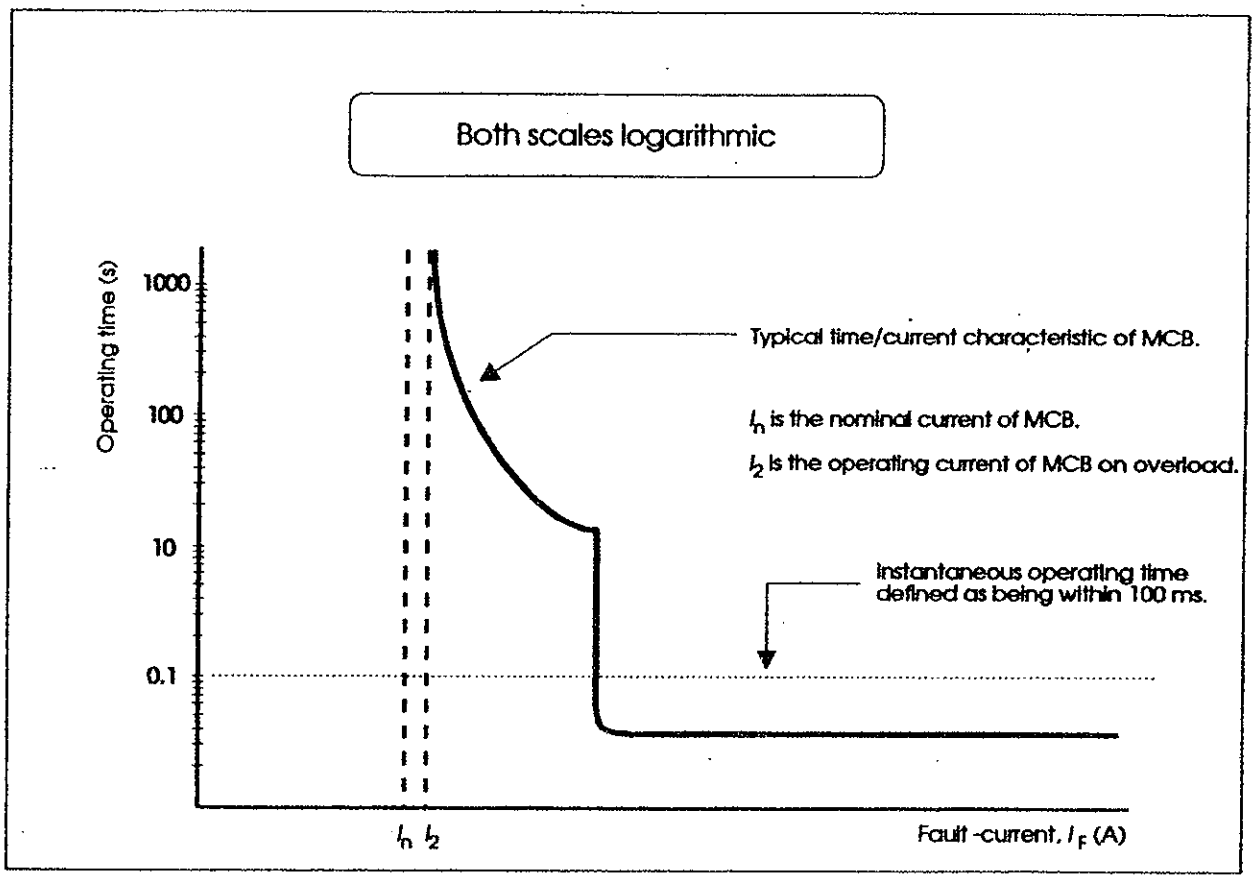
Conductor can be protected against short circuit by fuses and circuit breaker. As a general rule, if the adiabatic line of a cable is located to the right side of the characteristic curve of the protective device and does not cross it, then the conductor will be protected against short circuit.



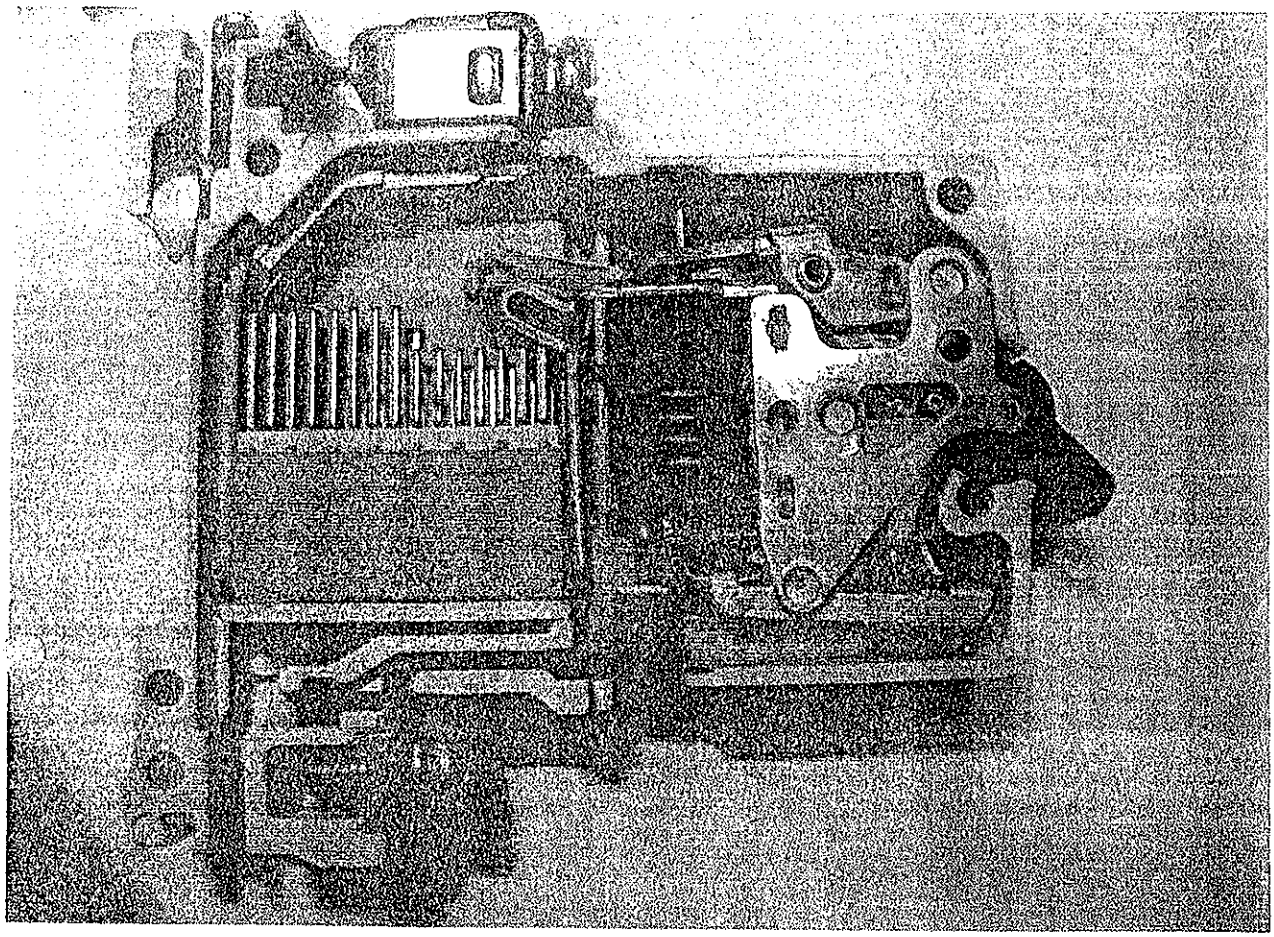


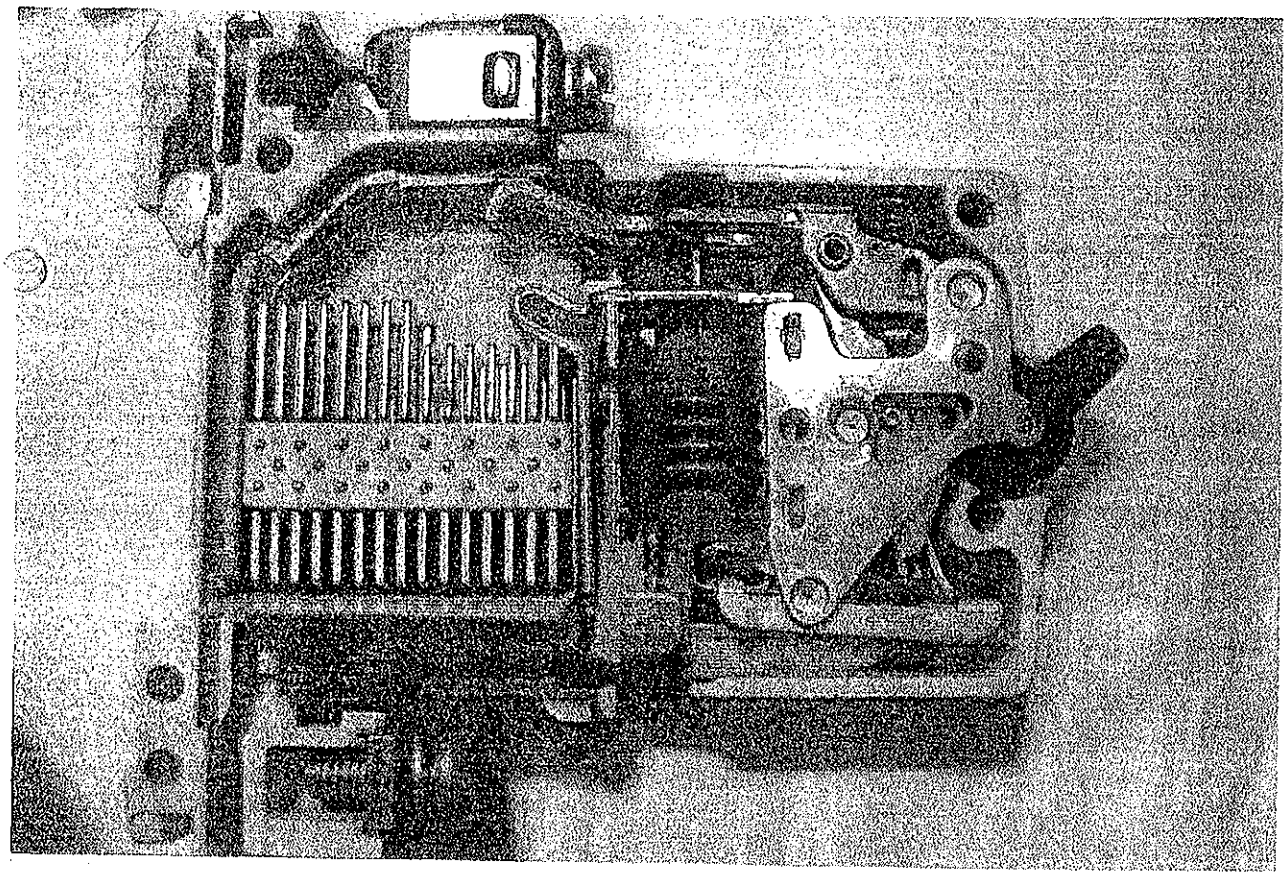


MCB characteristics



Typical operating characteristic of an MCB





Electrical Installation
CP5:1998

Sizing of Conductors

Learning Objectives for Topic Two

- Understand the sequence of design in cable sizing.
- Be conversant with the parameters in the equations of Appendix 4, CP5:1998 and how to relate them to cable sizing.
- Carry out a simple design of a small installation with reference made to other parts of CP5:1998.

CP5:1998

- Deals with fundamental principles
- Gives electrical designer a degree of freedom to design an installation
- Requires the designer to exercise his experience and knowledge to come up with the best or most economical design

In order to show that the design complies with the Code, records of the type of installation, main design calculations and assumptions must be kept.

Design calculations

Basically, all designs follow the same procedure:

- Assessment of general characteristics
- Determination of design current I_b
- Selection of protective device having nominal rating or setting I_n
- Selection of appropriate correction factors
- Calculation of tabulated conductor current I_t
- Selection of suitable conductor size
- Calculation of voltage drop
- Evaluation of shock risk
- Evaluation of thermal risks to conductors

Assessment of general characteristics

- Regardless of whether the installation is a whole one, an addition, or an alteration, there will always be certain design criteria to be considered before calculations are carried out.
- Part 3 of the Code, "Assessment of General Characteristics", indicates four main headings under which these considerations should be addressed. These are:
  - Purpose, supplies and structure
  - External influences
  - Compatibility
  - Maintainability

Let's look at one of the headings:

Purpose, supplies and structure

Purpose, supplies and structure

- For a new design, will the installation be suitable for its intended purpose?
- For a change of usage, is the installation being used for its intended purpose?
- If not, can it be used safely and effectively for any other purpose?
- Has the maximum demand been evaluated?
- Can diversity be taken into account?
- Are the supply and earthing characteristics suitable?
- Are the methods for protection for safety appropriate?
- If standby or safety supplies are used, are they reliable?
- Are the installation circuits arranged to avoid danger and facilitate safe operation?

Having looked at Assessment of General Characteristics, clearly one result of such assessment will be

the determination of the type and disposition of the installation circuits. Refer to Table 4A of Appendix 4 (pages 209 to 213)

Having made the choice of system and cable type, the next stage is to determine the design current.

Design current I_b

- This is defined as "the magnitude of the current to be carried by a circuit in normal service", and is either determined directly from manufacturers' details or calculated using the following formulae:
  - Single phase:

$$I_b = \frac{P}{V} \quad \text{or} \quad \frac{P}{V \times Eff\% \times PF}$$

  - Three phase:

$$I_b = \frac{P}{\sqrt{3} \times V_L} \quad \text{or} \quad \frac{P}{\sqrt{3} \times V_L \times Eff\% \times PF}$$

Diversity

- The application of diversity to an installation permits, by assuming that not all loads will be energized at the same time, a reduction in main or sub-main cable sizes.
- Refer to Diversity Table in CP5:1988 which tabulates diversity in the form of percentages of full load for various circuits in a range of installations.
- However it is for the designer to make a careful judgement as to the exact level of diversity to be applied.

D I V E R S I T Y

TABLE 4B

Allowances for diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies	Type of premises*		
	Individual household installations, including individual dwellings of a block	Small shops, stores, offices and business premises	Small hotels, boarding houses, guest houses, etc.
1. Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2. Heating and power (but see 3 to 8 below)	100% of total current demand up to 10 amperes + 50% of any current demand in excess of 10 amperes	100% f.l. of largest appliance + 75% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
3. Cooking appliances	10 amperes + 30% f.l. of connected cooking appliances in excess of 10 amperes + 5 amperes if socket-outlet incorporated in unit	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances	100% f.l. of largest appliance + 80% f.l. of 2nd largest appliance + 60% f.l. of remaining appliances
4. Motors (other than lift motors which are subject to special consideration)		100% f.l. of largest motor + 80% f.l. of 2nd largest motor + 60% f.l. of remaining motors	100% f.l. of largest motor + 50% f.l. of remaining motors
5. Water-heaters (instantaneous type)*	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances	100% f.l. of largest appliance + 100% f.l. of 2nd largest appliance + 25% f.l. of remaining appliances
6. Water-heaters (thermostatically controlled)	no diversity allowable †		
7. Floor warming installations	*(Reserved for future use)*		
8. Thermal storage space heating installations	*(Reserved for future use)*		
9. Standard arrangements of final circuits in accordance with Appendix 5	100% of current demand of largest circuit + 40% of current demand of every other circuit	100% of current demand of largest circuit + 50% of current demand of every other circuit	
10. Socket outlets other than those included in 9 above and stationary equipment other than those listed above	100% of current demand of largest point of utilisation + 40% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation + 75% of current demand of every point in main rooms (dining rooms, etc) + 40% of current demand of every other point of utilisation

Nominal rating or setting of protection I_n

Protective devices used for protection against overload have to be selected to conform to the first requirement in that $I_n = I_b$.

We can select for this condition from CP5 Tables 41B1, 41B2 or 41D (pp 43,44, 47).

For types and sizes outside the scope of these tables, details from the manufacturer will need to be sought.

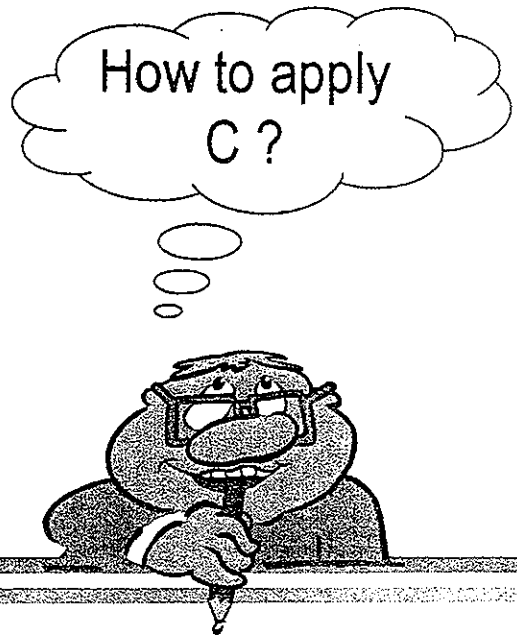
Correction factors

There are several conditions which may have an adverse effect on conductors and insulation, and in order to protect against this, correction factors (CFs) are applied. These are:

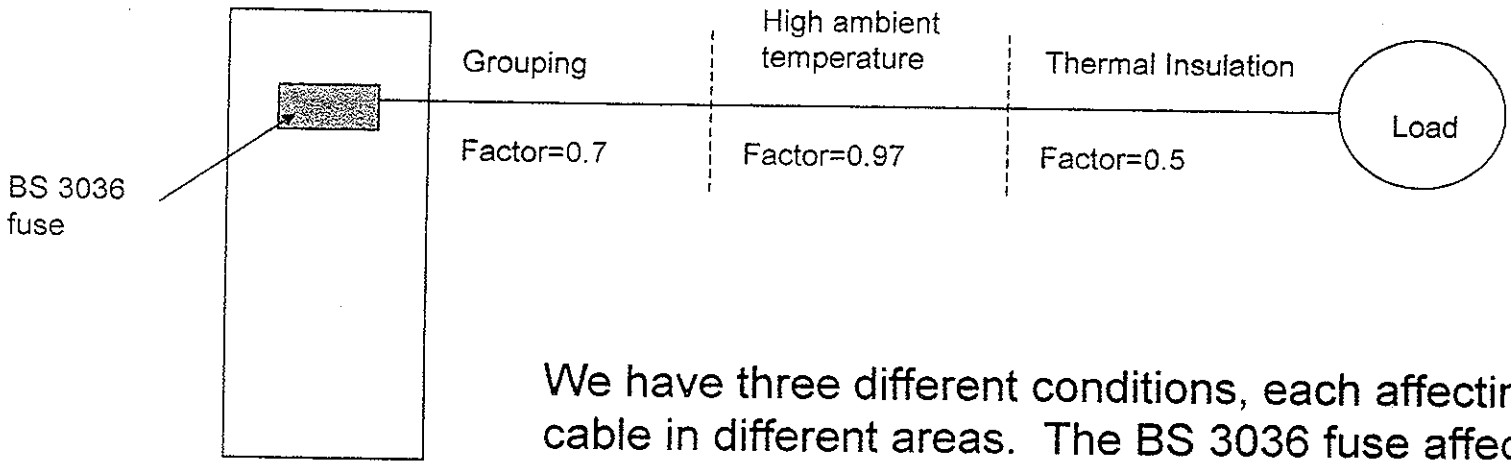
C_a	Factor for ambient temperature	Tables 4C1 or 4C2 ☆
C_g	Factor for groups of cables	Table 4B1 or 4B2 ☆
C_f	Factor if BS 3036 re-wireable fuse is used	Factor is 0.725
C_i	Factor if cable is surrounded by thermally insulating material	Table 52A ☆

Correction factors (C)

- The factors are applied as divisors to the setting of the protection I_n, the resulting value should be less than or equal to the tabulated current carrying capacity I_t of the conductor to be chosen.

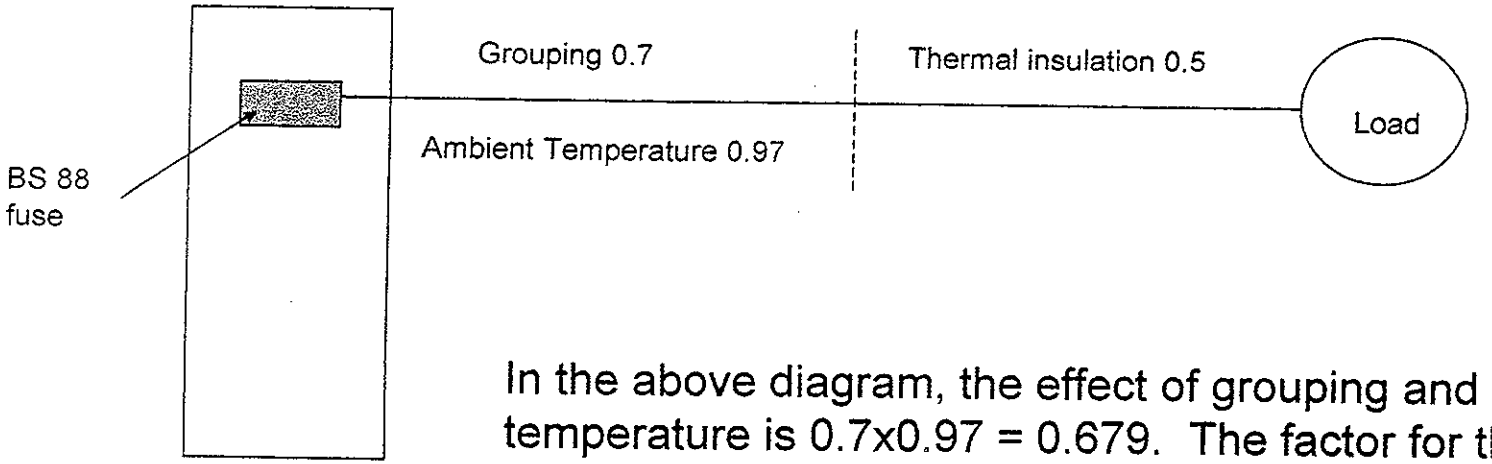


Example 1 on Correction factors



We have three different conditions, each affecting the cable in different areas. The BS 3036 fuse affects the whole cable run and therefore C_f must be used, but there is no need to apply all of the remaining factors as the worst one will automatically compensate for the others. The relevant factors are shown above and apply only if C_f=0.725 and C_i=0.5. If protection was not by BS3036 fuse, then apply only C_i=0.5.

Example 2 on Correction factors



In the above diagram, the effect of grouping and ambient temperature is 0.7x0.97 = 0.679. The factor for thermal insulation is still worse than this combination, and therefore C_i is the only one to be used.

Tabulated conductor current carrying capacity I_t

$$I_t \geq \frac{I_n}{C_a \times C_g \times C_f \times C_i}$$

Remember, only the relevant factors are to be used!

The Code permits the omission of overload protection in certain circumstances (473-01-04 & Item 6.3 of Appendix 4), in these circumstances, I_n is replaced by I_b and the formula becomes:

$$I_t \geq \frac{I_b}{C_a \times C_g \times C_i}$$

Selection of suitable conductor size

- During the early stages of the design, the external influences will have been considered, and a method of circuit installation chosen. Reference is made to Table 4A which gives examples of installation methods, and it is important to select the appropriate method in the current rating tables.
- For example, from Table 4D2A, the tabulated current ratings I_t for reference method 3 are less than those for method 1.
- Having selected the correct cable rating table and relevant reference method, the conductor size is determined to correspond with I_t = the corrected value of I_n or I_b as is the case.

Voltage drop

Clause 525-01-01L states "Under normal service conditions the voltage at the terminals of any fixed current-using equipment shall be greater than the lower limit corresponding to the Singapore Standard relevant to the equipment".

Where the fixed current-using equipment concerned is not the subject of a Singapore Standard, the voltage at the terminals shall be such as not to impair the safe functioning of that equipment.

Clause 525-01-02L states "... voltage drop between the origin of the installation and the equipment does not exceed 4% of the nominal voltage of the supply". This means a permitted drop of 9.2V for single-phase 230V supply and 16V for 400V three-phase supply.

Voltage drop

~~Accompanying the cable current rating tables (Table 4D1A to 4L4B)~~ are tabulated values of voltage drop based on the milli-volts (mV) dropped for every ampere of design current (A), for every metre of conductor length (m), ie.

Volt drop = mV/A/m

Or fully translated with I_b for A and L (length in metres):

$$\text{Volt drop} = \frac{mV \times I_b \times \text{length}}{1000} \text{ (Volts)}$$

For conductor sizes in excess of 16mm^2 the impedance values of volt droop (columns headed *z*) should be used. The columns headed *r* and *x* indicate the resistive and reactive components of the impedance values.

Evaluation of shock risk

This topic has been discussed in Topic One, suffice to say that the calculated value of loop impedance should not exceed the tabulated value quoted for the protective device in question.

Evaluation of thermal constraints

As we know, the 'let-through' energy of a protective device under fault conditions can be considerable and it is therefore necessary to ensure that the CPC is large enough either by satisfying the requirements of CP5 Table 54G or by comparing its size with the minimum derived from the formula:

$$S = \frac{\sqrt{I^2 t}}{k}\ mm^2$$

Design proper

How do you put the design procedure into practice?



Example 3

Four industrial single-phase fan assisted process heaters are to be installed adjacent to each other in a factory. Each one is rated at 50A/230V. The furthest heater is some 29m from a distribution board, housing BS88 fuses, located at the intake position. It has been decided to supply the heaters with PVC singles in steel trunking (reference method 3), and part of the run will be through an area where the ambient temperature may reach 35°C. The earthing system is TN-S with a measured Z_e of 0.22? . There is spare capacity in the distribution board, and the maximum demand will not be exceeded. Calculate the minimum size of live conductors and CPC.

Calculations will be based on the furthest heater. Also, only one common CPC need be used (CP5 Clause 543-01-02(i)).

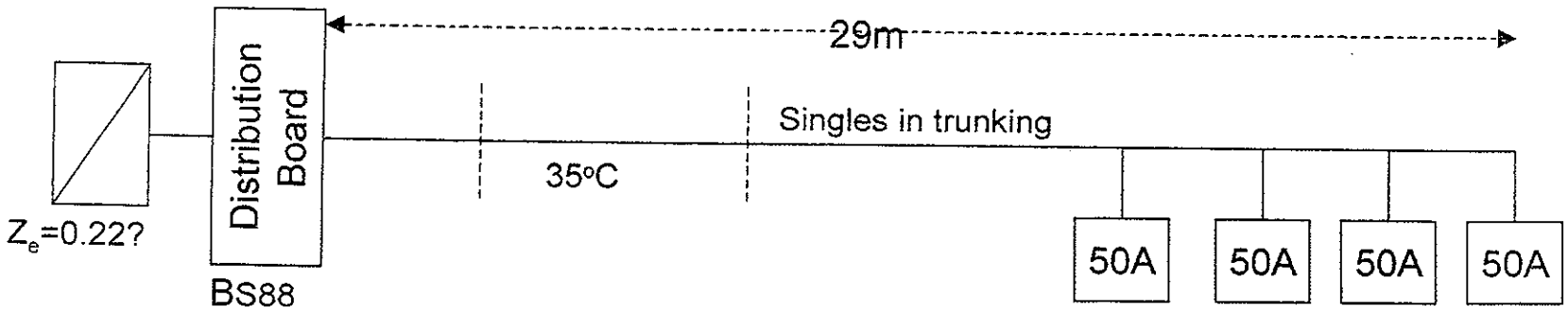
Example 3 (cont'd)

Design current I_b

$I_b = 50A$

Type and setting of protection I_n

$I_n = I_b$ so, from CP5 Table 41D, a BS 88 50A fuse would be used with a corresponding value of Z_s of 1.04? .



Example 3 (cont'd)

Correction factors

As the circuits will be grouped and, for part of the run, in a high ambient temperature, both C_a and C_g will need to be used.

C_a for 35°C	0.94 (Table 4C1)
C_g for four circuits	0.65 (Table 4B1)

Example 3 (cont'd)

Tabulated current carrying capacity I_t

As the heaters are fan assisted, they are susceptible to overload, hence I_n is used.

$$I_t \geq \frac{I_n}{C_a \times C_g}$$

$$I_t \geq \frac{50}{0.94 \times 0.65}$$

$$I_t \geq 82 (A)$$

Example 3 (cont'd)

Selection of conductor size

From CP5 Table 4D1A column 4, I_t = 101A, and the conductor size is 25.00 mm^2.

Voltage drop

From CP5 Table 4D1B, the mV drop for 25.0 mm^2 is 1.8 mV.

$$\text{Volt drop} = \frac{1.8 \times 50 \times 29}{1000}$$

$$= 2.61\ (\text{V}) \cdots\cdots \text{(acceptable)}$$

Example 3 (cont'd)

Evaluation of shock risk

In this case, as the conductors are singles, a CPC size has to be chosen either from Table 54G, or by calculation.

The former method will produce a size of 16mm^2, whereas calculation tends to produce considerably smaller sizes. The calculation involves the rearrangement of the formula:

$$Z_s = Z_e + \frac{(R_1 + R_2) \times L \times 1.38}{1000}$$

to find the maximum value of R_2 and selecting a CPC size to suit.

Example 3 (cont'd)

Evaluation of shock risk (cont'd)

The value of Zs used will be the tabulated maximum which in this case is 1.04? . The rearranged formula is:

$$R_2 = \left[\frac{(Z_s - Z_e)\times 1000}{L \times 1.38}\right] - R_1$$

$$= \left[\frac{(1.04 - 0.22)\times 1000}{29 \times 1.38}\right] - 0.727$$

$$= 19.76\, m\Omega$$

Example 3 (cont'd)

Evaluation of shock risk (cont'd)

The nearest value to this maximum is 18.1 m? giving a CPC size of 1.0mm^2. This will satisfy the shock risk requirements, but we will still have to know the actual value of Z_s, so:

$$Z_s = 0.22 + \frac{(0.727 + 18.1) \times 29 \times 1.38}{1000}$$

$$= 0.97\,\Omega$$

Example 3 (cont'd)

Evaluation of thermal constraints

$$Fault\ \ Current\ \ I = \frac{U_o}{Z_s} = \frac{230}{0.97} = 237\,A$$

t from 50A BS88 curve = 3 s

k = 115 (CP5 Table 54C)

$$s = \frac{\sqrt{I^2 t}}{k}$$

$$= \frac{\sqrt{237^2 \times 3}}{115}$$

$$= 3.6\,mm^2$$

Hence, our 1.0mm² CPC is too small to satisfy the thermal constraints, and hence a 4.0mm² CPC would have to be used. So the heaters would be supplied using 25mm² live conductors, a 4.0mm² CPC and 50A BS88 protection.

APPENDIX 4

CURRENT-CARRYING CAPACITY AND VOLTAGE DROP FOR CABLES AND FLEXIBLE CORDS

PREFACE TO THE TABLES

1. BASIS OF TABULATED CURRENT-CARRYING CAPACITY

The current-carrying capacity set out in this appendix takes account of IEC Publication 364-5-523 (1983), so far as the latter is applicable. For types of cable not treated in the IEC Publication (e.g. armoured cables) the current-carrying capacities given in this appendix are based on data provided by ERA Technology Ltd, and the British Cable Makers' Confederation. See also ERA Report 69-30 'Current rating standards for distribution cables'*.

The tabulated current-carrying capacity relates to continuous loading and is also known as the 'full thermal current rating' of the cable, corresponding to the conductor operating temperature indicated in the headings to the tables concerned. It is intended to provide for a satisfactory life of conductor and insulation subject to the thermal effects of carrying current for sustained periods in normal service. A cable may be seriously damaged, leading to early failure, or its service life may be significantly reduced, if it is operated for any prolonged period at a temperature higher than the indicated value.

In addition, there are other considerations affecting the choice of the cross-sectional area of a conductor, such as the requirements for protection against electric shock (See Chapter 41), protection against thermal effects (See Chapter 42), overcurrent protection (see Chapter 43 and item 5 below), voltage drop (see item 7 below) and the limiting temperatures for terminals of equipment to which the conductors are connected.

The tabulated current-carrying capacity relates to a single circuit in the installation methods shown in Table 4A, in an ambient air temperature of 30°C. The current-carrying capacity given in the tables for a.c. operation apply only to frequencies in the range 49 to 61 Hz. For other conditions appropriate correction factors are to be applied as described below.

The current ratings given for single-core armoured cable are for the condition of cable bonded at both ends and to earth.

Further information on cables installed in thermal insulation may be obtained from ERA Report 85-0111 'The temperature rise of cables passing through short lengths of thermal insulation'*.

2. CORRECTION FACTORS FOR CURRENT-CARRYING CAPACITY

The current-carrying capacity of a cable for continuous service is affected by ambient temperature, by grouping, by partial or total enclosure in thermal insulating material and, for a.c., by frequency. This appendix provides correction factors in these respects as follows.

2.1 **Ambient Temperature.** Tables 4C1 and 4C2 give the correction factor to be applied to the tabulated current-carrying capacity depending upon the actual ambient temperature of the location in which the cable is to be installed.

* ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey, United Kingdom KT22 7SA

In practice the ambient air temperatures may be determined by thermometers placed in free air as close as practicable to the position at which the cables are installed or are to be installed, subject to the proviso that the measurements are not to be influenced by the heat arising from the cables; thus if the measurements are made while the cables are loaded, the thermometers should be placed about 0.5 m or ten times the overall diameter of the cable, whichever is the lesser, from the cables, in the horizontal plane, or 150 mm below the lowest of the cables.

Tables 4C1 and 4C2 do not take account of temperature increase, if any, due to solar or other infra-red radiation. Where cables are subject to such radiation, the current-carrying capacity may need to be specially calculated.

2.2 Grouping. Tables 4B1, 4B2 and 4B3 give the correction factor to be applied to the tabulated current-carrying capacity where cables or circuits are grouped.

2.3 Other Frequencies. In extreme cases, notably for large multicore cables, the reduction in current-carrying capacity of cables carrying, for example, balanced 400 Hz a.c. compared with the current-carrying capacity at 50 Hz, may be as much as 50%. For small cables and flexible cords, such as may be used to supply individual tools, the difference in the 50 Hz and the 400 Hz current-carrying capacities may be negligible.

3. EFFECTIVE CURRENT-CARRYING CAPACITY

The current-carrying capacity of a cable corresponds to the maximum current that can be carried in specified conditions without the conductors exceeding the permissible limit of steady state temperature for the type of insulation concerned.

The values of current tabulated represent the effective current-carrying capacity only where no correction factor is applicable. Otherwise the current-carrying capacity corresponds to the tabulated value multiplied by the appropriate factor or factors for ambient temperature, grouping and thermal insulation, as applicable.

Irrespective of the type of overcurrent protective device associated with the conductors concerned, the ambient temperature correction factors to be used when calculating current-carrying capacity (as opposed to those used when selecting cable sizes) are those given in Table 4C1.

4. RELATIONSHIP OF CURRENT-CARRYING CAPACITY TO OTHER CIRCUIT PARAMETERS

The relevant symbols used in the Code are as follows:

I_z the current-carrying capacity of a cable for continuous service, under the particular installation conditions concerned.

I_t the value of current tabulated in this appendix for the type of cable and installation method concerned, for a single circuit in an ambient temperature of 30°C.

I_b the design current of the circuit, i.e. the current intended to be carried by the circuit in normal service.

I_n the nominal current or current setting of the device protecting the circuit against overcurrent.

I_2 the operating current (i.e. the fusing current or tripping current for the conventional operating time) of the device protecting the circuit against overload.

C a correction factor to be applied where the installation conditions differ from those for which values of current carrying capacity are tabulated in this Appendix. The various correction factors are identified as follows:

C_a for ambient temperature

C_g for grouping

C_i for thermal insulation

C_t for operating temperature of conductor

In all circumstances I_z must be not less than I_b and I_n also must be not less than I_b.

Where the overcurrent device is intended to afford protection against overload, I_2 must not exceed 1.45 times I_z and I_n must not exceed I_z (see item 5 below).

Where the overcurrent device is intended to afford short circuit protection only, I_n can be greater than I_z and I_2 can be greater than 1.45 times I_z. The protective device is then to be selected for compliance with Clause 434-03-03.

5. OVERLOAD PROTECTION

Where overload protection is required, the type of protection provided does not affect the current-carrying capacity of a cable for continuous service (I_z) but it may affect the choice of conductor size. The operating conditions of a cable are influenced not only by the limiting conductor temperature for continuous service, but also by the conductor temperature which might be attained during the conventional operating time of the overload protection device, in the event of an overload.

This means that the operating current of the protective device must not exceed 1.45 I_z. Where the protective device is a fuse to BS 88 or BS 1361 or a miniature circuit breaker to BS 3871 or SS 359, this requirement is satisfied by selecting a value of I_z not less than I_n.

In practice, because of the standard steps in nominal rating of fuses and circuit breakers, it is often necessary to select a value of I_n exceeding I_b. In that case, because it is also necessary for I_z in turn to be not less than the selected value of I_n, the choice of conductor cross-sectional area may be dictated by the overload conditions and the current-carrying capacity (I_z) of the conductors will not always be fully used.

The size needed for a conductor protected against overload by a BS 3036 semi-enclosed fuse can be obtained by the use of a correction factor, 1.45/2 = 0.725, which results in the same degree of protection as that afforded by other overload protective devices. This factor is to be applied to the nominal rating of the fuse as a divisor, thus indicating the minimum value of I_t required of the conductor to be protected. In this case also, the choice of conductor size is dictated by the overload conditions and the current-carrying capacity (I_z) of the conductors cannot be fully used.

6. DETERMINATION OF THE SIZE OF CABLE TO BE USED

Having established the design current (I_b) of the circuit under consideration, the appropriate procedure described in items 6.1 to 6.4 below will enable the designer to determine the size of the cable it will be necessary to use.

As a preliminary step it is useful to identify the length of the cable run and the permissible voltage drop for the equipment being supplied, as this may be an over-riding consideration (see Clause 525-01 and item 7 of this Appendix). The permissible voltage drop in mV, divided by I_b and by the length of run, will give the value of voltage drop in mV/A/m which can be tolerated. A voltage drop not exceeding that value is identified in the appropriate table and the corresponding cross-sectional area of conductor needed on this account can be read off directly before any other calculations are made.

The conductor size necessary from consideration of the conditions of normal load and overload is then determined. All correction factors affecting I_z (i.e. the factors for ambient temperature, grouping and thermal insulation) can, if desired, be applied to the values of I_t as multipliers. This involves a process of trial and error until a cross-sectional area is reached which ensures that I_z is not less than I_b and not less than I_n of any protective device it is intended to select. In any event, if a correction factor for protection by a semi-enclosed fuse is necessary, this has to be applied to I_n as a divisor. It is therefore more convenient to apply all the correction factors to I_n as divisors.

This method is used in items 6.1 to 6.3 and produces a value of current and that value (or the next larger value) can readily be located in the appropriate table of current-carrying capacity and the corresponding cross-sectional area of conductor can be identified directly. It should be noted that the value of I_t appearing against the chosen cross-sectional area is not I_z. It is not necessary to know I_z where the size of conductor is chosen by this method, but if it is desired to identify I_z the value is determined by the method indicated in item 3 above.

However, this method cannot be used for cables installed in enclosed trenches (installation methods 18, 19 and 20 of Table 4A) because the correction factors given in Table 4B3 are related to conductor cross-sectional areas. For such cables it is therefore necessary to use the process of trial and error described in the third paragraph above, selecting on a trial basis a particular size of cable from, for instance, voltage drop considerations.

6.1 **Where Overload Protection Is Afforded By A Fuse To BS 88 Or BS 1361, Or A Miniature Circuit Breaker To SS 359 Or BS 3871:**

6.1.1 **For single circuits**

- DIVIDE the nominal current of the protective device (I_n) by any applicable correction factor for ambient temperature (C_a) given in Table 4C1.
- then further DIVIDE by any applicable correction factor for thermal insulation (C_i).

The size of cable to be used is to be such that its tabulated current-carrying capacity (I_t) is not less than the value of nominal current of the protective device adjusted as above:

$$I_t \geq \frac{I_n}{C_a\, C_i} \qquad (1)$$

6.1.2 **For groups**

- DIVIDE the nominal current of the protective device (I_n) by the correction factor for grouping (C_g) given in Tables 4B1, 4B2 or 4B3:

$$I_t \geq \frac{I_n}{C_g} \qquad (2)$$

Alternatively, it may be selected in accordance with the following formulae, provided that the circuits of the group are not liable to simultaneous overload:

$$I_t \geq \frac{I_b}{C_g} \quad , \text{and} \tag{3}$$

$$I_t \geq \sqrt{I_n^2 + 0.48\ I_b^2\ (\frac{1 - C_g^2}{C_g^2})} \tag{4}$$

The size of cable to be used is to be such that its tabulated single-circuit current-carrying capacity (I_t) is not less than the value of I_t calculated in accordance with formula (2) above or, where formulae (3) and (4) are used not less than the larger of the resulting two values of I_t.

Where correction factors C_a and/or C_i are applicable, they are to be applied as divisors to the value of I_t determined by the above formulae.

6.2 **Where The Protective Device Is A Semi-enclosed Fuse To BS 3036:**

6.2.1 **For single circuits**

- DIVIDE the nominal current of the fuse (I_n) by any applicable correction factor for ambient temperature (C_a) given in Table 4C2
- then further DIVIDE by any applicable correction factor for thermal insulation, (C_i)
- then further DIVIDE by 0.725

The size of cable to be used is to be such that its tabulated current-carrying capacity (I_t) is not less than the value of nominal current of the fuse adjusted as above:

$$I_t \geq \frac{I_n}{0.725\ C_a\ C_i} \tag{5}$$

6.2.2 **For groups**

- DIVIDE the nominal current of the fuse I_n by 0.725 and by the applicable correction factor grouping (C_g) given in Table 4B1, 4B2 or 4B3:

$$I_t \geq \frac{I_n}{0.725\ C_g} \tag{6}$$

Alternatively, it may be selected by the following formulae, provided that the circuits of the group are not liable to simultaneous overload:

$$I_t \geq \frac{I_b}{C_g} \text{ , and} \qquad (7)$$

$$I_t \geq \sqrt{1.9\, I_n^2 + 0.48\, I_b^2 \left(\frac{1 - C_g^2}{C_g^2}\right)} \qquad (8)$$

The size of cable to be used is to be such that its tabulated single-circuit current-carrying capacity (I_t) is not less than the value of I_t calculated in accordance with formula (6) above or, where formulae (7) and (8) are used, not less than the larger of the resulting two values of I_t.

Where correction factors C_a and/or C_i are applicable, they are to be applied as divisors to the value of I_t determined by the above formulae.

6.3 Where Overload Protection Is Not Required:

Where Clause 473-01-04 applies, and the cable under consideration is not required to be protected against overload, the design current of the circuit (I_b) is to be divided by any applicable correction factors, and the size of the cable to be used is to be such that its tabulated current-carrying capacity (I_t) for the installation method concerned is not less than the value of I_b adjusted as above:

$$I_t \geq \frac{I_b}{C_a\, C_g\, C_i} \qquad (9)$$

6.4 Variation Of Installation Conditions Along A Cable Route

The procedures in items 6.1 to 6.3 above are based on the assumption that all the conditions necessitating the use of correction factors apply to the same part of the route of the conductors of the circuit. Where various factors apply to different parts of the route, each part may be treated separately, or alternatively only the factor or combination of factors appropriate to the most onerous conditions encountered along the route may be applied to the whole of the route. It is permissible to obtain more precise factors by calculation of the various conductor temperature rises that will occur along such a route, provided that the appropriate limiting temperature of the conductor is nowhere exceeded (see Clause 523-01).

7. TABLES OF VOLTAGE DROP

In the Tables, values of voltage drop are given for a current of one ampere for a metre run, i.e. for a distance of 1 m along the route taken by the cables, and represent the result of the voltage drops in all the circuit conductors. The values of voltage drop assume that the conductors are at their maximum permitted normal operating temperatures.

The values in the tables, for a.c. operation, apply only to frequencies in the range 49 to 61 Hz and for single-core armoured cables the tabulated values apply where the armour is bonded to earth at both ends. The values of voltage drop for cables operating at higher frequencies may be substantially greater.

For a given run, to calculate the voltage drop (in mV) the tabulated value of voltage drop per ampere per metre for the cable concerned has to be multiplied by the length of the run in metres and by the current the cable is intended to carry, namely the design current of the circuit (I_b) in amperes. For three-phase circuits the tabulated mV/A/m values relate to the line voltage and balanced conditions have been assumed.

For cables having conductors of 16 mm^2 or less cross-sectional area their inductances can be ignored and $(mV/A/m)_r$ values only are tabulated. For cables having conductors greater than 16 mm^2 cross-sectional area the impedance values are given as $(mV/A/m)_z$, together with the resistive component $(mV/A/m)_r$ and the reactive component $(mV/A/m)_x$.

The *direct* use of the tabulated $(mV/A/m)_r$ or $(mV/A/m)_z$ values, as appropriate, may lead to pessimistically high calculated values of voltage drop or, in other words, to unnecessarily low values of permitted circuit lengths.

For example, where the design current of a circuit is significantly less than the effective current-carrying capacity of the cable chosen, the actual voltage drop would be less than the calculated value because the conductor temperature (and hence its resistance) will be less than that on which the tabulated mV/A/m had been based.

As regards power factor in a.c. circuits the use of the tabulated mV/A/m values, (for the larger cable sizes, the tabulated $(mV/A/m)_z$ values) to calculate the voltage drop is strictly correct only when the phase angle of the cable equals that of the load. When the phase angle of the cable does not equal that of the load, the direct use of the tabulated mV/A/m or $(mV/A/m)_z$ values leads to a calculated value of voltage drop higher than the actual value. In some cases it may be advantageous to take account of the load power factor when calculating voltage drop.

Where a more accurate assessment of voltage drop is desirable the following methods may be used.

7.1 Correction For Operating Temperature

For cables having conductors of cross-sectional area 16 mm^2 or less the design value of mV/A/m is obtained by multiplying the tabulated value by a factor C_t, given by

$$C_t = \frac{230 + t_p - (C_a^2\, C_g^2 - \frac{I_b^2}{I_t^2})\ (t_p - 30)}{230 + t_p} \qquad (10)$$

where t_p = maximum permitted normal operating temperature, °C

This equation applies only where the overcurrent protective device is other than a BS 3036 fuse and where the actual ambient temperature is equal to or greater than 30°C

NOTE. For convenience, the above formula is based on the resistance-temperature coefficient of 0.004 per °C at 20°C for both copper and aluminium conductors.

For cables having conductors of cross-sectional area greater than 16 mm^2, only the resistive component of the voltage drop is affected by the temperature and the factor C_t is therefore applied only to the tabulated value of $(mV/A/m)_r$ and the design value of $(mV/A/m)_z$ is given by the vector sum of $C_t(mV/A/m)_r$ and $(mV/A/m)_x$.

For very large conductor sizes where the resistive component of voltage drop is much less than the corresponding reactive part (i.e. when $x/r \geq 3$) this correction factor need not be considered.

7.2 Correction For Load Power Factor

For cables having conductors of cross-sectional area of 16 mm^2 or less the design value of mV/A/m is obtained approximately by multiplying the tabulated value by the power factor of the load, $\cos \phi$.

For cables having conductors of cross-sectional area greater than 16 mm^2 the design value of mV/A/m is given approximately by:

$$\cos \phi \text{ (tabulated } (mV/A/m)_r) + \sin \phi \text{ (tabulated } (mV/A/m)_x)$$

For single-core cables in flat formation the tabulated values apply to the outer cables and may under-estimate for the voltage drop between an outer cable and the centre cable for cross-sectional areas above 240 mm^2 and power factors greater than 0.8.

7.3 Combined Correction For Both Operating Temperature And Load Power Factor

From items 7.1 and 7.2 above, where it is considered appropriate to correct the tabulated mV/A/m values for both operating temperature and load power factor, the design values of mV/A/m are given by:

for cables having conductors of 16 mm^2 or less cross-sectional area

$C_t \cos \phi$ (tabulated mV/A/m)

for cables having conductors of cross-sectional area greater than 16 mm^2

$C_t \cos \phi$ (tabulated $(mV/A/m)_r$) + $\sin \phi$ (tabulated $(mV/A/m)_x$).

8. METHODS OF INSTALLATION OF CABLES

Table 4A lists the methods of installation for which this appendix provides guidance for the selection of the appropriate cable size. The methods of installation distinguished by bold type are reference methods for which the current-carrying capacities given in Tables 4D1 to 4L4 have been determined. For the other methods, an indication is given of the appropriate reference method having values of current-carrying capacity which can safely be applied.

As stated in Clause 521-07-01L the use of other methods is not precluded, where specified by a suitably qualified electrical engineer; in that case the evaluation of current-carrying capacity may need to be based on experimental work.

TABLE 4B1

Correction factors for groups of more than one circuit of single-core cables, or more than one multicore cable (to be applied to the corresponding current-carrying capacity for a single circuit in Tables 4D1 to 4D4, 4E1 to 4E4, 4F1 and 4F2, 4J1, 4K1 to 4K4, 4L1 to 4L4)**

Reference method of installation (see Table 4A)		Correction factor (C_g) Number of circuits or multicore cables													
		2	3	4	5	6	7	8	9	10	12	14	16	18	20
Enclosed (Method 3 or 4) or bunched and clipped direct to a non-metallic surface (Method 1)		0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.48	0.45	0.43	0.41	0.39	0.38
Single layer clipped to a non-metallic surface (Method 1)	Touching	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	-	-	-	-	-	-
	Spaced*	0.94	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Single layer *multicore* on a perforated metal cable tray, vertical or horizontal (Method 11)	Touching	0.86	0.81	0.77	0.75	0.74	0.73	0.73	0.72	0.71	0.70	-	-	-	-
	Spaced*#	0.91	0.89	0.88	0.87	0.87	-	-	-	-	-	-	-	-	-
Single layer *single-core* on a perforated metal cable tray, touching (Method 11)	Horizontal	0.90	0.85	-	-	-	-	-	-	-	-	-	-	-	-
	Vertical	0.85	-	-	-	-	-	-	-	-	-	-	-	-	-
Single layer multicore touching on ladder supports (Method 13)		0.86	0.82	0.80	0.79	0.78	0.78	0.78	0.77	-	-	-	-	-	-

* Spaced by a clearance between adjacent surfaces of at least one cable diameter (D_e). Where the horizontal clearances between adjacent cables exceeds $2D_e$ no correction factor need be applied.

** When cables having differing conductor operating temperatures are grouped together, the current rating shall be based upon the lowest operating temperature of any cable in the group.

\- Correction factor not tabulated.

\# Not applicable to mineral-insulated cables see Table 4B2.

TABLE 4B2

Correction factors for mineral insulated cables installed on perforated tray, (to be applied to the corresponding current-carrying capacity for single circuits for reference method 11 in Table 4J1A)

Tray orientation	Arrangement of cables	Number of trays	Number of multicore cables or circuits					
			1	2	3	4	6	9
Horizontal	Multiconductor cables touching	1	1.0	0.90	0.80	0.80	0.75	0.75
Horizontal	Multiconductor cables spaced ‡	1	1.0	1.0	1.0	0.95	0.90	-
Vertical	Multiconductor cables touching	1	1.0	0.90	0.80	0.75	0.75	0.70
Vertical	Multiconductor cables spaced ‡	1	1.0	0.90	0.90	0.90	0.85	-
Horizontal	Single conductor cables trefoil separated ‡‡	1	1.0	1.0	0.95			
Vertical	Single conductor cables trefoil separated ‡‡	1	1.0	0.90	0.90			

‡ Spaced by a clearance between adjacent surfaces of at least one cable diameter (D_e).

‡‡ Separated by a clearance between adjacent surfaces of at least two cable diameters ($2D_e$).

\- Correction factor not tabulated.

NOTES to Tables 4B1 and 4B2

1. The factors in the table are applicable to groups of cables all of one size. The value of current derived from application of the appropriate factors is the maximum current to be carried by any of the cables in the group.
2. If, due to known operating conditions, a cable is expected to carry not more than 30% of its *grouped* rating, it may be ignored for the purpose of obtaining the rating factor for the rest of the group.
   For example, a group of N loaded cables would normally require a group reduction factor of C_g applied to the tabulated I_t. However, if M cables in the group carry loads which are not greater than $0.3\ C_g I_t$ amperes the other cables can be sized by using the group rating factor corresponding to (N-M) cables.
3. When cables having differing conductor operating temperatures are grouped together, the current rating shall be based on the lowest operating temperature of any cable in the group.
4. Where the horizontal clearances between adjacent cables exceeds $2D_e$, no correction factor need be applied.

TABLE 4B3

Correction factors for cables installed in enclosed trenches (Installation Methods 18, 19 and 20 of Table 4A)*

The correction factors tabulated below relate to the disposition of cables illustrated in items 18 to 20 of Table 4A and are applicable to the current-carrying capacities for Reference Methods 12 or 13 of Table 4A as given in the relevant tables of this appendix.

Conductor cross-sectional area	Correction factor									
	Installation Method 18				Installation Method 19			Installation Method 20		
	2 single-core cables, or 1 three- or four-core cable	3 single-core cables, or 2 two-core cables	4 single-core cables, or 2 three- or four-core cables	6 single-core cables, 4 two-core cables, or 3 three- or four-core cables	6 single-core cables, 4 two-core cables, or 3 three- or four-core cables	8 single-core cables, or 4 three- or four-core cables	12 single-core cables, 8 two-core cables, or 6 three- or four-core cables	12 single-core cables, 8 two-core cables, or 6 three- or four-core cables	18 single-core cables, 12 two-core cables, or 9 three- or four-core cables	24 single-core cables, 16 two-core cables, or 12 three- or four-core cables
1	2	3	4	5	6	7	8	9	10	11
(mm²)										
4	0.93	0.90	0.87	0.82	0.86	0.83	0.76	0.81	0.74	0.69
6	0.92	0.89	0.86	0.81	0.86	0.82	0.75	0.80	0.73	0.68
10	0.91	0.88	0.85	0.80	0.85	0.80	0.74	0.78	0.72	0.66
16	0.91	0.87	0.84	0.78	0.83	0.78	0.71	0.76	0.70	0.64
25	0.90	0.86	0.82	0.76	0.81	0.76	0.69	0.74	0.67	0.62
35	0.89	0.85	0.81	0.75	0.80	0.74	0.68	0.72	0.66	0.60
50	0.88	0.84	0.79	0.74	0.78	0.73	0.66	0.71	0.64	0.59
70	0.87	0.82	0.78	0.72	0.77	0.72	0.64	0.70	0.62	0.57
95	0.86	0.81	0.76	0.70	0.75	0.70	0.63	0.68	0.60	0.55
120	0.85	0.80	0.75	0.69	0.73	0.68	0.61	0.66	0.58	0.53
150	0.84	0.78	0.74	0.67	0.72	0.67	0.59	0.64	0.57	0.51
185	0.83	0.77	0.73	0.65	0.70	0.65	0.58	0.63	0.55	0.49
240	0.82	0.76	0.71	0.63	0.69	0.63	0.56	0.61	0.53	0.48
300	0.81	0.74	0.69	0.62	0.68	0.62	0.54	0.59	0.52	0.46
400	0.80	0.73	0.67	0.59	0.66	0.60	0.52	0.57	0.50	0.44
500	0.78	0.72	0.66	0.58	0.64	0.58	0.51	0.56	0.48	0.43
630	0.77	0.71	0.65	0.56	0.63	0.57	0.49	0.54	0.47	0.41

* When cables having different conductor operating temperatures are grouped together the current rating shall be based on the lowest operating temperature of any cable in the group.

TABLE 4A (continued)

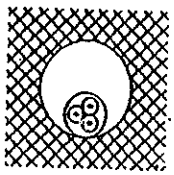
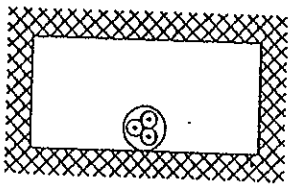
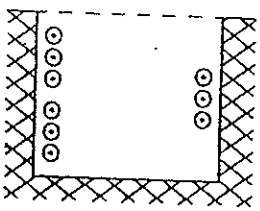
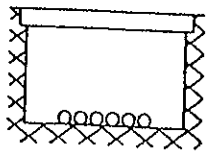
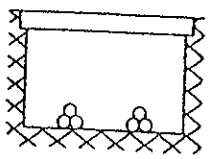
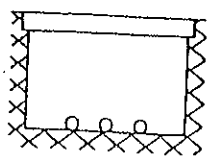
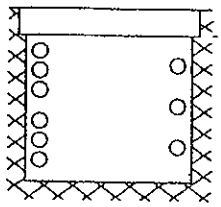
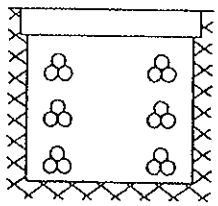
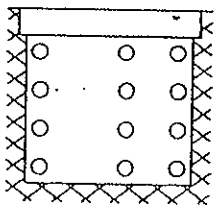
Installation method		Examples	Appropriate Reference Method for determining current-carrying capacity
Number	Description		
1	2	3	4
16	**Sheathed cables in ducts or voids formed by the building structure, other than thermally insulating materials**	 	Method 4 **Where the cable has a diameter D_e and the duct has a diameter not greater than $5D_e$ or a perimeter not greater than $20D_e$** Method 3 Where the duct has either a diameter greater than $5D_e$ or a perimeter greater than $20D_e$ NOTE 1 - Where the perimeter is greater than $60D_e$, installation Methods 18 to 20, as appropriate, should be used. NOTE 2 - D_e is the overall cable diameter. For groups of cables D_e is the sum of the cable diameters.
Cables in trenches:			
17	Cables supported on the wall of an open or ventilated trench, with spacings as indicated for Reference Method 12 or 13 as appropriate		Method 12 or 13, as appropriate
18	**Cables in enclosed trench 450 mm wide by 300 mm deep (minimum dimensions) including 100 mm cover.**	Two single-core cables with surfaces separated by a minimum of one cable diameter.  Three single-core cables in trefoil and touching throughout.  Multicore cables or groups of single-core cables with surfaces separated by a minimum of 50 mm 	**Method 18** **Use rating factors in Table 4B3**

TABLE 4A (continued)

Installation method		Examples	Appropriate Reference Method for determining current-carrying capacity
Number	Description		
1	2	3	4
19	**Cables in enclosed trench 450 mm wide by 600 mm deep (minimum dimensions) including 100 mm cover**	Single-core cables arranged in flat groups of two or three on the vertical trench wall with surfaces separated by one diameter with a minimum distance of 50 mm between groups. Multicore cables installed with surfaces separated by a minimum* of 75 mm. All cables spaced at least 25 mm from the trench wall. 	**Method 19** **Use rating factors in Table 4B3**
20	**Cables in enclosed trench 600 mm wide by 760 mm deep (minimum dimensions) including 100 mm cover**	Single-core cables arranged in groups of two or three in flat formation with the surfaces separated by one diameter or in trefoil formation with cables touching.  Groups separated by a minimum* of 50 mm either horizontally or vertically. Multicore cables installed with surfaces separated by a minimum* of 75 mm either horizontally or vertically. All cables spaced at least 25 mm from the trench wall. 	**Method 20** **Use rating factors in Table 4B3**

* Larger spacing to be used where practicable.

TABLE 4C1

Correction factors for ambient temperature where protection is against short-circuit

NOTE: This table applies where the associated overcurrent protective device is intended to provide short-circuit protection only. Except where the device is a semi-enclosed fuse to BS 3036 the table also applies where the device is intended to provide overload protection.

Type of insulation	Operating temperature	Ambient temperature (°C)														
		25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Rubber (flexible cables only)	60°C	1.04	1.0	0.91	0.82	0.71	0.58	0.41	-	-	-	-	-	-	-	-
General purpose pvc	70°C	1.03	1.0	0.94	0.87	0.79	0.71	0.61	0.50	0.35	-	-	-	-	-	-
Paper	80°C	1.02	1.0	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45	0.32	-	-	-	-
Rubber	85°C	1.02	1.0	0.95	0.90	0.85	0.80	0.74	0.67	0.60	0.52	0.43	0.30	-	-	-
Heat resisting pvc*	90°C	1.03	1.0	0.97	0.94	0.91	0.87	0.84	0.80	0.76	0.71	0.61	0.50	0.35	-	-
Thermosetting	90°C	1.02	1.0	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58	0.50	0.41	0.29	-	-
Mineral	70°C sheath	1.03	1.0	0.93	0.85	0.77	0.67	0.57	0.45	0.31	-	-	-	-	-	-
	105°C sheath	1.02	1.0	0.96	0.92	0.88	0.84	0.80	0.75	0.70	0.65	0.60	0.54	0.47	0.40	0.32

NOTES:

1. Correction factors for flexible cords and for 85°C or 150°C rubber-insulated flexible cables are given in the relevant table of current-carrying capacity.
2. This table also applies when determining the current-carrying capacity of a cable.
3. * These factors are applicable only to ratings in columns 2 to 5 of Table 4D1.

TABLE 4C2

Correction factors for ambient temperature where the overload protective device is a semi-enclosed fuse to BS 3036.

Type of insulation	Operating temperature	Ambient temperature (°C)														
		25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Rubber (flexible cables only)	60°C	1.04	1.0	0.96	0.91	0.87	0.79	0.56	-	-	-	-	-	-	-	-
General purpose pvc	70°C	1.03	1.0	0.97	0.94	0.91	0.87	0.84	0.69	0.48	-	-	-	-	-	-
Paper	80°C	1.02	1.0	0.97	0.95	0.92	0.90	0.87	0.84	0.76	0.62	0.43	-	-	-	-
Rubber	85°C	1.02	1.0	0.97	0.95	0.93	0.91	0.88	0.86	0.83	0.71	0.58	0.41	-	-	-
Heat resisting pvc*	90°C	1.03	1.0	0.97	0.94	0.91	0.87	0.84	0.80	0.76	0.72	0.68	0.63	0.49	-	-
Thermosetting	90°C	1.02	1.0	0.98	0.95	0.93	0.91	0.89	0.87	0.85	0.79	0.69	0.56	0.39	-	-
Mineral: bare and exposed to touch or pvc covered	70°C sheath	1.03	1.0	0.96	0.93	0.89	0.86	0.79	0.62	0.42	-	-	-	-	-	-
Bare and not exposed to touch	105°C sheath	1.02	1.0	0.98	0.96	0.93	0.91	0.89	0.86	0.84	0.82	0.79	0.77	0.64	0.55	0.43

NOTES:

1. Correction factors for flexible cords and for 85°C or 150°C rubber-insulated flexible cables are given in the relevant table of current-carrying capacity.
2. * These factors are applicable only to ratings in columns 2 to 5 of Table 4D1.

TABLE 4D1A

Single-core pvc-insulated cables, non-armoured, with or without sheath
(COPPER CONDUCTORS)

BS 6004
BS 6231
BS 6346

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30°C
Conductor operating temperature: 70°C

Conductor cross-sectional area	Reference Method 4 (enclosed in conduit in thermally insulating wall etc.)		Reference Method 3 (enclosed in conduit on a wall or in trunking etc.)		Reference Method 1 (clipped direct)		Reference Method 11 (on a perforated cable tray horizontal or vertical)		Reference Method 12 (free air)		
									Horizontal flat spaced	Vertical flat spaced	Trefoil
	2 cables, single-phase a.c. or d.c.	3 or 4 cables, three-phase a.c.	2 cables, single-phase a.c. or d.c.	3 or 4 cables, three-phase a.c.	2 cables, single-phase a.c. or d.c. flat and touching	3 or 4 cables, three-phase a.c. flat and touching or trefoil	2 cables, single-phase a.c.or d.c. flat and touching	3 or 4 cables, three-phase a.c. flat and touching or trefoil	2 cables, single-phase a.c. or d.c. or 3 cables three-phase a.c.	2 cables, single-phase a.c. or d.c. or 3 cables three-phase a.c.	3 cables trefoil, three phase a.c.
1	2	3	4	5	6	7	8	9	10	11	12
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	11	10.5	13.5	12	15.5	14	-	-	-	-	-
1.5	14.5	13.5	17.5	15.5	20	18	-	-	-	-	-
2.5	19.5	18	24	21	27	25	-	-	-	-	-
4	26	24	32	28	37	33	-	-	-	-	-
6	34	31	41	36	47	43	-	-	-	-	-
10	46	42	57	50	65	59	-	-	-	-	-
16	61	56	76	68	87	79	-	-	-	-	-
25	80	73	101	89	114	104	126	112	146	130	110
35	99	89	125	110	141	129	156	141	181	162	137
50	119	108	151	134	182	167	191	172	219	197	167
70	151	136	192	171	234	214	246	223	281	254	216
95	182	164	232	207	284	261	300	273	341	311	264
120	210	188	269	239	330	303	349	318	396	362	308
150	240	216	300	262	381	349	404	369	456	419	356
185	273	245	341	296	436	400	463	424	521	480	409
240	320	286	400	346	515	472	549	504	615	569	485
300	367	328	458	394	594	545	635	584	709	659	561
400	-	-	546	467	694	634	732	679	852	795	656
500	-	-	626	533	792	723	835	778	982	920	749
630	-	-	720	611	904	826	953	892	1138	1070	855
800	-	-	-	-	1030	943	1086	1020	1265	1188	971
1000	-	-	-	-	54	1058	1216	1149	1420	1	1079

COPPER CONDUCTORS

NOTES:

1. Where the conductor is to be protected by a semi-enclosed fuse to BS 3036, see item 6.2 of the preface to this appendix.
2. The current-carrying capacities in columns 2 to 5 are also applicable to flexible cables to BS 6004 table 1(c) and to 90°C heat resisting pvc cables to BS 6231 tables 8 and 9 where the cables are used in fixed installations.

TABLE 4D1B

VOLTAGE DROP (per ampere per metre):

Conductor operating temperature: 70°C

Conductor cross-sectional area	2 cables d.c.	2 cables, single-phase a.c.									3 or 4 cables, three-phase a.c.									
		Reference Methods 3 & 4 (enclosed in conduit etc. in or on a wall)			Reference Methods 1 & 11 (clipped direct or on trays, touching)			Reference Method 12 (spaced*)			Reference Methods 3 & 4 (enclosed in conduit etc. in or on a wall)			Reference Methods 1, 11 & 12 (in trefoil)			Reference Methods 1 & 11 (flat and touching)			Reference Method 12 (flat spaced*)		
1	2	3			4			5			6			7			8			9		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
1	44	44			44			44			38			38			38			38		
1.5	29	29			29			29			25			25			25			25		
2.5	18	18			18			18			15			15			15			15		
4	11	11			11			11			9.5			9.5			9.5			9.5		
6	7.3	7.3			7.3			7.3			6.4			6.4			6.4			6.4		
10	4.4	4.4			4.4			4.4			3.8			3.8			3.8			3.8		
16	2.8	2.8			2.8			2.8			2.4			2.4			2.4			2.4		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.75	1.80	0.33	1.80	1.75	0.20	1.75	1.75	0.29	1.80	1.50	0.29	1.55	1.50	0.175	1.50	1.50	0.25	1.55	1.50	0.32	1,55
35	1.25	1.30	0.31	1.30	1.25	0.195	1.25	1.25	0.28	1.30	1.10	0.27	1.10	1.10	0.170	1.10	1.10	0.24	1.10	1.10	0.32	1.15
50	0.93	0.95	0.30	1.00	0.93	0.190	0.95	0.93	0.28	0.97	0.81	0.26	0.85	0.80	0.165	0.82	0.80	0.24	0.84	0.80	0.32	0.86
70	0.63	0.65	0.29	0.72	0.63	0.185	0.66	0.63	0.27	0.69	0.56	0.25	0.61	0.55	0.160	0.57	0.55	0.24	0.60	0.55	0.31	0.63
95	0.46	0.49	0.28	0.56	0.47	0.180	0.50	0.47	0.27	0.54	0.42	0.24	0.48	0.41	0.155	0.43	0.41	0.23	0.47	0.40	0.31	0.51
120	0.36	0.39	0.27	0.47	0.37	0.175	0.41	0.37	0.26	0.45	0.33	0.23	0.41	0.32	0.150	0.36	0.32	0.23	0.40	0.32	0.30	0.44
150	0.29	0.31	0.27	0.41	0.30	0.175	0.34	0.29	0.26	0.39	0.27	0.23	0.36	0.26	0.150	0.30	0.26	0.23	0.34	0.26	0.30	0.40
185	0.23	0.25	0.27	0.37	0.24	0.170	0.29	0.24	0.26	0.35	0.22	0.23	0.32	0.21	0.145	0.26	0.21	0.22	0.31	0.21	0.30	0.36
240	0.180	0.195	0.26	0.33	0.185	0.165	0.25	0.185	0.25	0.31	0.17	0.23	0.29	0.160	0.145	0.22	0.160	0.22	0.27	0.160	0.29	0.34
300	0.145	0.160	0.26	0.31	0.150	0.165	0.22	0.150	0.25	0.29	0.14	0.23	0.27	0.130	0.140	0.190	0.130	0.22	0.25	0.130	0.29	0.32
400	0.105	0.130	0.26	0.29	0.120	0.160	0.20	0.115	0.25	0.27	0.12*	0.22	0.25	0.105	0.140	0.175	0.105	0.21	0.24	0.100	0.29	0.31
500	0.086	0.110	0.26	0.28	0.098	0.155	0.185	0.093	0.24	0.26	0.10	0.22	0.25	0.086	0.135	0.160	0.086	0.21	0.23	0.081	0.29	0.30
630	0.068	0.094	0.25	0.27	0.081	0.155	0.175	0.076	0.24	0.25	0.08	0.22	0.24	0.072	0.135	0.150	0.072	0.21	0.22	0.066	0.28	0.29
800	0.053		-		0.068	0.150	0.165	0.061	0.24	0.25		-		0.060	0.130	0.145	0.060	0.21	0.22	0.053	0.28	0.29
1000	0.042		-		0.059	0.150	0.160	0.050	0.24	0.24		-		0.052	0.130	0.140	0.052	0.20	0.21	0.044	0.28	0.28

NOTE: * Spacings larger than those specified in Method 12 (see table 4A) will result in larger voltage drop.

TABLE 4D4A

Multicore armoured pvc-insulated cables
(COPPER CONDUCTORS)
BS 6346

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30°C
Conductor operating temperature: 70°C

Conductor cross-sectional area	Reference Method 1 (clipped direct)		Reference Method 11 (on a perforated horizontal or vertical cable tray) or Reference Method 13 (free air)	
	1 two-core cable, single-phase a.c. or d.c.	1 three- or four-core cable, three-phase a.c.	1 two-core cable, single-phase a.c. or d.c.	1 three- or four-core cable, three-phase a.c.
1	2	3	4	5
(mm²)	(A)	(A)	(A)	(A)
1.5	21	18	22	19
2.5	28	25	31	26
4	38	33	41	35
6	49	42	53	45
10	67	58	72	62
16	89	77	97	83
25	118	102	128	110
35	145	125	157	135
50	175	151	190	163
70	222	192	241	207
95	269	231	291	251
120	310	267	336	290
150	356	306	386	332
185	405	348	439	378
240	476	409	516	445
300	547	469	592	510
400	621	540	683	590

COPPER CONDUCTORS

NOTE:
Where the conductor is to be protected by a semi-enclosed fuse to BS 3036, see item 6.2 of the preface to this appendix.

TABLE 4D4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70°C

Conductor cross-sectional area	Two-core cable, d.c.	Two-core cable, single-phase a.c.			Three- or four-core cable, three-phase a.c.		
1	2	3			4		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1.5	29	29			25		
2.5	18	18			15		
4	11	11			9.5		
6	7.3	7.3			6.4		
10	4.4	4.4			3.8		
16	2.8	2.8			2.4		
		r	x	z	r	x	z
25	1.75	1.75	0.170	1.75	1.50	0.145	1.50
35	1.25	1.25	0.165	1.25	1.10	0.145	1.10
50	0.93	0.93	0.165	0.94	0.80	0.140	0.81
70	0.63	0.63	0.160	0.65	0.55	0.140	0.57
95	0.46	0.47	0.155	0.50	0.41	0.135	0.43
120	0.36	0.38	0.155	0.41	0.33	0.135	0.35
150	0.29	0.30	0.155	0.34	0.26	0.130	0.29
185	0.23	0.25	0.150	0.29	0.21	0.130	0.25
240	0.180	0.190	0.150	0.24	0.165	0.130	0.21
300	0.145	0.155	0.145	0.21	0.135	0.130	0.185
400	0.105	0.115	0.145	0.185	0.100	0.125	0.160

TABLE 4E2A

Multicore cable having thermosetting insulation, non armoured
(COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes): BS 5467 / BS 7211

Ambient temperature: 30°C
Conductor operating temperature: 90°C

Conductor cross-sectional area	Reference Method 4 (enclosed in an insulated wall, etc.)		Reference Method 3 (enclosed in conduit on a wall or ceiling, or in trunking)		Reference Method 1 (clipped direct)		Reference Method 11 (on a perforated cable tray) or Reference Method 13 (free air)	
	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.	1 two-core cable*, single-phase a.c. or d.c.	1 three- or four-core cable*, three-phase a.c.
1	2	3	4	5	6	7	8	9
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	14.5	13	17	15	19	17	21	18
1.5	18.5	16.5	22	19.5	24	22	26	23
2.5	25	22	30	26	33	30	36	32
4	33	30	40	35	45	40	49	42
6	42	38	51	44	58	52	63	54
10	57	51	69	60	80	71	86	75
16	76	68	91	80	107	96	115	100
25	99	89	119	105	138	119	149	127
35	121	109	146	128	171	147	185	158
50	145	130	175	154	209	179	225	192
70	183	164	221	194	269	229	289	246
95	220	197	265	233	328	278	352	298
120	253	227	305	268	382	322	410	346
150	290	259	334	300	441	371	473	399
185	329	295	384	340	506	424	542	456
240	386	346	459	398	599	500	641	538
300	442	396	532	455	693	576	741	621
400	-	-	625	536	803	667	865	741

COPPER CONDUCTORS

NOTES:

1. **Where the conductor is to be protected by a semi-enclosed fuse to BS 3036, see item 6.2 of the preface to this appendix.**
2. Where a conductor operates at a temperature exceeding 70°C it shall be ascertained that the equipment connected to the conductor is suitable for the conductor operating temperature (see Regulation 512-02).
3. * With or without a protective conductor.
4. For cables in rigid pvc conduit the values stated in table 4D2 are applicable (see Regulation 521-05).
5. Where cables in this table are connected to equipment or accessories designed to operate at a temperature not exceeding 70°C, the current ratings given in the equivalent table for 70°C pvc insulated cables (BS 6004, BS 6346) shall be used (see also Regulation 523-01-01).
6. Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

TABLE 4E2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90°C

Conductor cross-sectional area	Two-core cable, d.c.	Two-core cable, single-phase a.c.			Three- or four-core cable, three-phase a.c.		
1	2	3			4		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1	46	46			40		
1.5	31	31			27		
2.5	19	19			16		
4	12	12			10		
6	7.9	7.9			6.8		
10	4.7	4.7			4.0		
16	2.9	2.9			2.5		
		r	x	z	r	x	z
25	1.85	1.85	0.160	1.90	1.60	0.140	1.65
35	1.35	1.35	0.155	1.35	1.15	0.135	1.15
50	0.98	0.99	0.155	1.00	0.86	0.135	0.87
70	0.67	0.67	0.150	0.69	0.59	0.130	0.60
95	0.49	0.50	0.150	0.52	0.43	0.130	0.45
120	0.39	0.40	0.145	0.42	0.34	0.130	0.37
150	0.31	0.32	0.145	0.35	0.28	0.125	0.30
185	0.25	0.26	0.145	0.29	0.22	0.125	0.26
240	0.195	0.200	0.140	0.24	0.175	0.125	0.21
300	0.155	0.160	0.140	0.21	0.140	0.120	0.185
400	0.120	0.130	0.140	0.190	0.115	0.120	0.165

Protection Against Electric Shock

EFFECT OF CURRENT, EARTHING & GROUND POTENTIAL

1 Effect of Current on Human Beings and Livestock

For a given current path through the human body (e.g. hand to hand, one hand to both feet and etc.), the danger to persons depends mainly on the **magnitude and duration (i.e. time) of the current flow**.

However the time/current relationship cannot be applied directly in practice for designing protection against electrical shock, the necessary criterion being the **admissible limit of touch voltage** (i.e. the product of the current through the body and the body impedance) as a function of time.

Hence, for a given current path through the human body (e.g. hand to hand, one hand to both feet and etc.), the danger to persons depends mainly on the magnitude and duration (i.e. time) of the ADMISIBLE LIMIT OF TOUCH VOLTAGE.

The impedance of a human body is not linear, because the impedance of the human body varies with the magnitude of the touch voltage. In general, the human body impedance is lower for a higher touch voltage, and the body impedance is higher for a lower touch voltage.

The human body impedance depend on a number of factors such as (1) the **current path** (2) a.c. or d.c. touch voltage (3) **duration** of the current flow (4) the frequency (5) the degree of **moisture** of the skin e.g. wet is very conductive to current (6) the **surface area** of contact e.g. big or small area, rough or smooth surface etc. (7) the **pressure** exerted and (8) the temperature.

Accidents with direct current are much less frequent than would be expected from the number of d.c. applications, and fatal accidents occur only under very unfavourable conditions, e.g. in mines. For direct current, the let-go of parts gripped is less difficult and that for shock duration longer than the period of the cardiac cycle, the threshold of ventricular fibrillation remains considerably higher than for a.c.

The main differences between the effects of a.c. and d.c. on human body result from the fact that excitatory actions of the current (stimulation of nerves and muscles, induction of cardiac atrial or ventricular fibrillation) are linked to the changes of the current magnitude especially when making and braking the current. To produce the same excitatory effects the magnitude of direct current strength is 2 to 4 times greater than that of a.c.

2 Effects of Sinusoidal Alternating Current in The Range of 15Hz to 100Hz

2.1 Threshold of Perception and Threshold of Reaction

Depend on: (1) The body in contact with an electrode (contact area)
(1) The conditions of contact (dry, wet, pressure, temperature)
(2) The physiological characteristics of the individual.

A general value of 0.5mA is assumed to be the threshold of reaction.

2.1.1 Threshold of Let-Go

The threshold of let-go depends on:

(1) the contact area
(2) the shape and size of electrode
(3) the physiological characteristics of the individual.

2.1.2 Threshold of Ventricular Fibrillation

The following table explains the time/current zone of figure 14

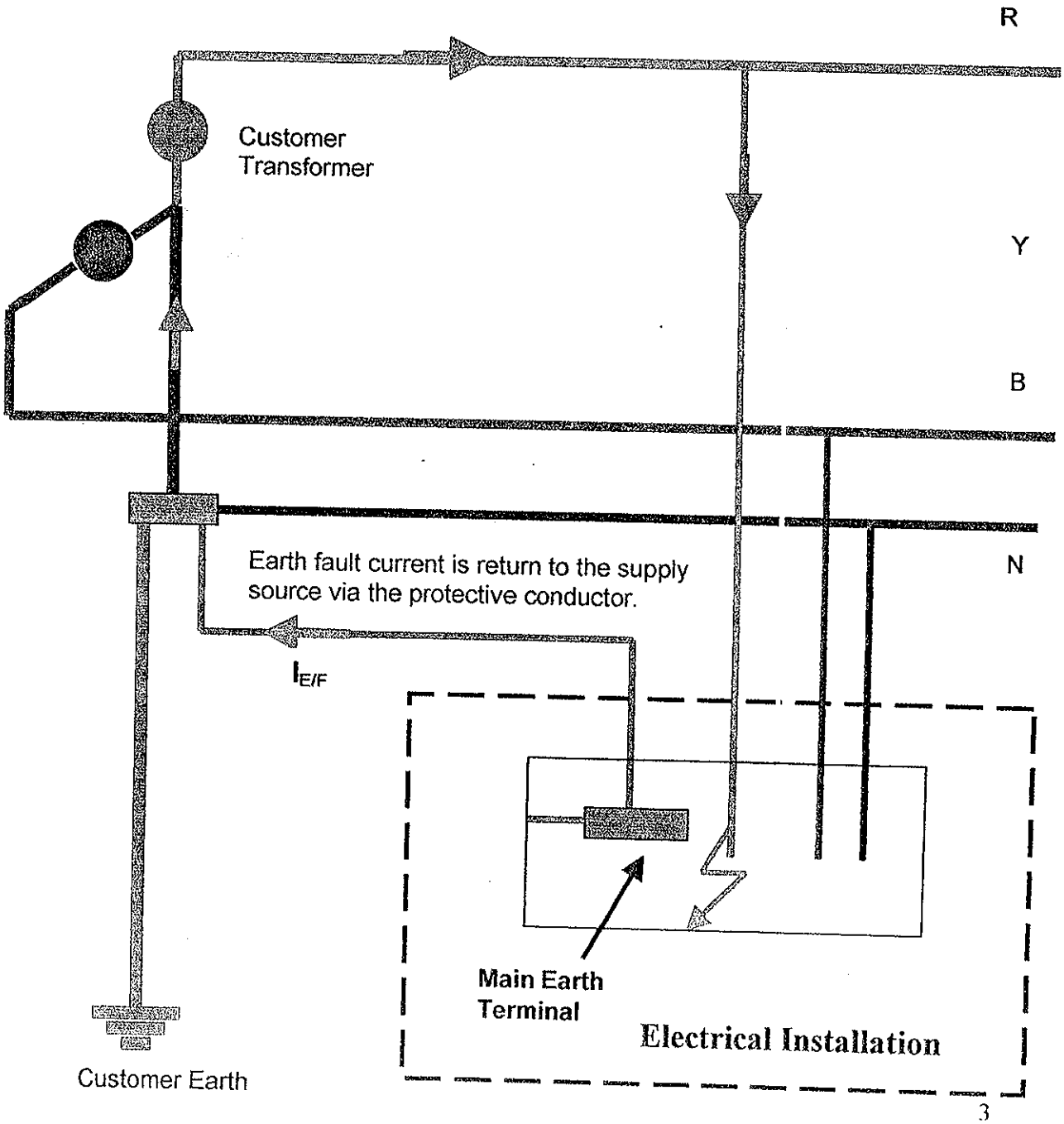
Zone designation	Zone limits	Physiological effects
AC-1	Up to 0.5 mA line-a	Usually no reaction.
AC-2	0.5 mA up to line-b *	Usually no harmful physiological effects.
AC-3	Line-b up to curve-C_1	Usually no organic damage to be expected, likelihood of cramp like muscular contractions and difficulty in breathing for duration of current flow longer than 2 seconds. Reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
AC-4	Above curve-C_1	Increasing with magnitude and time, dangerous pathophysiological effects such as cardiac arrest, breathing arrest and severe burns may occur in addition to the effects of Zone 3.
AC-4.1	C_1 to C_2	Probability of ventricular fibrillation increasing up to about 5%.
AC-4.2	C_2 to C_3	Probability of ventricular fibrillation up to about 50%.
AC-4.3	Beyond Curve C_3	Probability of ventricular fibrillation above 50%.
* For duration of current-flow below 10 mSec, the limit of the body current for line-b remains constant at a value of 200 mA.		

e.g. A current of 200 mA hand to hand has the same likelihood of producing ventricular fibrillation as a current of 80 mA left hand to both feet.

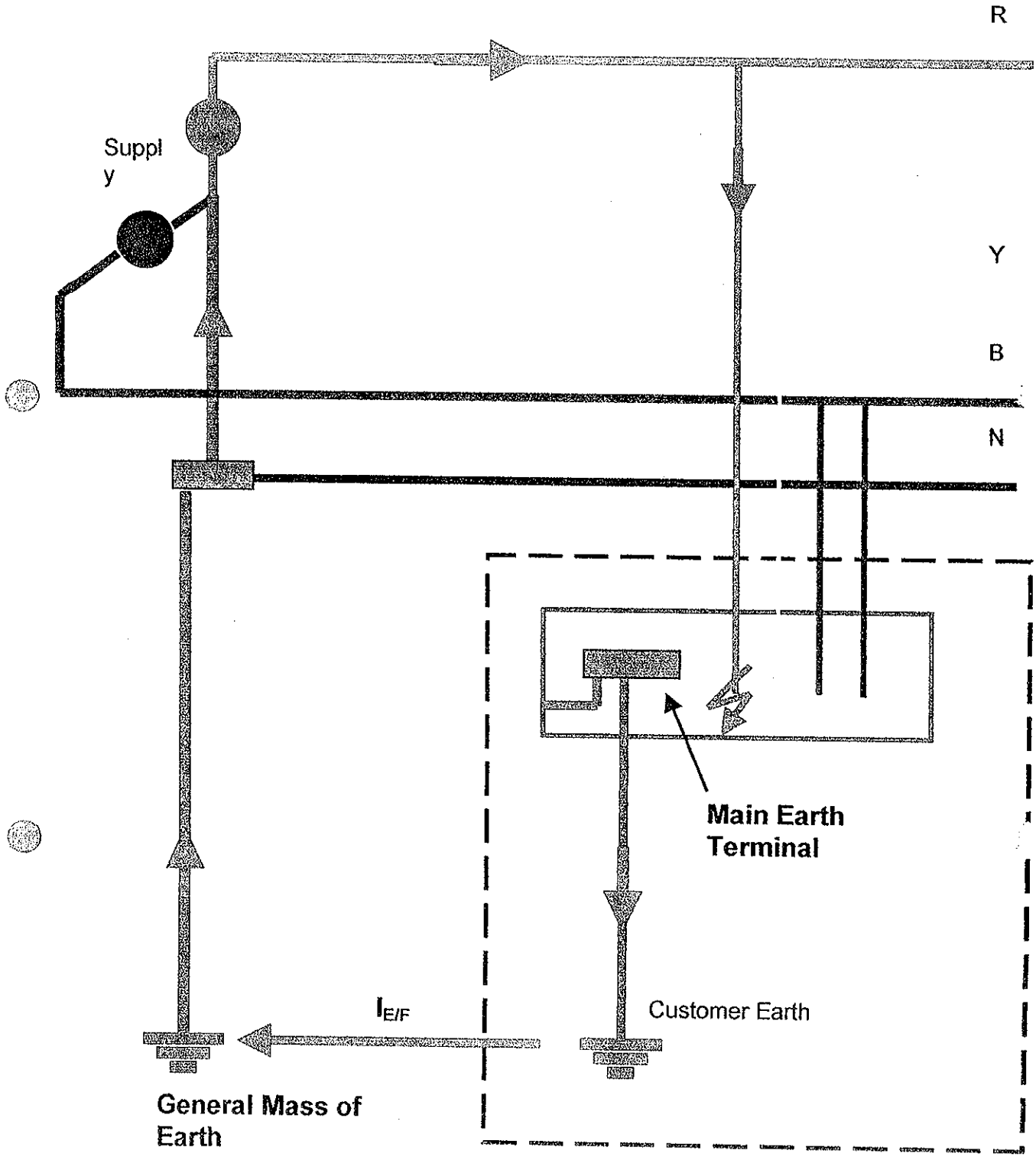
3 Supply System Earthing Arrangement

In Singapore only TNS- and/or TT- system of earthing is allowed where one point of the supply source must be connected to the general mass of the earth. This is not applicable to installation using separated extra low voltage system.

(1) TNS-system



(2) TT-System



Earth fault current is return to the supply source via the general mass of Earth.

4 Earthing for Electrical Installation

CP16 specify the requirement for Earthing.

Earthing is applicable to TN-S and TT system. Earthing is to allow safe passage of earth fault current to the general mass of earth, and/or limit the voltage rise between simultaneously accessible exposed-conductive-parts and extraneous-conductive parts which include the general mass of earth.

Earthing is not applicable to an electrical installation which uses one of the following method for protection against electric shock:

(i) Protection by use of Class II Equipment or by Equivalent Insulation

(ii) Protection by Non-Conducting Location

(iii) Protection by Earth-Free Local Equipotential Bonding

(iv) Use of Separated Extra-Low Voltage System.

4.1 Effect of Current Flowing in an Earth Electrode

Refer to figure (1), the current will flow in the ground radially outward from the customer earth electrode. The general mass of the earth can be visualised as an electrolyte in a tank, and the electrodes are like the electrode dip inside the electrolyte. Electrolyte has resistance and it can be easily mixed to become homogeneous and provide uniform resistance distribution in the tank. However, the content of the soil in the earth is naturally formed and cannot be made simply to become homogeneous. Hence the resistance of the soil varies from places to places. Therefore, the voltage drop along the ground for the same current magnitude will varies according to the soil condition.

A voltmeter can be used to measure the potential at any point on the ground. By linking all the points on the ground which has the same potential, then the line formed by this points is called the equipotential line of so much volts. E.g. the line-b is an equipotential line of 160V.

The shape of the equipotential line can be a circle with the customer earth electrode as the center if the resistance of the soil is homogeneous, e.g. equipotential line-a. For non-homogeneous soil, the equipotential line can be of any shape e.g. equipotential line-b and line-c.

If earth electrode 5 and 6 are inserted into the ground at the location as shown. A human being with his both hands has come into direct contact with these two electrodes through separate conductors. He will receive an electrical shock of 70V, as there is a potential difference of 70V.

Is there a potential difference between earth electrode 7 and 8?

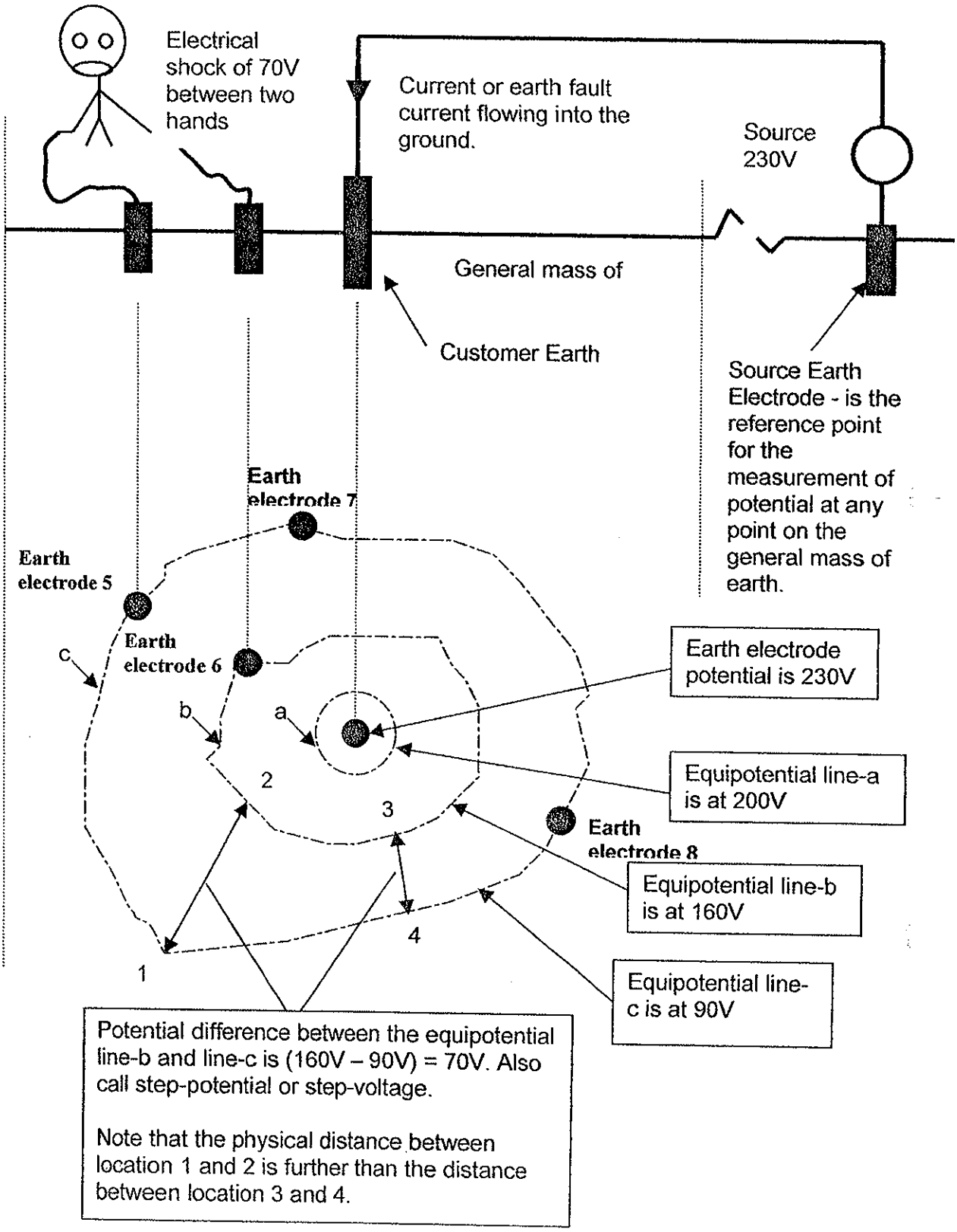
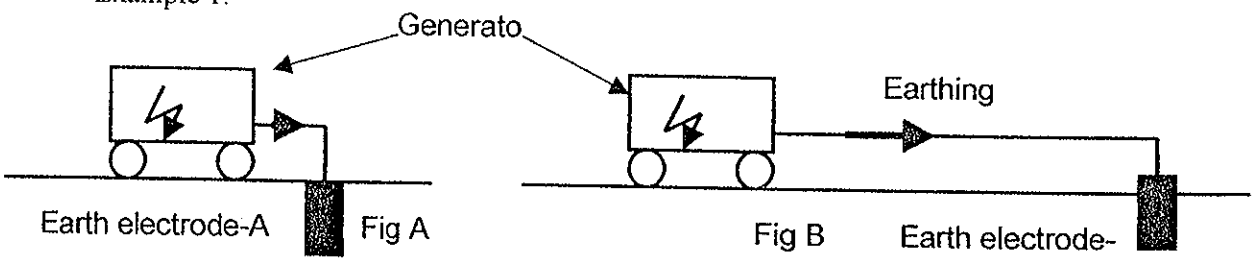


Fig (1) Equipotential line on the ground when subjected to current flow in the ground between the two earth electrodes which are far apart.

Example 1:

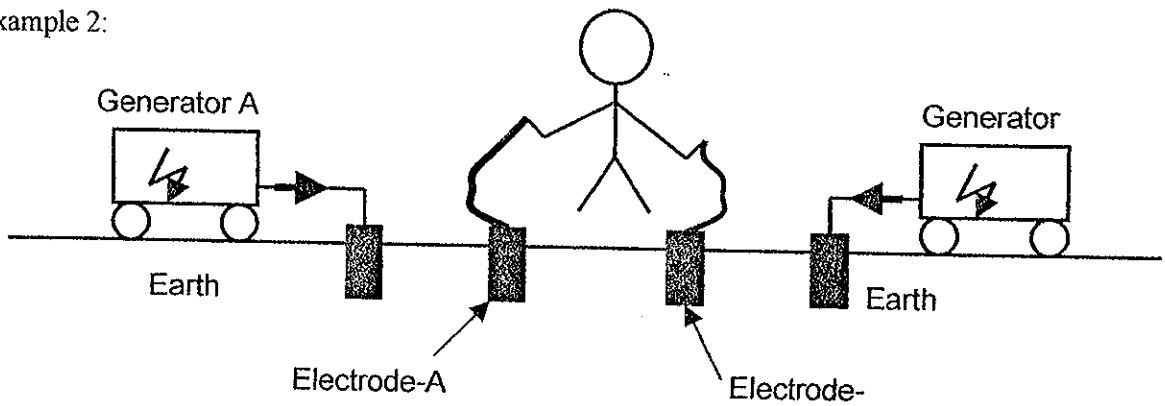


The metallic casing of the mobile generator is insulated from the general mass of the earth. The generator is connected to earth by an earth electrode via an earthing conductor. For the purposes of reducing the possibility of electrical shock.

(i) Which has a higher degree of safety, Fig A or Fig B?

(ii) What is the reason for higher degree of safety?

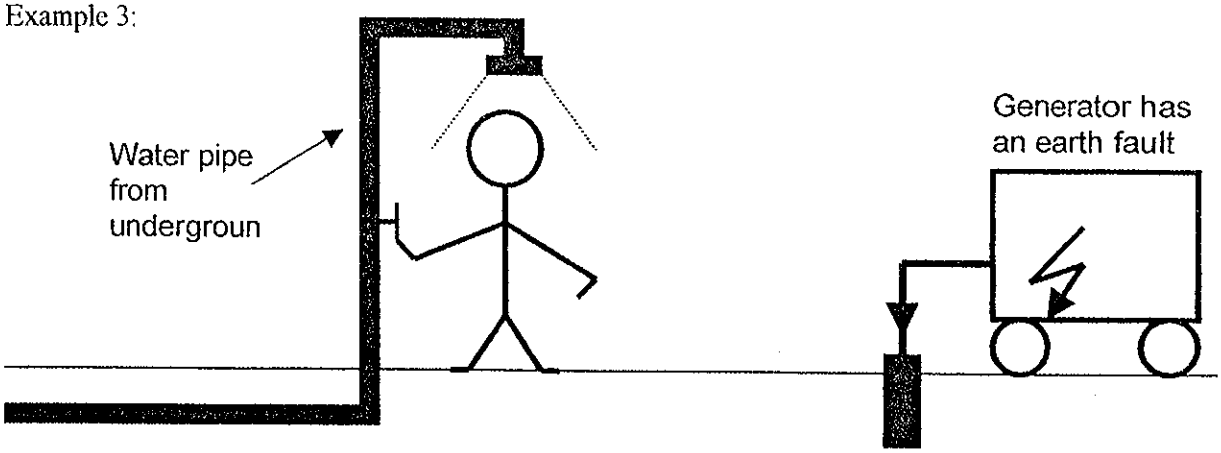
Example 2:



Under the circumstances of an earth fault simultaneously occurred in generator A and generator B. Both hands of the person is coming into direct contact with the electrode A and electrode B. Which of the following statement is most correct.

(a) The person will not get an electrical shock because the earth fault current for the two generator cancel each other in the ground.
(b) The person will only get an electrical shock from one of the generator.
(c) The person will not get a fatal electrical shock.
(d) The person will get electrical shock due to generator-A and generator-B simultaneously.

Example 3:



A person is taking a shower at the construction site with his feet come into direct contact with the ground. Which of the following statement is correct?

(a) The person will not get an electrical shock because his body and the ground are wet.
(b) The person will get an electrical shock because the ground is wet.
(c) The person will get an electrical shock and is most severe when the shower stop running.
(d) The person will not get an electrical shock under any circumstances.

5 Construction of Earth Electrode System with Equipotential Bonding

The Main Earth Terminal is a reference point for the electrical installation. It is connected to the earth electrode system via the earthing conductors. The main equipotential bonding conductor will be connected between the main earthing terminal and the extraneous conductive parts such as the main water pipe, main gas pipe, and exposed metallic structure of the building.

The common types of earth electrode can be:

(1) Earth rods. (typically 15mm diameter with 1.2m length)
(2) Copper tapes.
(3) Copper plate.

Prohibit using the metalwork of any gas pipe and water pipe as earth electrode.

Earth rod is the most commonly used type of earth electrode. In general, the resistance of the earth rod in the general mass of earth can be decreased by:

(1) Increasing the length of the rod by cascading more electrodes by the use of rod coupler. (Note: increasing rod diameter has less effect in decreasing resistance)
(2) Inserting more earth rods into the ground and connect them up by the use of Earthing and Bonding Clamp to SS 322.

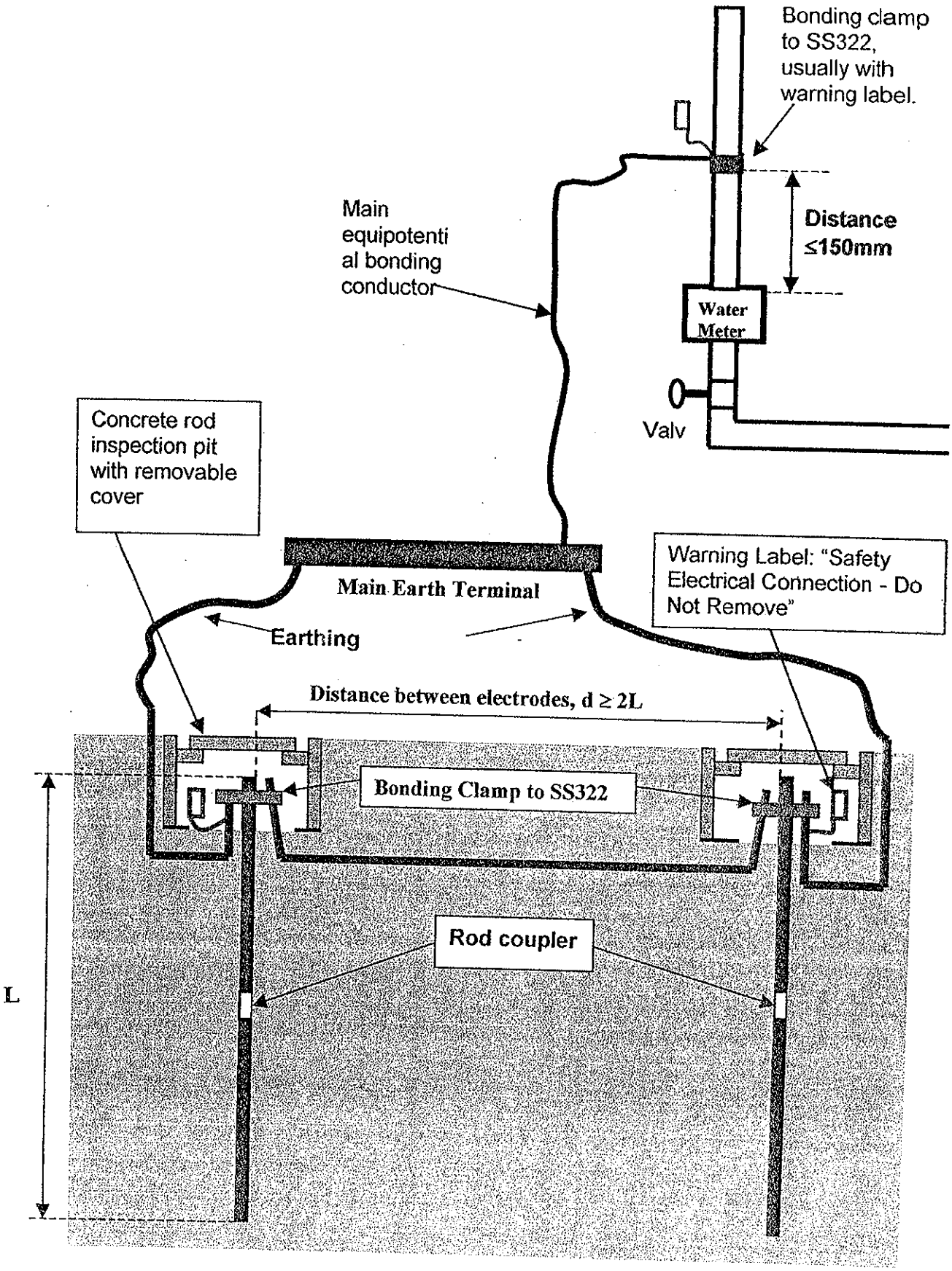
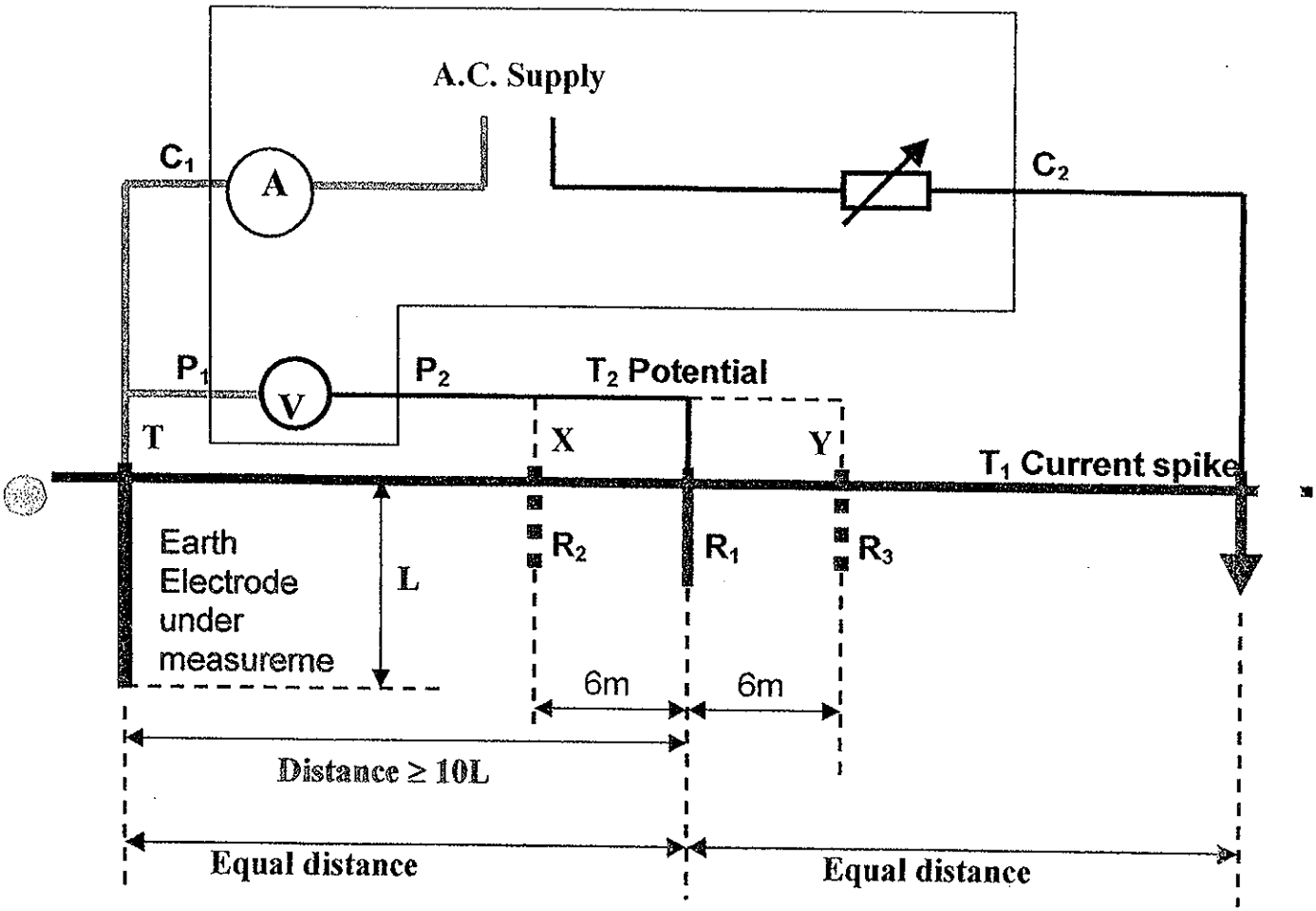


Fig (2) Construction of Earth Electrode System

5.1 Measurement of Earth Electrode Resistance of a Single Rod



(1) The potential spike shall be located at a distance at least 10 times the length of the electrode under measurement.

(2) There are 3 readings to be taken from the measurement.

(a) A measurement with reading R_1, is taken with the potential spike located **midway**.
(b) A measurement with reading R_2, is taken with the potential spike at location X, **6m nearer** to the earth electrode under test.
(c) A measurement with reading R_3, is taken with the potential spike at location Y, **6m away** from the earth electrode under test.

(3) Calculate the average resistance, $R_A = (R_1 + R_2 + R_3) / 3$

Calculate percentage deviation, $PD1 = (R_1 - R_A)x100/ R_A$

Calculate percentage deviation, $PD2 = (R_2 - R_A)x100/ R_A$

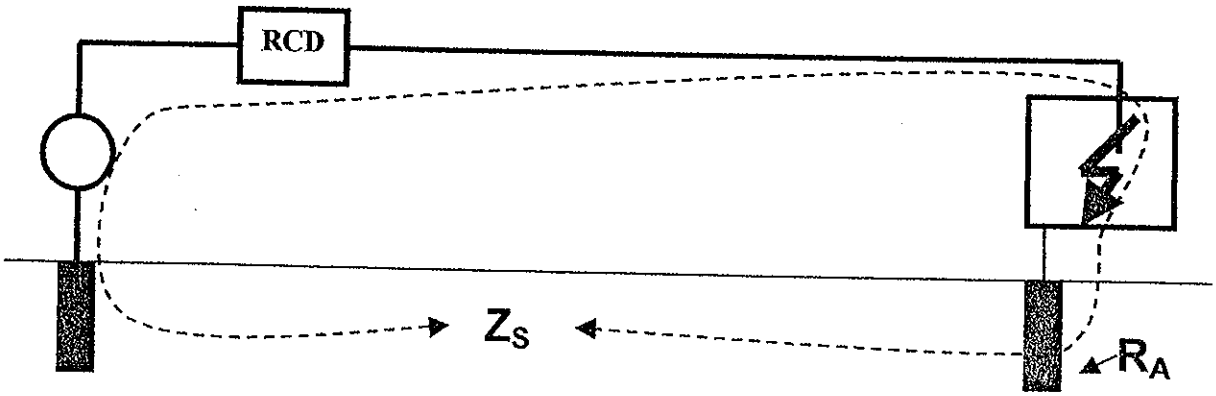
Calculate percentage deviation, $PD3 = (R_3 - R_A)x100/ R_A$

(4) If any of the calculated percentage deviation, PD1, PD2 or PD3 is more than 5 %, repeat the measure from step (1) again with the test spike located further away from the earth electrode under test.

(5) If any of the calculated percentage deviation, PD1, PD2 or PD3 is 5 % or less, then R_A will be taken as the resistance of the earth electrode.

For an installation which form part of TT-system and using Residual Current Devices as an automatic disconnection device, there must be sufficient earth fault current to be detected by the RCD for it to disconnect the supply within the required time duration. The earth fault current is inversely proportional to the line-earth-loop impedance, Z_s.

Residual Operating Current, $I_{\Delta n}$



As the resistance of the earth electrode, R_A is much greater than that of other constituent parts of the Z_s, the measured earth electrode resistance, R_A may be taken as Z_s, then

$$I_{\Delta n} Z_s \leq 50 \text{ Volts}$$

Or $$I_{\Delta n} R_A \leq 50 \text{ Volts}$$

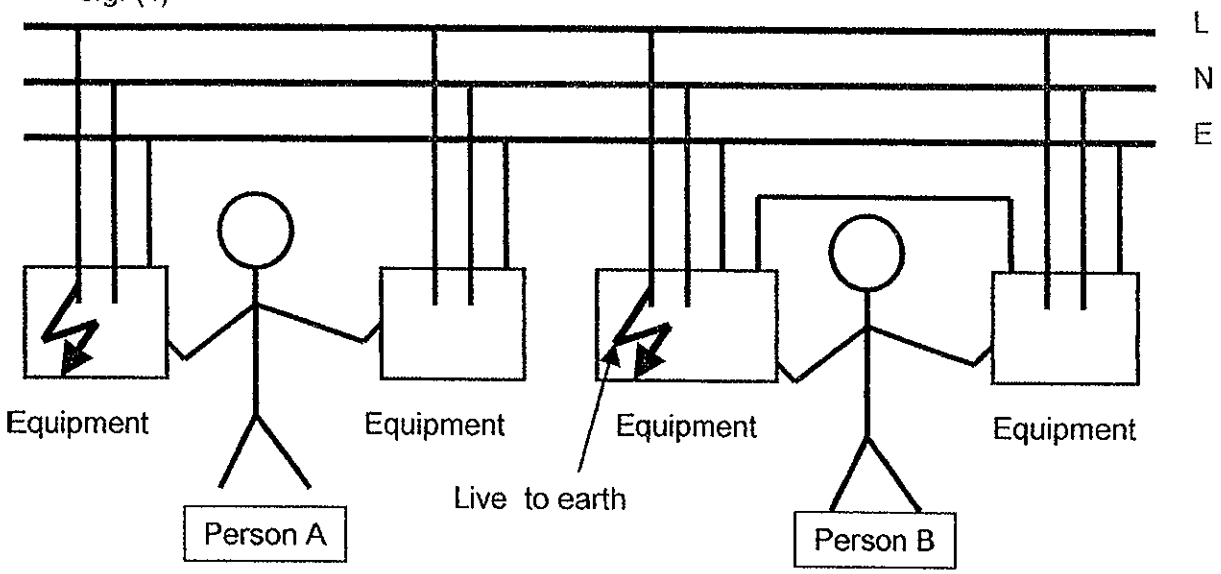
Note: The measurement of Z_s is carried out by using an Earth Loop Impedance Tester with all the main equipotential bonding conductors disconnected from the main earthing terminal.

6 Equipotential Bonding

Equipotential bonding is for the purpose of equalising the potential difference between any two simultaneously accessible exposed conductive parts, extraneous conductive parts or exposed and extraneous conductive parts.

Equipotential is done by using a suitable size of conductor connecting the two conductive parts together.

e.g. (1)

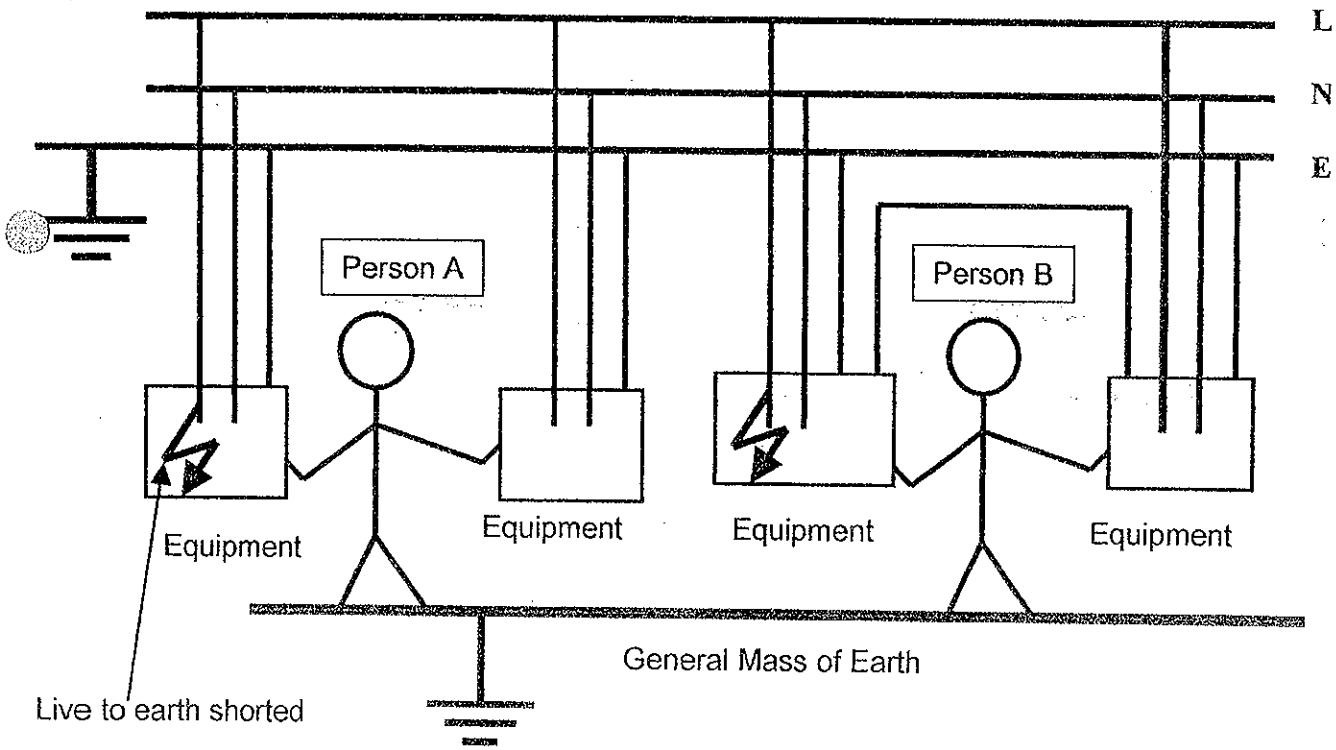


In the above diagram, equipment A, B, C and D are the same type of equipment and they are installed and operate in the same manner. The live is shorted to the metallic frame of equipment A and C, the feet of the 2 person does not has direct contact with earth.

(1) Which person is likely to receive a higher degree of electrical shock?

(2) If a person is likely to receive a lesser degree of electrical shock, Why?

e.g. (2)

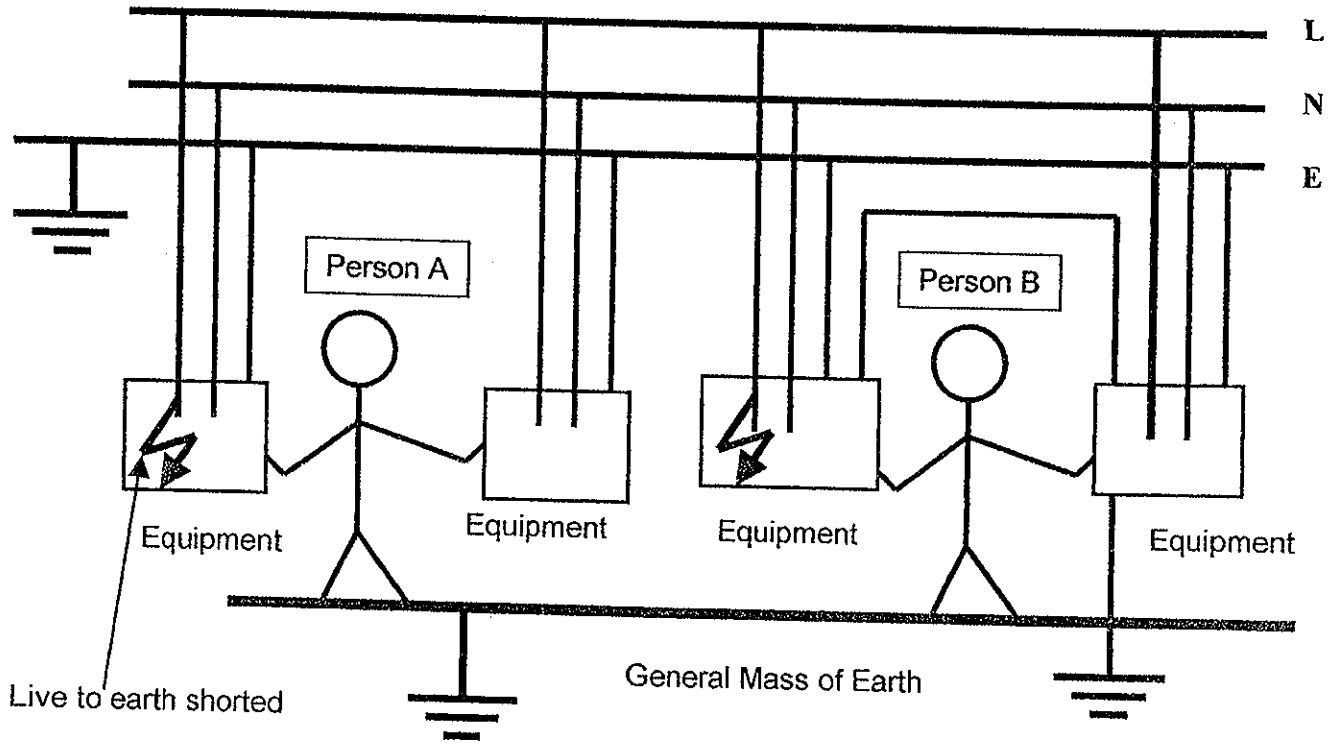


In the above diagram, equipment A, B, C and D are the same type of equipment and they are installed and operate in the same manner. The live is shorted to the frame of equipment A and C, the feet of the 2 persons is standing on general mass of earth.

(1) Which person is likely to receive a higher degree of electrical shock?

(2) If one of a person is likely to receive a lesser degree of electrical shock, Why?

e.g. (3)



All the condition are the same as e.g. (2), except that the metallic frame of equipment D is connected to an earth electrode which is located next to the person B.

(i) For person A, list the situation (in term of the example No.) in the decreasing order of electrical shock.

(ii) For person B, list the situation (in term of the example No.) in the decreasing order of electrical shock.

EQUIPOTENTIAL BONDING IN AN ELECTRICAL INSTALLATION

1 Introduction

In the Singapore Standard Code of Practice for Electrical Installation CP5, one of the methods for protection against Indirect Contact is called **Earthed Equipotential Bonding and Automatic Disconnection of Supply**.

The meaning of Indirect Contact is referred to an electric shock received from the exposed conductive part or metallic enclosure of electrical equipment. This exposed conductive part is not charged at an electric potential with respect to the earth under normal operation of the equipment. However, when there is fault developed in the equipment, then the exposed conductive part or the metallic enclosure of the electrical equipment may charge to a potential of 230V with respect to earth. For example, if there is an internal short circuit between the live part and the metallic enclosure of the heating element of the electric water kettle, then the metallic casing of the whole kettle will be charged to 230V. Hence any person standing on the ground and with the both feet come in contact with the ground and the hand touching the metallic casing of the electric water kettle, the person will receive a touch voltage of 230V and hence experience an electric shock which may be fatal. An illustration is shown in Fig (1).

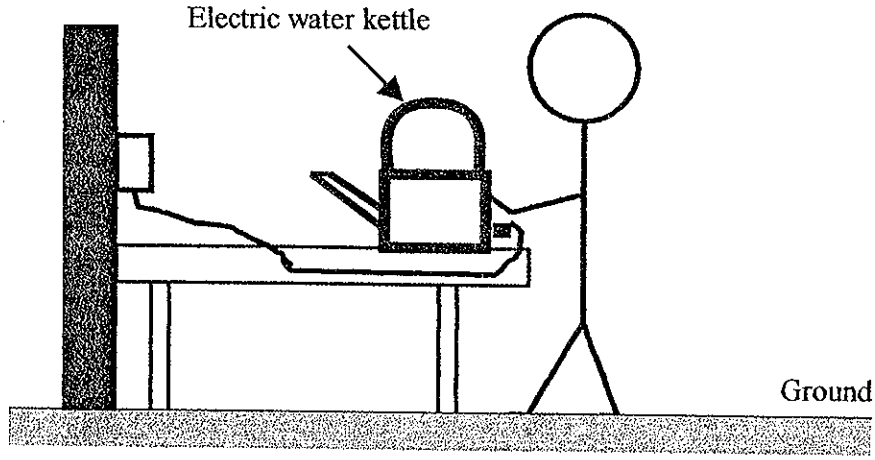


Fig (1) Illustration of an electric shock due to indirect contact

If there is a way to charge the ground to a potential of 230V when there is a fault develop in the electric water kettle, then the person will receive a potential of 230V at the hand and the feet at the same time. The potential at the hand minus the potential at the feet will give a zero potential difference between the hand and feet and the person will not experience an electric shock.

Equipotential bonding can achieve nearly zero potential difference between any two exposed conductive parts.

2 Equipotential Bonding

Equipotential can be achieved by using a conductor called equipotential bonding conductor of suitable size to connect two physically isolated conductive parts together as illustrated in Fig (2b) and Fig (3b).

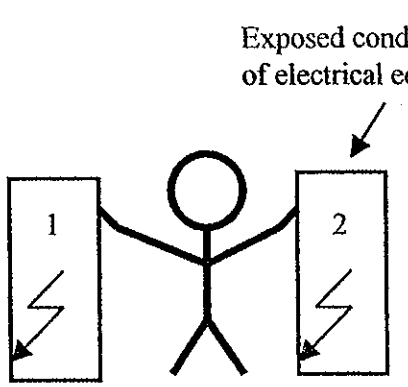


Fig (2a) Electric shock due to potential difference across both hands

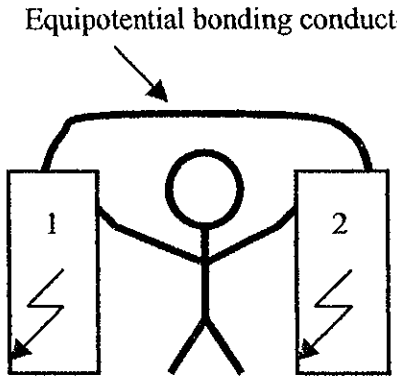
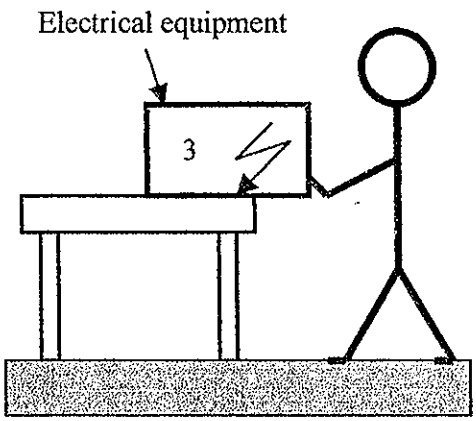


Fig (2b) No potential difference across both hands. No electric shock.



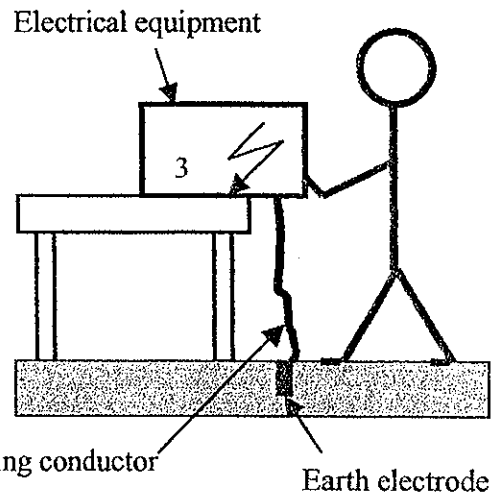


Fig. (3a) Electric shock due to potential difference across both hand and feet.

Fig. (3b) No Potential difference across both hand and feet. No electric shock.

In Fig (2b) the equipotential bonding conductor will make the exposed conductive parts of equipment 1 and 2 having the same potential rise at the same time for any single equipment or both equipment develop an internal earth fault. Similarly, the exposed conductive part of equipment 3 and the ground where the person is standing nearby are having the same potential rise due to the equipotential bonding conductor.

3 Extraneous Conductive Parts in a Building

Any conductive part, which is in contact with the general mass of the earth, is called extraneous conductive part. One pole of the low voltage supply source needs to be connected to earth for a conventional supply system. Therefore the general mass of earth is connected to one pole of the supply source, hence any extraneous conductive part which is in contact with the earth and presence in the building shall be associated with the pole of the supply source. The extraneous conductive parts of the building are water pipes, gas pipes, sewage pipes and exposed metallic structure of building and etc.

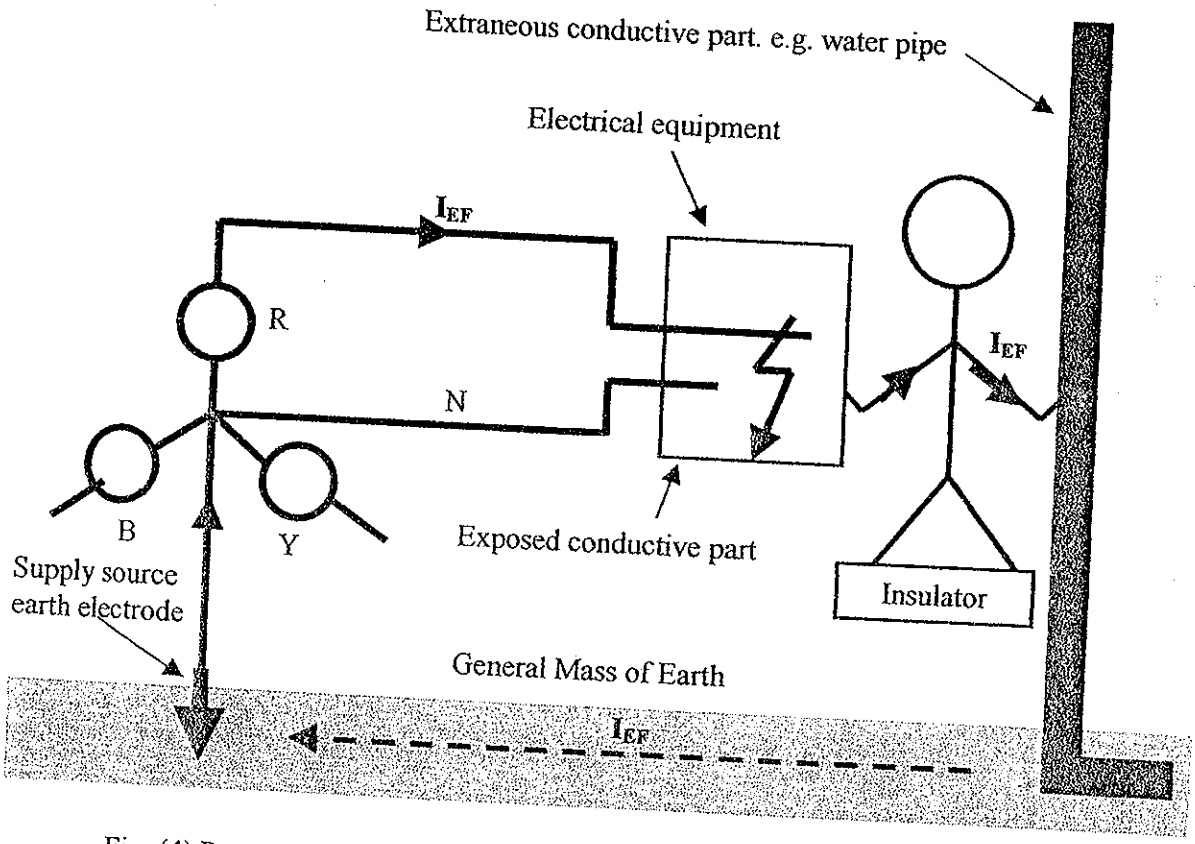


Fig. (4) Potential difference received by a person in an electrical installation

In fig. (4), the live part of the electrical equipment is shorted to its exposed conductive part and hence the exposed conductive part will rise to a potential of 230V with respect to the general mass of the earth. The person will receive a potential difference of 230V between the two hands and experience an electric shock. The earth fault current will flow to the supply source via the person's body, extraneous conductive part and the general mass of the earth. The magnitude of the earth fault current shall be mainly depended on the body impedance between hand to hand of the person.

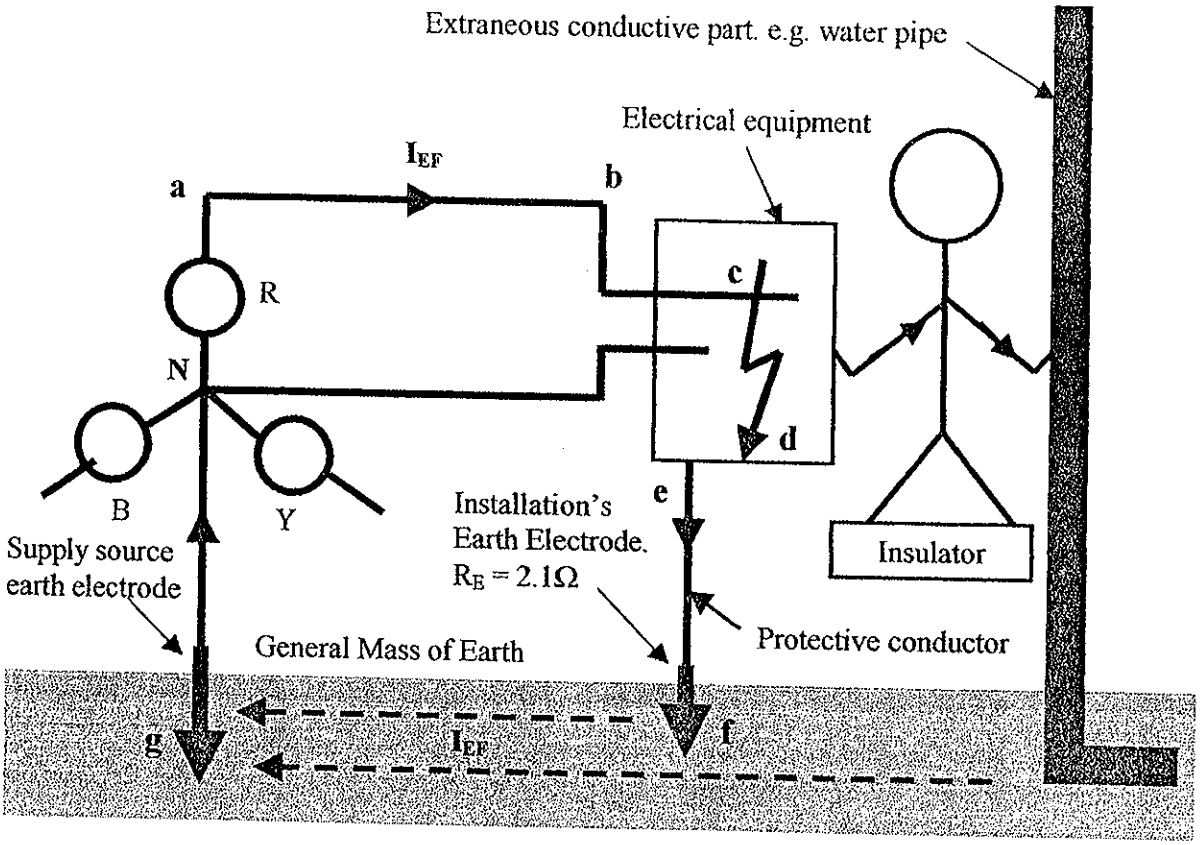


Fig. (5) Potential difference received by a person in an electrical installation

In fig (5), an installation's earth electrode is sunk in the general mass of earth and connected to the exposed conductive part of the electrical equipment so that the earth fault current, I_{EF}, can be flow back to the supply source via the installation's earth electrode and the general mass of the earth. However, there shall be resistance between the installation's earth electrode and the general mass of earth and this is called the earth electrode resistance. The earth fault current flows through a closed loop abcdefgNa, and the impedance formed by the impedance of the circuit conductors and earth electrode resistance around this closed loop is called Earth Fault Loop Impedance, Z_S.

Assuming the earth electrode resistance, R_E= 2.1 Ohm and the earth fault loop impedance, Z_S= 2.3 Ohm and the resistance of the protective conductor is negligibly small compared with the installation's earth electrode. Further assume that earth electrode resistance of the supply source earth electrode is zero. For a supply phase voltage V_{ph}= 230V, the potential difference received by the both hands of the person will be calculated as follow:

Earth fault current, $I_{EF} = (V_{ph} / Z_S) = 230/2.3 = 100$ A

Received Potential difference, $V_{pd} = I_{EF} \times R_E = 100 \times 2.1 = 210$ V

The person shall experience an electric shock based on the potential difference of 210V.

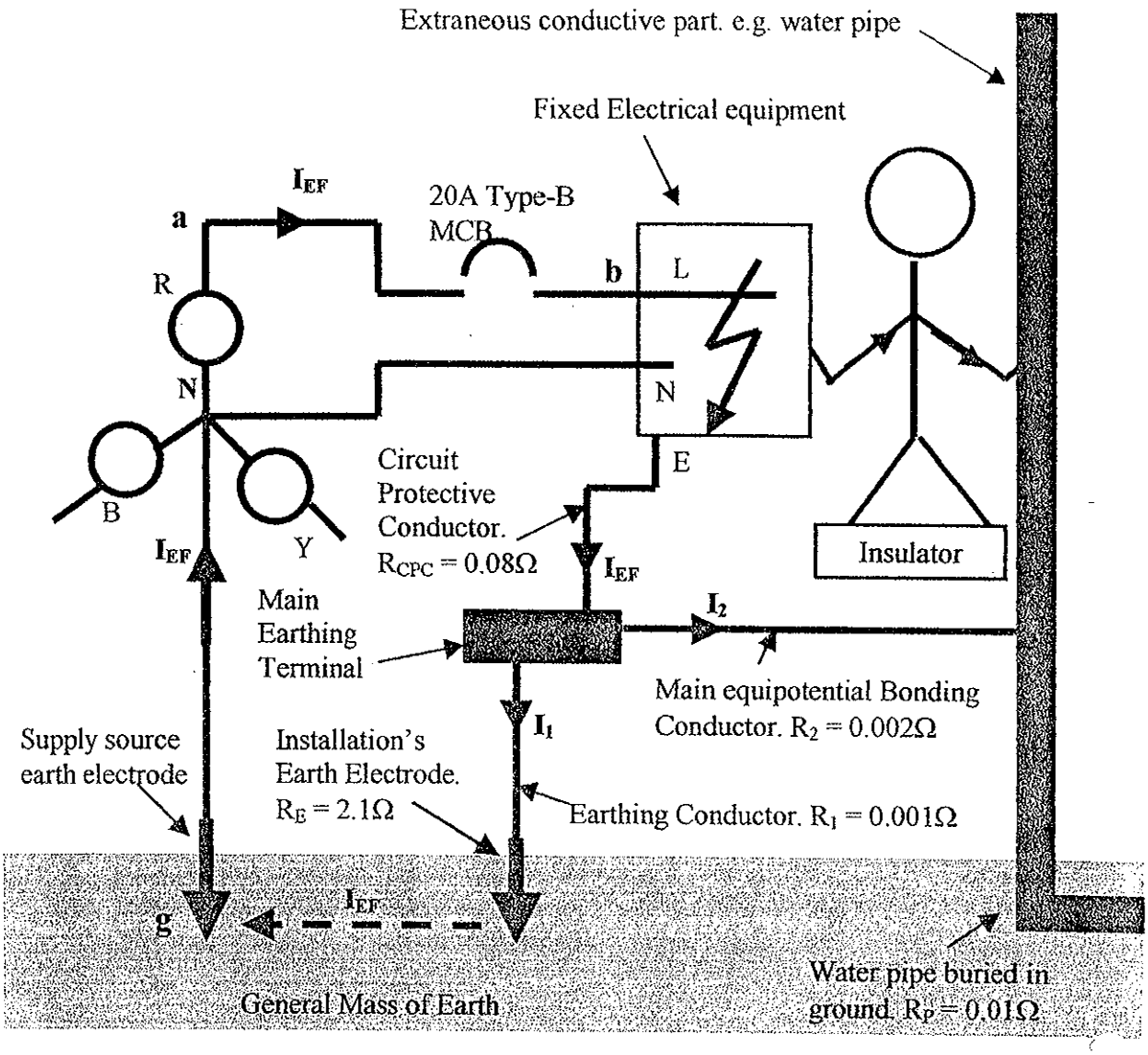


Fig. (6) Electrical installation with TT-Earthing System

Fig. (6) is similar to Fig. (5), except that a Main Earth Terminal and a Main Equipotential Bonding Conductor is added to the electrical installation in Fig. (6). Furthermore, the protective conductor as indicated in Fig. (5) is represented by circuit protective conductor and earthing conductor as shown in Fig. (6).

The resistance of the path gab shall be calculated first based on Fig. (5) before calculation of the earth fault loop impedance based on Fig. (6).

As the Z_S = (Resistance of the path gab of the supply source) + R_{CPC} + R_1 + R_E = 2.3 Ω

(Resistance of the path gab of the supply source) = $Z_S - R_{CPC} - R_1 - R_E$
= 2.3 - 0.08 – 0.001 – 2.1
= 0.119 Ω

The resistance of ($R_1 + R_E$) are in parallel with ($R_2 + R_P$), their effective resistance is R_T.

$1/R_T = 1/(R_1 + R_E) + 1/(R_2 + R_P)$

$1/R_T = 1/(0.001 + 2.1) + 1/(0.002 + 0.01)$

$1/R_T = 1/(2.101) + 1/(0.012)$

$1/R_T = 0.4760 + 83.3333$

$1/R_T = 83.8093$

$R_T = 0.0119\ \Omega$

The earth fault loop impedance for Fig. (6) is Z_S'.

Z_S' = (Resistance of the path gab of the supply source) + $R_{CPC} + R_T$

$Z_S' = 0.119 + 0.08 + 0.0119$
$= 0.2109\ \Omega$

The earth fault current in Fig. (6), $I_{EF} = V_{PH} / Z_S' = (230/0.2109) = 1090A$

The potential rise at the main earth terminal, $V_{ET} = I_{EF} R_T$
= 1090 x 0.0119
= 12.97 V

The current flows in the main equipotential bondng conductor, $I_2 = V_{ET} / (R_2 + R_P)$
= 12.97/(0.002 + 0.01)
= 1081 A

The voltage drop across the equipotential bonding conductor, $V_{BC} = I_2 R_2$
= 1081 x 0.002
= 2.16 V

The voltage drop across the circuit protective conductor, $V_{CPC} = I_{EF} R_{CPC}$
= 1090 x 0.08
=87.2V

The potential difference across the two hand, $V_{PD} = V_{CPC} + V_{BC}$
= 87.2 + 2.16
= 89.36 V

Hence, the person shall experience an electric shock based on 89.36V with the presence of the main equipotential bonding conductor for the same installation. This is 57.45% lower than the potential difference of 210V as describe in paragraph 3.

5 Magnitude of Potential Difference Dependent on Parameter

The parameters which can be varied are R_{CPC} , R_1 , R_2 , R_E and R_P in general

Let the earth resistance of the water pipe increases to $R_P = 1\ \Omega$. After going through the calculation in paragrapg 4, the value of $R_T = 0.6784\Omega$, $Z_S = 0.8774\Omega$, $I_{EF} = 262A$, $V_{ET} = 177.74V$, $I_2 = 177.39A$, $V_{BC} = 0.35V$, $V_{CPC} = 20.96V$ and $\mathbf{V_{PD} = 21.35V}$.

6 Conclusion

Equipotential bonding can be used to reduce the magnitude of the potential difference occurring everywhere in an electrical installation.

Usually, the parameter R_E and R_P are difficult to control in practice as they are affected by the property of the general mass of the earth where the earth electrode and water pipe are laid within. The magnitude of the potential difference is mainly due to the voltage drop across the circuit protective conductor in the presence of the main equipotential bonding conductor.

In clause 413-02-12 of CP5: 1998, for a final circuit which supplies a socket outlet or portable equipment, the disconnection time of the automatic disconnection device is allowed to extend up to 5 seconds maximum provided the maximum voltage drop across the circuit protective conductor is limited to 50 volts. So as to comply with clause 413-02-04L which state that:

"The characteristics of each protective device for automatic disconnection, the earthing arrangements for the installation and the relevant impedance of the circuit concerned shall be coordinated so that during an earth fault the voltages between simultaneously accessible exposed- and extraneous-conductive-parts occurring anywhere in the installation shall be of such magnitude and duration as not to cause danger."

SINGAPORE STANDARD CP5: 1998

PROTECTION AGAINST ELECTRIC SHOCK

1 Effect of Current Passing Through the Human Body (IEC 479-1)

For a given current path through the human body, the **danger** to persons depends mainly on the **magnitude** and **duration** of the current flow.

1.1 Admissible Limit of Touch Voltage

ALTV as a function of time is a criterion in practice for designing protection against electric shock.

ALTV = I x Z_T ..... Note: Z_T **is non-linear**

Where I = Current through the body.

Z_T = Body impedance.

1.2 Total Impedance of Human Body, Z_T

Total body impedance Z_T for a current path hand to hand a.c. 50/60 Hz, for **large surface** areas of contact (5000mm^2 to 10000mm^2) and **dry condition**

Touch Voltage V	Values for the total body impedance (Ω) that are not exceeded for a percentage (percentile rank) of		
	5% of the population	50% of the population	95% of the population
25	1,750	3,250	6,100
50	1,450	2,625	4,375
75	1,250	2,200	3,500
100	1,200	1,875	3,200
125	1,125	1,625	2,875
220	**1,000**	**1,350**	**2,125**
700	750	1,100	1,550
1000	700	1,050	1,500
Asymptotic value	650	750	850

Note: Some measurements indicate that the total body impedance for the current path hand to foot is somewhat lower than for a current path hand to hand (10% to 30%)

2.0 Effects of Alternating Current in the Range of 15 Hz to 100 Hz

2.1 Threshold of Perception

The minimum value of current which causes any sensation for the person through which it is following. e.g. 0.5mA independent of time.

Depends on contact area, dry, wet, pressure, temperature and physiological characteristic of the individual.

2.2 Threshold of Let-go

The maximum value of current at which a person holding electrodes can let go of the electrodes. e.g. 10mA.

Depends on contact area, the shape and size of the electrodes, and physiological characteristic of individual.

2.3 Threshold of Ventricular Fibrillation

The minimum value of current which causes "ventricular fibrillation". (Main cause of death)

Depends on physiological parameters (anatomy of the body, state of cardiac function etc.) and electrical parameters (duration of current flow, kind of current etc.)

For shock duration < 0.1s, fibrillation may occur for current > 500mA and is likely to occur for current magnitudes in the order of several amperes.

In fig.14, curve c_1 was established for a current path left hand to both feet, below which fibrillation is unlikely (!!??) to occur.

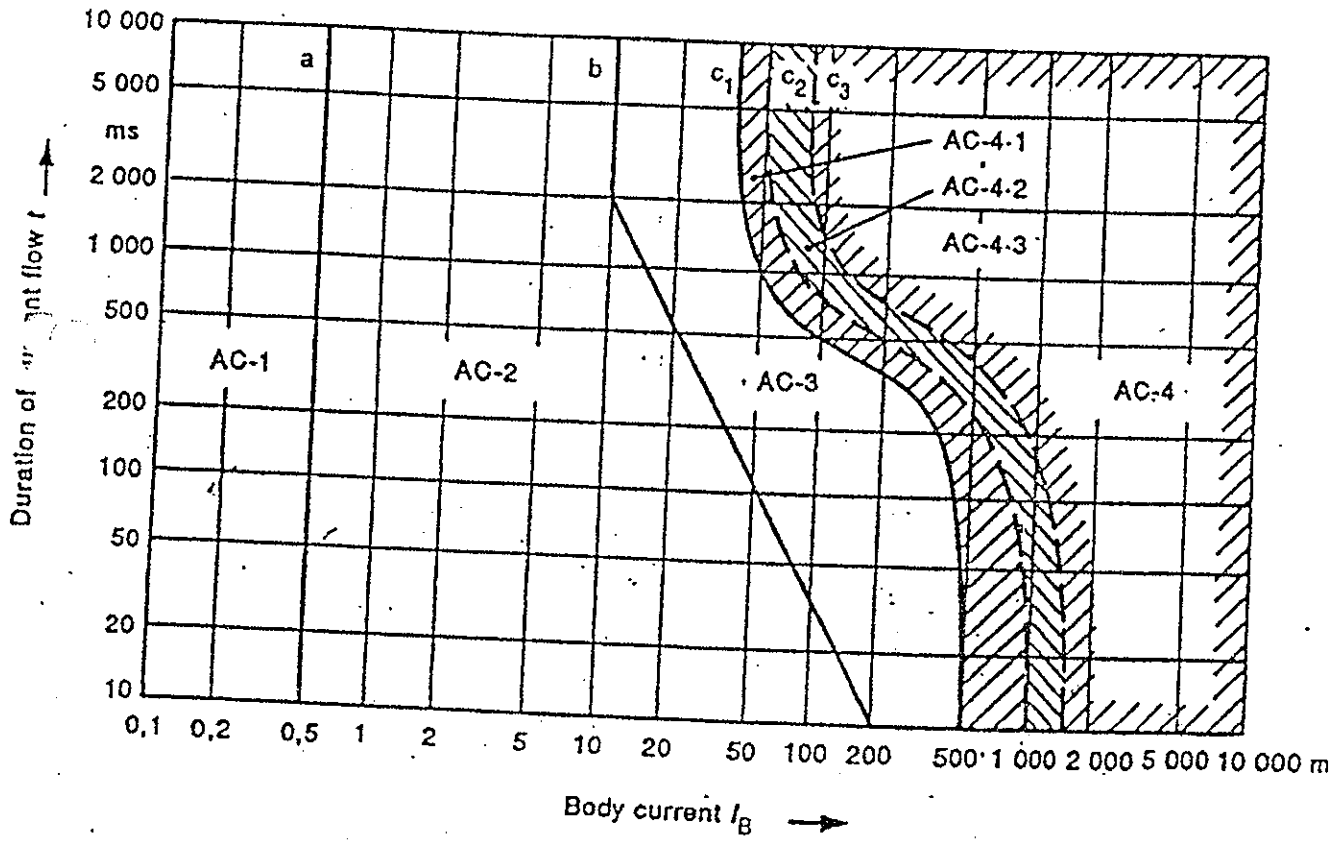
3.0 Definition of Terms in CP5:1998

3.1 "Direct Contact"
Contact of persons or livestock with live parts.

3.2 "Indirect Contact"
Contact of persons or livestock with exposed-conductive-parts which have become live under fault conditions.

3.3 "Exposed-conductive-parts"
A conductive part of equipment which can be touched and which is not a live part but which may become live under fault conditions.

3.4 "Extraneous-conductive-parts"
A conductive part liable to introduce a potential, generally earth potential, and not forming part of the electrical installation.



NC As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to both feet. For other current paths, see 3.6 and table 5. The threshold values for durations of current flow below 0,2 s apply only to current flowing during the vulnerable period of the cardiac cycle.

Figure 14 – Time/current zones of effects of a.c. currents 15 Hz to 100 Hz
(For explanations, see table 4)

3.5 "Arms reach"

A zone of accessibility to touch, extending from any point on a surface where persons usually stand or move to the limits which a person can reach with a hand in any direction without assistance.

This zone of accessibility is illustrated by the following figure in which the values refer to bare hands without any assistance, e.g. from tools or a ladder.

3.6 "Main Earthing Terminal"

The terminal or bar provided for the connection of protective conductors, including equipotential bonding conductors, and conductors for functional earthing, if any, to the means of earthing.

3.7 "Functional earthing"

Connection to Earth necessary for proper functioning of electrical equipments.

3.8 "Earth"

The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

3.9 "Earth electrode"

A conductor or group of conductors in intimate contact with, and providing an electrical connection to, Earth.

3.10 "Earthing conductor"

A protective conductor connecting the main earthing terminal of an installation to an earth electrode or to other means of earthing.

3.11 "Protective conductor"

A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts.

(i) exposed-conductive parts.
(ii) extraneous-conductive parts.
(iii) the main earthing terminal.
(iv) earth electrode(s).
(v) the earthed point of the source, or an artificial neutral.

3.12 "Earthing"

Connection of the exposed-conductive-parts of an installation to the main earthing-terminal of that installation.

3.13 "Earth fault current"

A fault current which flows to Earth.

3.14 "Earth leakage current"

A current which flows to Earth, or to extraneous-conductive parts, in a circuit which is electrically sound. This current may have a capacitive component including that resulting from the deliberate use of capacitors.

3.15 "Earthed equipotential bonding"

A zone within which exposed-conductive-parts and extraneous-conductive-parts are maintained at substantially the same potential by bonding, such that under fault conditions, the differences in potential between simultaneously accessible exposed- and extraneous-conductive-parts will not cause electric shock.

3.16 "Equipotential bonding"

Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential.

3.17 "Extra low voltage"

Normally not exceeding 50 V a.c. rms or 120 V ripple free d.c., whether between conductors or to Earth.

3.18 "SELV (separated extra-low voltage)"

An extra-low voltage system which is electrically separated from Earth and from other systems in such a way that a single fault cannot give rise to the risk of electric shock.

3.19 "PELV (Protective extra-low voltage)"

An extra-low voltage system which is not electrically separated from earth, but which otherwise specified in the Code.

3.20 "Functional extra-low voltage (FELV)"

An extra-low voltage in which not all of the protective measures required for SELV or PELV have been applied.

3.21 "Class I equipment (L)"

Equipment in which protection against electric shock does not rely on basic insulation only, but which includes means for the connection of exposed-conductive-parts to a protective conductor in the fixed wiring of the installation (see IEC 536 or BS 2754).

3.22 "Class II equipment"

Equipment in which protection against electric shock dose not rely on basic insulation only, but in which additional safety precautions such as supplementary insulation are provided, there being no provision for the connection of exposed metal work of the equipment to a protective conductor, and no reliance upon precautions to be taken in the fixed wiring of the installation (see IEC 536 or BS 2754).

4.0 Protective Measure for Protection Against Both Direct and Indirect Contact

(1) SELV.
(2) Limitation of discharge of energy.

Prohibition: Cannot use "Functional Extra-low Voltage" **alone**.

4.1 Requirement for SELV

(1) Nominal voltage ≤ extra-low voltage.

(2) Supply shall be any of the follow:

- (i) Safety isolating transformer, IEC 742.
- (ii) Motor-generator, electrical separation same as safety isolating transformer.
- (iii) Electrochemical source / engine driven generator.
- (iv) certain electronic devices.

(3) Prohibition to the use of equipment with lesser degree of electrical separation. e.g. auto-transformer, potentiometer and semiconductor device.

(4) Selection & erection of Mobile source: requirement = "Class II Equipment" or "By Equivalent Insulation".

(5) Live part of SELV system **shall**

(i) **be electrically separated** from other higher voltage system.
(ii) **Not be connected** to **Earth**, **protective conductor** or **live part** of another system.

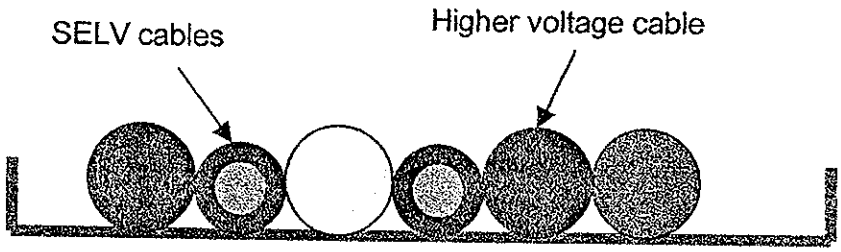
(6) Circuit conductors of SELV shall be

(i) Physically separated from those of any other system.



or

(ii) Insulated for the highest voltage present.

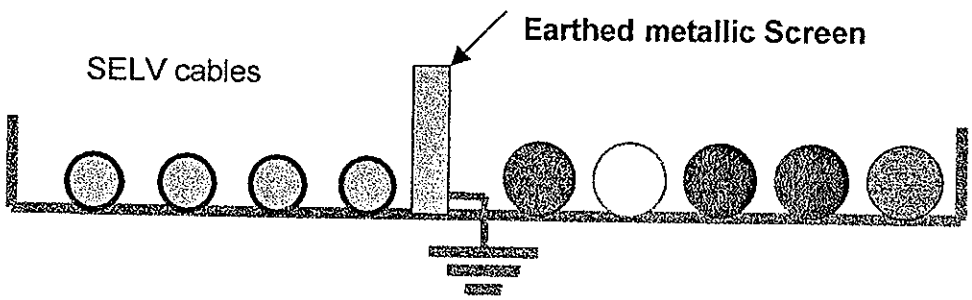


or

(iii) of **non-metallic** sheathed cables. Or

or

(iv) separated from the conductors of higher voltage system by the use of **earthed metallic screen**. Or



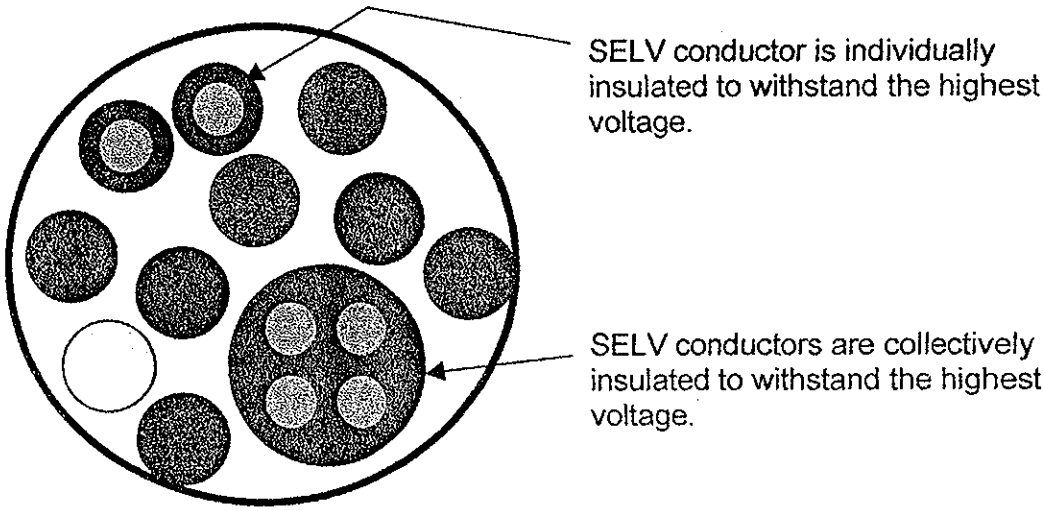
or

(v) separated from the **"conductors of higher voltage system with earthed metallic sheath"**.



or

(vi) For multicore cable

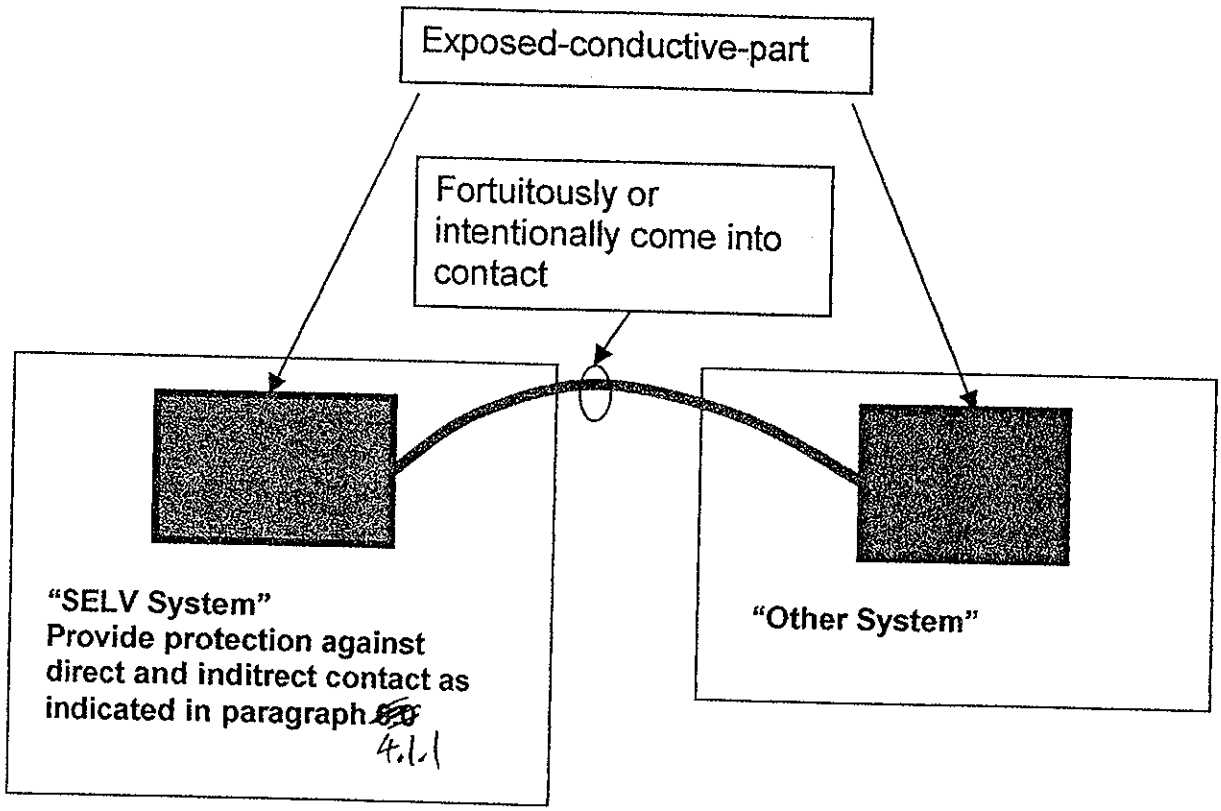


(7) Exposed conductive-part of SELV system shall not be connected to

(i) Earth.
(ii) an exposed conductive-part of another system. [refer to item(8) below]
(iii) a protective conductor of another system.
(iv) An extraneous-conductive-parts.
(precaution below)

Precaution: If the exposed conductive-part of SELV equipment is connected to extraneous-conductive-part, measure shall be incorporated so that the parts cannot attain a voltage exceeding Extra Low Voltage.

(8) Precaution to be taken:



(9) Socket-outlet and plug for use in SELV system:

(i) no protective conductor contact.
(ii) not interchangeable with those used for any other system in use in the same premises.

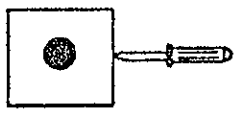
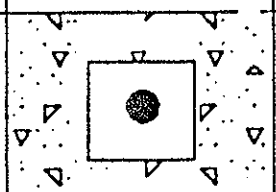
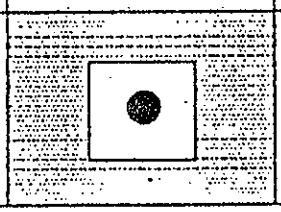
(10) Cannot use luminaire support coupler having a protective conductor contact.

(11) Only for SELV system with nominal voltage > 25V a.c. r.m.s. or 60V ripple-free d.c., provide protection against direct contact as follow:

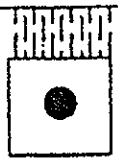
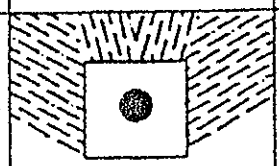
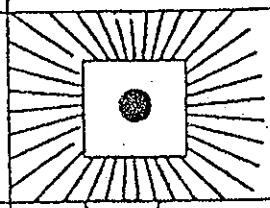
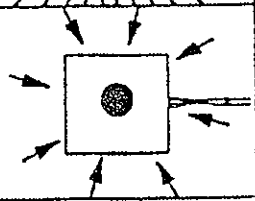
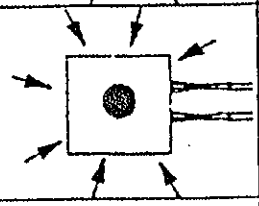
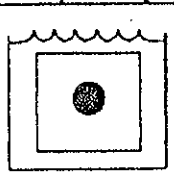
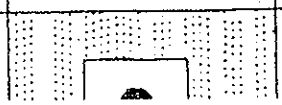
(i) a barrier or an enclosure to IP2X or IPXXB, **and/or**
(ii) insulation, to withstand a test voltage of 500V for 60 seconds.

DEGREES OF PROTECTION PROVIDED BY ENCLOSURES

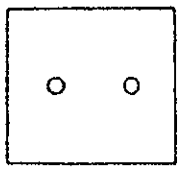
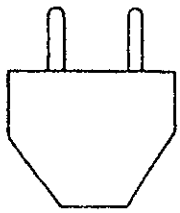
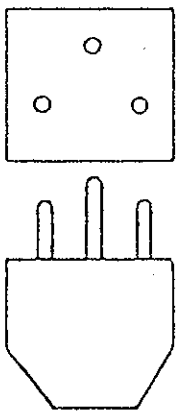
(IP CODES) Tests according to EN60529

	TEST	Protection
X	No Tests	None
0	No Tests	Some protection available
1		Protection against solid bodies greater than 50mm.
2		Protection against solid bodies greater than 12.5mm
3		Protection against solid bodies greater than 2.5mm.
4		Protection against solid bodies greater than 1mm.
5		Protection against dust (no harmful deposits)
6		Total protection against dust

IP 54

	TEST	Protection
X	No Tests	None
0	No Tests	Some protection available
1		Protection against vertical drops of water (condensation)
2		Protection against drops of water falling up to 15° from vertical
3		Protection against rainwater up to 60° from vertical
4		Protection against water projected from all directions
5		Protection against hosing with water from all directions
6		Protection against swamping with water
7		Protection against the effects of immersion
		Protection against the effects of

Schedule 2.4 – Plugs and sockets for SELV circuits

Equipment	Installation	Requirement
Sockets		Plugs from other voltage systems in use in the same premises shall be excluded from use in SELV socket Protective conductors shall not be provided except as detailed below
Plugs		Shall not be able to enter socket outlets of other voltage systems in use in the same premises.
Sockets and plugs for particular compliance	 Where protective conductor required	Where compliance with the Electricity (Factories Act) Special Regulations 1908 and 1944 is required. Two pin plugs and sockets must be connected to equipment having Class II insulation with double or reinforced insulation or a factory built assembly having total insulation to BS5486 or supplementary or reinforced insulation as a process of its erection. Where Class II insulation is not provided a protective conductor is required. Such socket must not receive a plug from another voltage system and such a plug must be excluded from socket outlets of other voltage systems.

4.1.1 Requirement for Extra-low Voltage System Other Than SELV (e.g. Functional Extra-low Voltage System and PELV System)

4.1.2 Requirement for PELV System

For Extra-low Voltage System which has an earthed point – provide protection against direct contact as follow (exception see note below):

(i) Barriers or enclosures to at least IP2X or IPXXB, **or**

(ii) Insulation – withstanding a test voltage of 500V d.c. for 60 seconds.

Note: Protection against direct contact as stipulated above is not required when all of the following conditions are complied:

(i) The equipment is located in a building in which "main equipotential bonding" is applied in accordance with Clause 413-02-02. **and**

(ii) The voltage does not exceed

(a) 25V a.c. r.m.s. or 60V ripple-free d.c., used in dry area, no large-area contact of live parts with human body. **Or**

(b) 6V a.c. r.m.s. or 15V ripple-free d.c. in all other cases.

4.1.3 Requirement for Functional Extra-low Voltage System

Applicable only if the Extra-low Voltage System does not comply with all the requirements of SELV in some respect other than that specified in paragraph ~~6.1~~ 4.1.2 above. All of the following Item (1), (2) and (3) must be complied.

(1) Provide protection against direct contact as follow:

(a) Fully comply with all the measures as stipulated for the method **"Protection By barrier or Enclosure" (412-03). and/or**

(b) **Insulation** corresponding to the minimum test volage required for the primary circuit. Otherwise, the **accessible insulation** of that equipment shall be reinforced during erection to withstand a test voltage of 1500V a.c. r.m.s. for 60 seconds.

(2) Provide protection against indirect contact as follow:

(a) **Primary circuit** of the FELV source is protected by **Automatic Disconnection,** exposed conductive-conductive-parts of equipment in the FELV system shall be connected to the **protective conductor** of the primary circuit. A conductor of the FELV system may be connected to the protective conductor of the primary circuit when necessary.

(b) **Primary circuit** of the FELV source is protected by **Electrical Separation,** exposed conductive-conductive-parts of equipment in the FELV system shall be connected to the **non-earthed protective conductor** of the primary circuit. A conductor of the FELV system may be connected to the protective conductor of the primary circuit and shall be deemed **not contravene Clause 413-06-04 and 413-06-05.**

(3) Every **socket-outlet** and luminaire support coupler in FELV system shall require the use of a **plug**, which is **not interchangeable** with those used for any other system in the same premises.

4.2 Protection By Limitation of Discharge of Energy

Comply with the two following requirement.

(1) Equipment complying with the appropriate approved standard which incorporates means of limiting the current which can pass through the body of a person or livestock to a value lower than that likely to cause danger.

(2) Live part of SELV system shall

(i) be electrically separated from other higher voltage system.

(ii) Not be connected to **Earth, protective conductor** or **live part** of another system.

(3) .Comply with paragraph 4.1 (6) of this note. (i.e. CP5:1998 Clause 411-02-06)

5.0 PROTECTIVE MEASURE FOR PROTECTION AGAINST DIRECT CONTACT

One or more of the following basic protective measures shall be used.

(1) Protection by **insulation of live parts.**
(2) Protection by **barrier or enclosure.**
(3) Protection by **obstacles.**
(4) Protection by **placing out of reach.**

Additional supplementary protection by residual current devices.

5.1 Protection By Insulation of Live Parts

The requirement are:

(i) Live parts shall be **completely covered** with insulation.
(ii) can only be removed by **destruction**.
(iii) can withstand the **electrical, mechanical, thermal and chemical stresses**.
(iv) Where insulation is applied during erection of the installation, the quality of the insulation shall be verified by tests equivalent to those specified in the SS or the IEC Publication or the BS for similar type-tested equipment.

5.2 Protection By Barrier and Enclosure

(1) Live parts shall be inside enclosures or behind barriers providing at least the degree of protection IP2X or IPXXB.

(2) Where an opening larger than that permitted for IP2X or IPXXB, both of the following requirements apply.

(i) suitable precautions to **prevent unintentional contact with live parts**, and
(ii) a person will be **aware** that live part can be touch through the opening and should not be touched. (e.g. lampho;der complying with SS 125 or other appropriate standard)

(3) **Horizontal top surface** which is readily accessible shall provide a degree of protection of at last **IP4X**.

(4) Every barrier and enclosure shall be **firmly secured** in place and have **sufficient stability** and **durability** to maintain the required degree of protection and appropriate separation from any live part in the known conditions of normal service.

(5) To remove a barrier or to open an enclosure or to remove a part of an enclosure, one or more of the following requirements shall be satisfied:

(i) by use of a key or tool. **and/or**
(ii) removal or opening shall be possible only after disconnection of the supply. **and/or**
(iii) restoration of the supply being possible only after replacement or reclosure of the barrier or enclosure. **and/or**
(iv) provision of intermediate barrier to IP2X or IPXXB and removable only by the use of a tool.

5.3 Protection By Obstacles

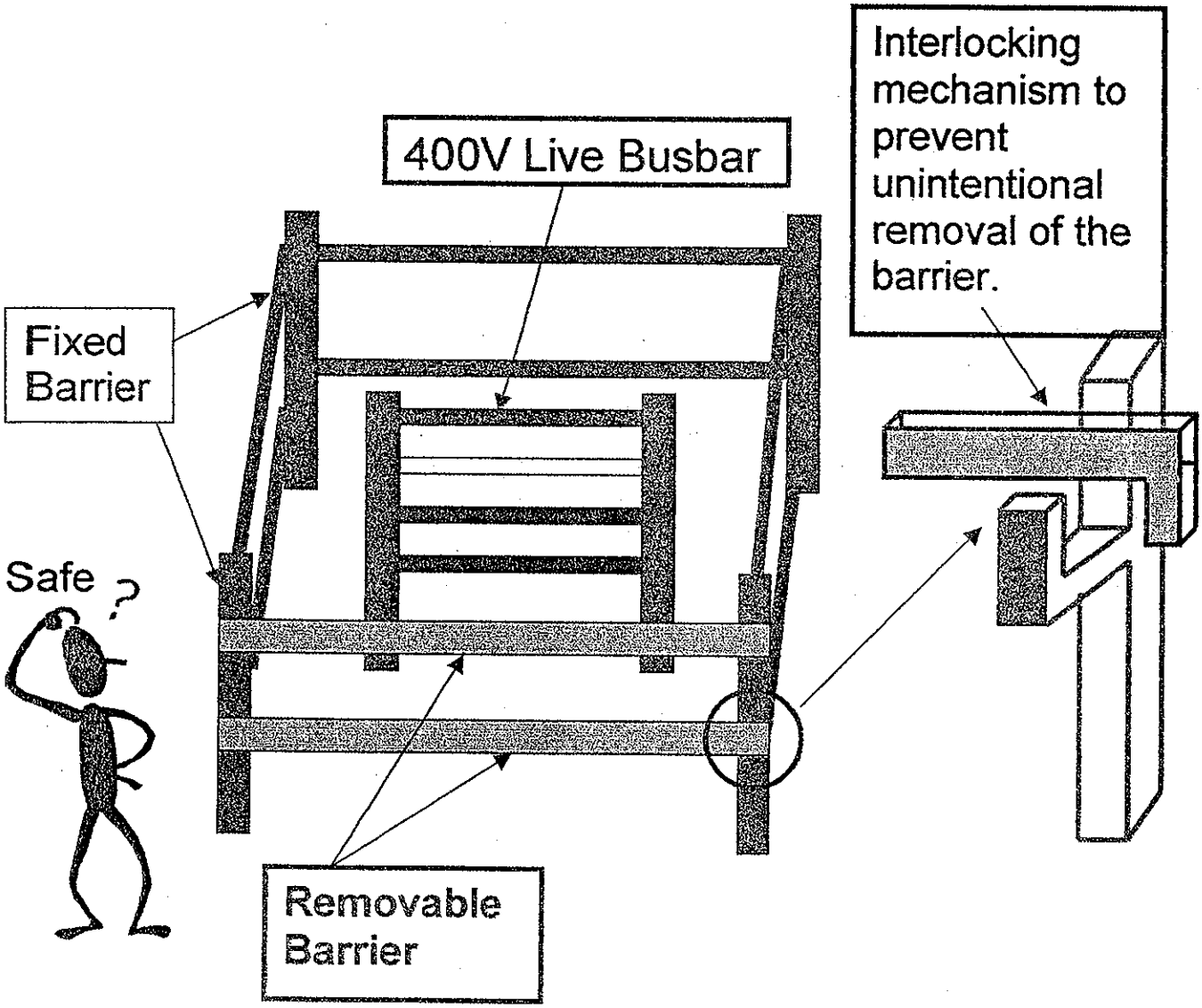
(1) An obstacle shall prevent, as appropriate, either of the following:

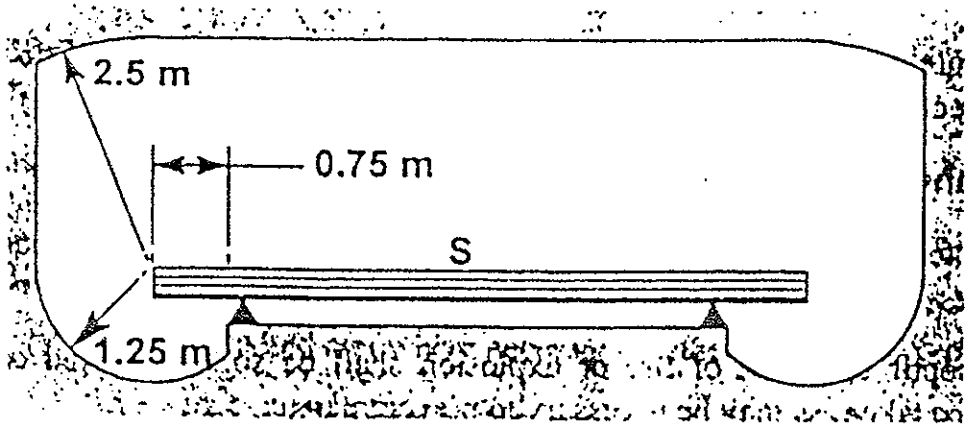
(i) unintentional bodily approach to a live part.
(ii) Unintentional contact with a live part.

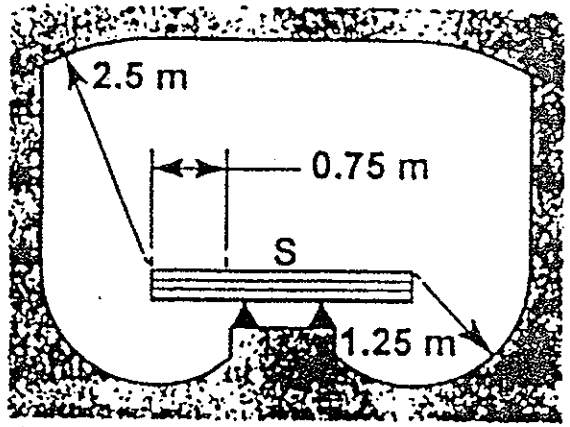
(3) so secured as to prevent unintentional removal.

(4) may be removable without using a key or tool.

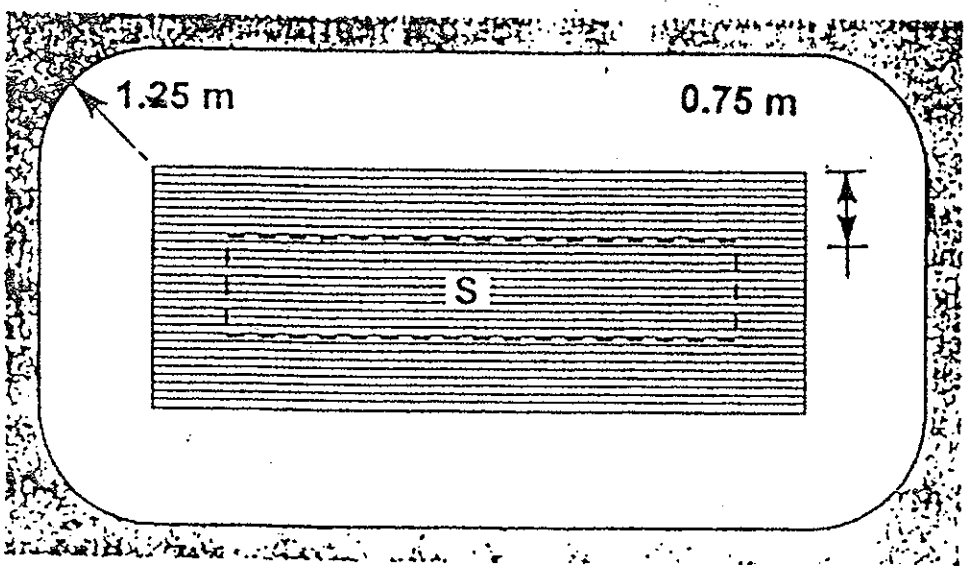
Below is an example to illustrate the use of fixed and removal barrier for a 400V LT board which comply with the CP5 for protection against direct contact.

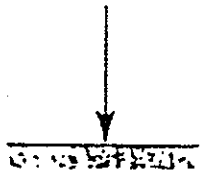






S = surface expected to be occupied by persons





limit of arm's reach

5.4 Protection By Placing Out of Reach

(1) Overhead lines for distribution between buildings and structure.

(i) use fully insulated line.
(ii) supported at suitable interval.
(iii) Suspended by catenary wires at a height ≥ 5 m from the ground at vehicular crossing place.

The following measures (2), (3) and (4) are applicable to location accessible only to **skilled persons**, or **instructed person under the direct supervision of a skilled person**.

For some installations and locations of increased shock risk this protective measure shall not be used.

(2) Bare live part shall not be within arm's reach or **2.5 m** of any of the following:

(i) an exposed-conductive-part.
(ii) an extraneous-conductive-part.
(iii) a bare live part of any other circuit.
(iv) In each place where any bulky or long conducting object is normally handled, the **distance shall be increased accordingly.**

(3) If access to live part from a normally occupied position is restricted in the horizontal plane by an obstacle (e.g. handrail, mesh, screen) affording a degree of protection less than IP2X or IPXXB, the extent of arm's reach shall be measured from that obstacle.

In each place where any bulky or long conducting object is normally handled, the **distance shall be increased accordingly.**

5.5 Supplementary Protection By Residual Current Devices

(1) Prohibit the use of RCD as the sole means of protection against direct contact. and

(2) RCD can be used in conjunction with any of the measures (para 5.1, 5.2, 5.3 & 5.4) for protection against direct contact. And

(3) RCD shall have tripping characteristic comply with SS 97 as follow:

(i) have a rated residual operating current ≤ **30 mA.**
(ii) Have an operating time ≤ **40 ms** at a residual current of 150 mA.

6.0 PROTECTION AGAINST INDIRECT CONTACT

There are 5 basic measure as shown below:

(1) protection by earthed equipotential bonding and automatic disconnection of supply.

(2) protection by Class II equipment or by equivalent insulation.

(3) Protection by non-conducting location.

(4) Protection by earth-free local equipotential bonding.

(5) Protection by electrical separation.

6.1 PROTECTION BY EARTHED EQUIPOTENTIAL BONDING AND AUTOMATIC DISCONNECTION OF SUPPLY

6.1.1 Requirements Applicable to TN-S System and TT System

(1) **Main equipotential bonding conductors** shall connect to the main earthing terminal for that installation extraneous-conductive-parts including the following:

(i) Water service pipes.

(ii) Gas installation pipes.

(iii) Other service pipes and ducting.

(iv) Central heating and air conditioning system.

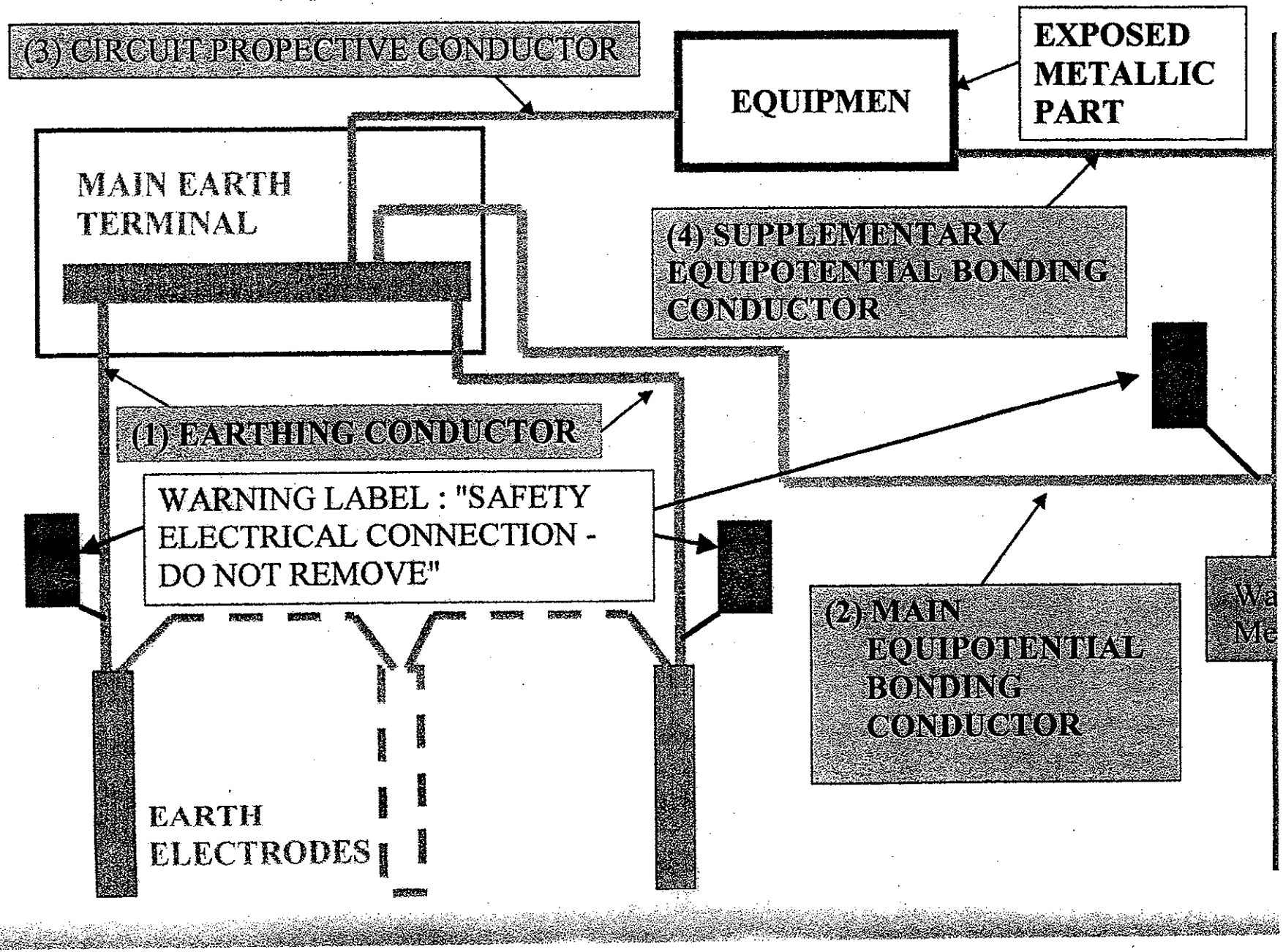
(v) Exposed metallic structural parts of the building.

(2) **Simultaneously accessible** exposed-conductive-part shall be connected to the same earthing system individually, in groups or collectively.

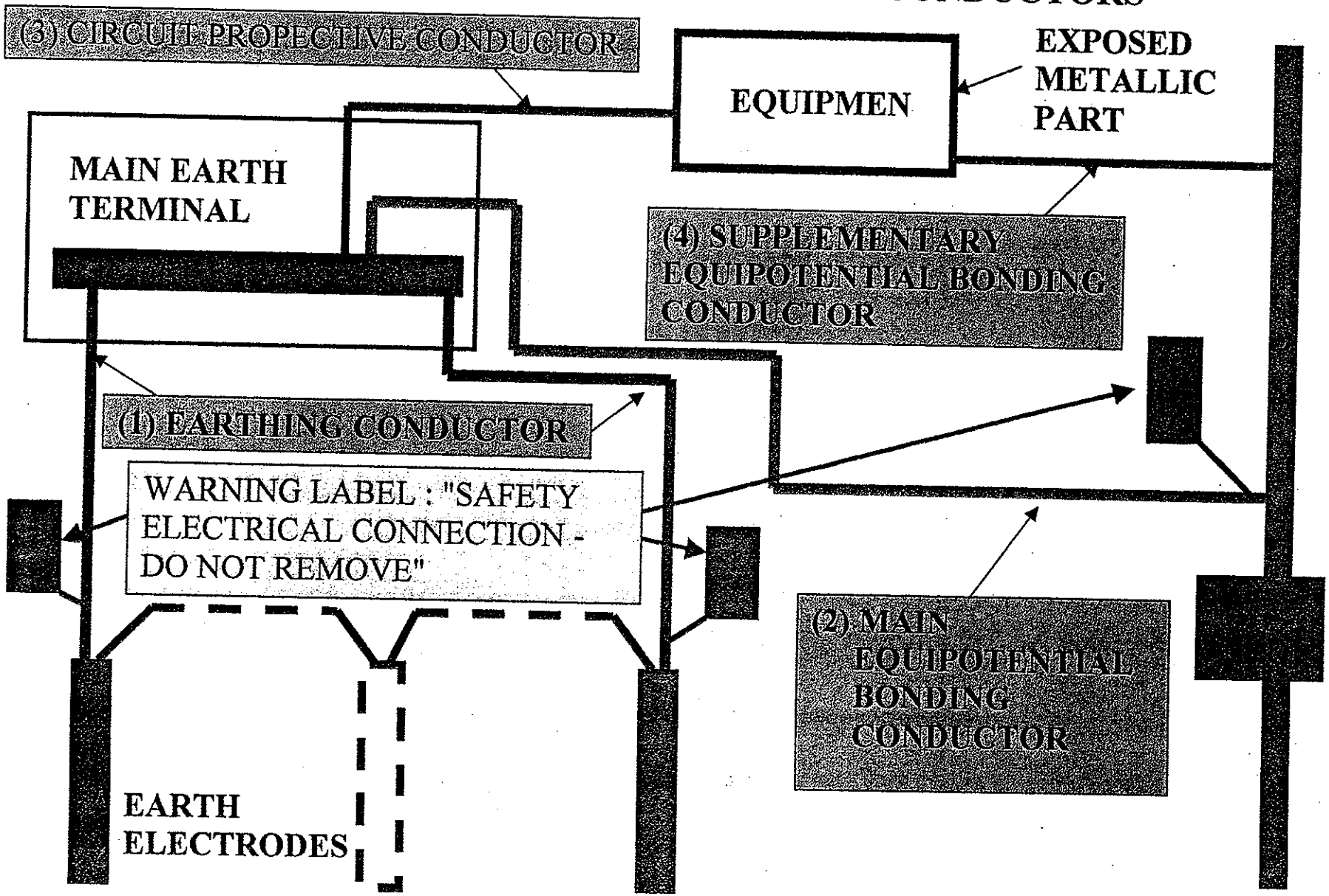
(3) The **characteristics** of each protective device for automatic disconnection, the **earthing arrangements** for the installation and relevant **impedance** of the circuit concerned shall be coordinated so that during an earth fault the **voltages** between simultaneously accessible exposed- and extraneous-conductive-parts occurring anywhere in the installation shall be of such **magnitude and duration** as not to cause danger.

(4) Account shall be taken of the increase of temperature and resistance of circuit conductors as a result of currents.

FOUR TYPES OF PROTECTIVE CONDUCTORS



WARNING LABE_ FOR PROTECTIVE CC..DUCTORS



6.1.2 Additional Requirements for TN-S System

(1) Each exposed-conductive-part (ecp) of the installation shall be connected by a protective conductor (pc) to the main earthing terminal (MET) of the installation and that terminal shall be connected to the earthed point of the supply source.

(2) One or more of the following types of protective device shall be used:

(i) an overcurrent protective device.

(ii) a residual current device.

(3) Always consider negligible impedance occurs between a phase conductor and pc or an ecp anywhere in the installation. Then

$$Z_s \leq U_0 / I_a$$

Where:

Z_s = earth fault loop impedance.
I_a = the current causing the automatic operation of the disconnecting protective device within the time required.

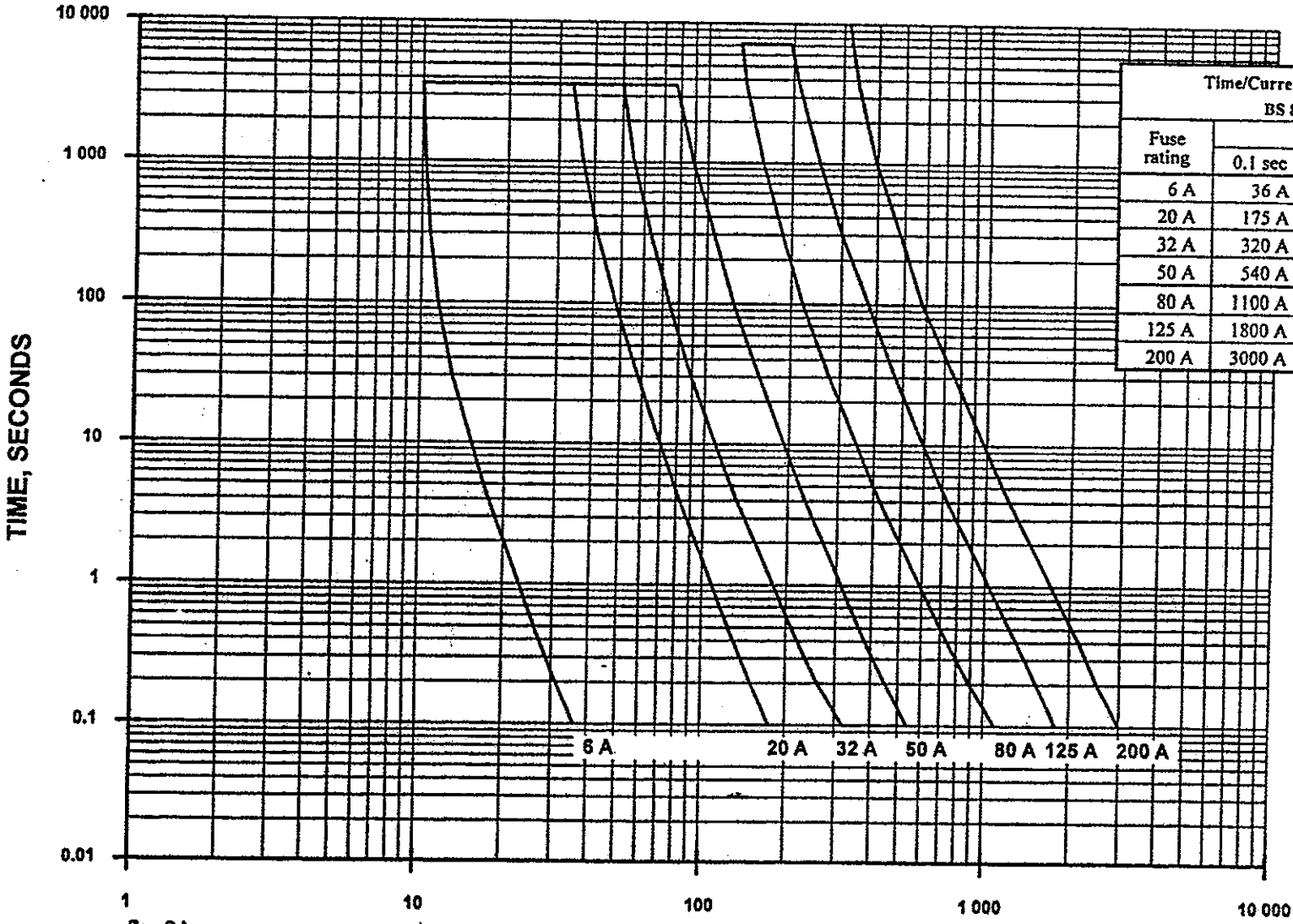
U_0 = Nominal voltage to earth.

(4) **(413-02-09)** The **maximum disconnection times** of Table 41A (L) shall apply to a **circuit supplying socket-outlets** and to other **final circuits which supply portable equipment** intended for manual movement during use, or **handheld class I equipment**.

Table 41A (L)	
Installation nominal voltage U_0 (volts)	Maximum disconnection time t (seconds)
120	0.8
230	0.4
400	0.2
>400	0.1
For intermediate values of voltage, the next higher value of voltage in the table is to be used.	

(5) Where fuses are used as automatic disconnection device under earth fault condition. The maximum values of earth fault loop impedance (Z_s) corresponding to a disconnection time of 0.4s are stated in Table 41B1 (L) for U_0 = 230V.

Where circuit breaker is used, refer to Table 41B2 (L).



Time/Current characteristics for fuses to BS 88: Part 2 and Part 6				
Fuse rating	Current for time			
	0.1 sec	0.2 sec	0.4 sec	5 secs
6 A	36 A	31 A	27 A	17 A
20 A	175 A	150 A	130 A	79 A
32 A	320 A	260 A	220 A	125 A
50 A	540 A	450 A	380 A	220 A
80 A	1100 A	890 A	740 A	400 A
125 A	1800 A	1500 A	1300 A	690 A
200 A	3000 A	2500 A	2200 A	1200 A

fig. 3A

413-02-10L Where a fuse is used to satisfy the requirements of Clause 413-02-09, maximum values of earth fault loop impedance (Z_s) corresponding to a disconnection time of 0.4s are stated in Table 41B1 for a nominal voltage to Earth (U_o) of 230V. For types and rated currents of general purpose (*gG*), fuses other than those mentioned in Table 41B1, and for motor circuit fuses (*gM*), reference should be made to the appropriate approved standard, to determine the value of I_a for compliance with Clause 413-02-08.

TABLE 41A (L)

Maximum disconnection times for TN-S systems
(see Clause 413-02-09)

Installation nominal voltage U_o (volts)	Maximum disconnection time t (seconds)
120	0.8
230	0.4
400	0.2
greater than 400	0.1

NOTE. For intermediate values of voltage, the next higher value of voltage in the table is to be used.

TABLE 41B1 (L)

Maximum earth fault loop impedance (Z_s) for fuses, for 0.4s disconnection time with U_o of 230 V (see Clause 413-02-10)

(a) General purpose (*gG*) fuses to BS 88 Parts 2 and 6

Rating (amperes)	6	10	16	20	25	32	40	50
Z_s (ohms)	8.51	5.10	2.70	1.77	1.43	1.04	0.82	0.60

(b) Fuses to BS 1361

Rating (amperes)	5	15	20	30	45
Z_s (ohms)	10.44	3.28	1.70	1.15	0.57

(c) Fuses to BS 3036

Rating (amperes)	5	15	20	30	45
Z_s (ohms)	9.58	2.55	1.77	1.09	0.59

(d) Fuse to SS 167

Rating (amperes)	13
Z_s (ohms)	2.42

NOTE. The circuit loop impedances given in the table should not be exceeded when the conductors are at their normal operating temperature. If the conductors are at a different temperature when tested, the reading should be adjusted accordingly.

413-02-11 Where a circuit-breaker is used to satisfy the requirements of Clause 413-02-09, the maximum value of earth fault loop impedance (Z_s) shall be determined by the formula of Clause 413-02-08. Alternatively, for a nominal voltage to earth of 230V and a disconnection time of 0.4s, the values specified in Table 41B2 for the types and ratings of circuit-breaker listed may be used instead of calculation.

TABLE 41B2 (L)

Maximum earth fault loop impedance (Z_s) for miniature circuit-breakers, for disconnection times of both 0.4 s with U_o of 230 V (see Clause 413-02-11) **and 5 s** (see Clauses 413-02-12 and 413-02-14)

(e) Type 1 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	9.58	5.75	3.59	2.87	1.80	1.43	1.15	0.91	0.57	$57.50/I_n$

(f) Type 2 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	5.47	3.28	2.05	1.63	1.02	0.82	0.66	0.52	0.33	$230/(7I_n)$

(g) Type B miniature circuit-breakers to SS 359

Rating (amperes)	6	10	16	20	32	40	45	50	63	100	I_n
Z_s(ohms)	7.67	4.60	2.87	2.30	1.43	1.15	1.02	0.92	0.72	0.46	$46/I_n$

(h) Type C miniature circuit-breakers to SS 359 and Type 3 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	3.83	2.30	1.44	1.15	0.72	0.57	0.46	0.36	0.23	$23/I_n$

(i) Type D miniature circuit-breakers to SS 359

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Z_s(ohms)	1.92	1.15	0.72	0.58	0.38	0.29	0.23	0.18	0.12	$11.5/I_n$

NOTE: The circuit loop impedances given in the table should not be exceeded when the conductors are at their normal operating temperature. If the conductors are at a different temperature when tested, the reading should be adjusted accordingly.

413-02-12 Irrespective of the value of U_o, for a final circuit which supplies a socket-outlet or portable equipment intended for manual movement during use, or hand-held Class I equipment, it shall be permissible to increase the disconnection time to a value not exceeding 5 s of the types and ratings of the overcurrent protective devices and associated maximum impedances of the circuit protective conductors shown in Table 41C. The impedance of the protective conductor shall be referred to the point of connection to the main equipotential bonding. Where additional equipotential bonding is installed in accordance with Clause 413-02-13 (ii) then the impedance of the circuit protective conductor specified in this paragraph applies to that portion of the circuit protective conductor between the point of additional bonding and the socket-outlet, or portable equipment.

TABLE 41C (L)

Maximum impedance of circuit protective conductor related to the final circuit protective device
(see Clause 413-02-12)

(a) General purpose (*gG*) fuses to BS 88 Parts 2 and 6

Rating (amperes)	6	10	16	20	25	32	40	50
Impedance (ohms)	2.94	1.61	0.91	0.63	0.50	0.40	0.29	0.23

(b) Fuses to BS 1361

Rating (amperes)	5	15	20	30	45
Impedance (ohms)	3.57	1.09	0.61	0.40	0.21

(c) Fuses to BS 3036

Rating (amperes)	5	15	20	30	45
Impendance (ohms)	3.85	1.16	0.83	0.58	0.35

(d) Fuse to SS 167

Rating (amperes)	13
Impendance (ohms)	0.83

(e) Type 1 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Impedance (ohms)	2.08	1.25	0.78	0.63	0.39	0.31	0.25	0.2	0.12	$12.5/I_n$

(f) Type 2 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Impedance	1.19	0.71	0.45	0.36	0.22	0.18	0.14	0.11	0.07	$50/(7I_n)$

Contd. 41 C (CL)

(g) Type B miniature circuit-breakers to SS 359

Rating (amperes)	6	10	16	20	32	40	45	50	63	I_n
Impedance (ohms)	1.67	1.00	0.63	0.50	0.31	0.25	0.22	0.20	0.16	$10/I_n$

(h) Type C miniature circuit-breakers to SS 359 and Type 3 miniature circuit-breakers to BS 3871

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Impedance (ohms)	0.83	0.50	0.31	0.25	0.16	0.13	0.10	0.08	0.05	$5/I_n$

(i) Type D miniature circuit-breakers to SS 359

Rating (amperes)	6	10	16	20	32	40	50	63	100	I_n
Impedance (ohms)	0.42	0.25	0.16	0.12	0.08	0.06	0.05	0.04	0.03	$2.5/I_n$

NOTE: The circuit loop impedances given in the table should not be exceeded when the conductors are at their normal operating temperature. If the conductors are at a different temperature when tested, the reading should be adjusted accordingly.

413-02-13 For a distribution circuit a disconnection time not exceeding 5 s is permitted.

For a final circuit supplying only stationary equipment and for a final circuit for which the requirement of Clause 413-02-09 does not apply a disconnection time not exceeding 5 s is permitted. Where the disconnection time for such a final circuit exceeds that required by Table 41A and another final circuit requiring a disconnection time according to Table 41A is connected to the same distribution board or distribution circuit, one of the following conditions shall be fulfilled:

(i) the impedance of the protective conductor between the distribution board and the point at which the protective conductor is connected to the main equipotential bonding shall not exceed the value given in Table 41C for the appropriate protective device in the final circuit, or, for protective devices not included in Table 41C, $50Z_s/U_o$ ohms (where Z_s is the earth fault loop impedance corresponding to a disconnection time of 5 s), or

(ii) there shall be equipotential bonding at the distribution board, which involves the same types of extraneous-conductive-parts as the main equipotential bonding according to Clause 413-02-02 and is sized in accordance with Clause 547-02-01.

413-02-14L Where a circuit-breaker is used to satisfy the requirements of Clause 413-02-13, the maximum value of earth fault loop impedance (Z_s) shall be determined by the formula of Clause 413-02-08. Alternatively the values specified in Table 41B2 may be used instead of calculation for a nominal voltage to Earth (U_o) of 230 V for the types and ratings of circuit-breaker listed therein.

Where a fuse is used to satisfy the requirements of Clause 413-02-13, maximum values of earth fault loop impedance (Z_s) corresponding to a disconnection time of 5 s are stated in Table 41D for a nominal voltage to Earth (U_o) of 230 V.

For types and rated currents of general purpose (*gG*) fuses other than those mentioned in Table 41D and for motor circuit fuses (*gM*) reference should be made to the appropriate approved standard to determine the value of I_a for compliance with Clause 413-02-08.

TABLE 41D (L)

Maximum earth fault loop impedance (Z_s) for 5 s disconnection time with U_o 230 V
(see Clauses 413-02-13 and 413-02-14)

(a) General purpose (*gG*) fuses to BS 88 Parts 2 and 6

Rating (amperes)	6	10	16	20	25	32	40	50
Z_s(ohms)	13.51	7.41	4.17	2.91	2.30	1.84	1.35	1.04

Rating (amperes)	63	80	100	125	160	200
Z_s(ohms)	0.82	0.57	0.42	0.33	0.25	0.19

(b) Fuses to BS 1361

Rating (amperes)	5	15	20	30	45	60	80	100
Z_s(ohms)	16.38	5.00	2.80	1.84	0.95	0.70	0.49	0.36

(c) Fuses to BS 3036

Rating (amperes)	5	15	20	30	45	60	100
Z_s(ohms)	17.72	5.34	3.83	2.64	1.59	1.12	0.53

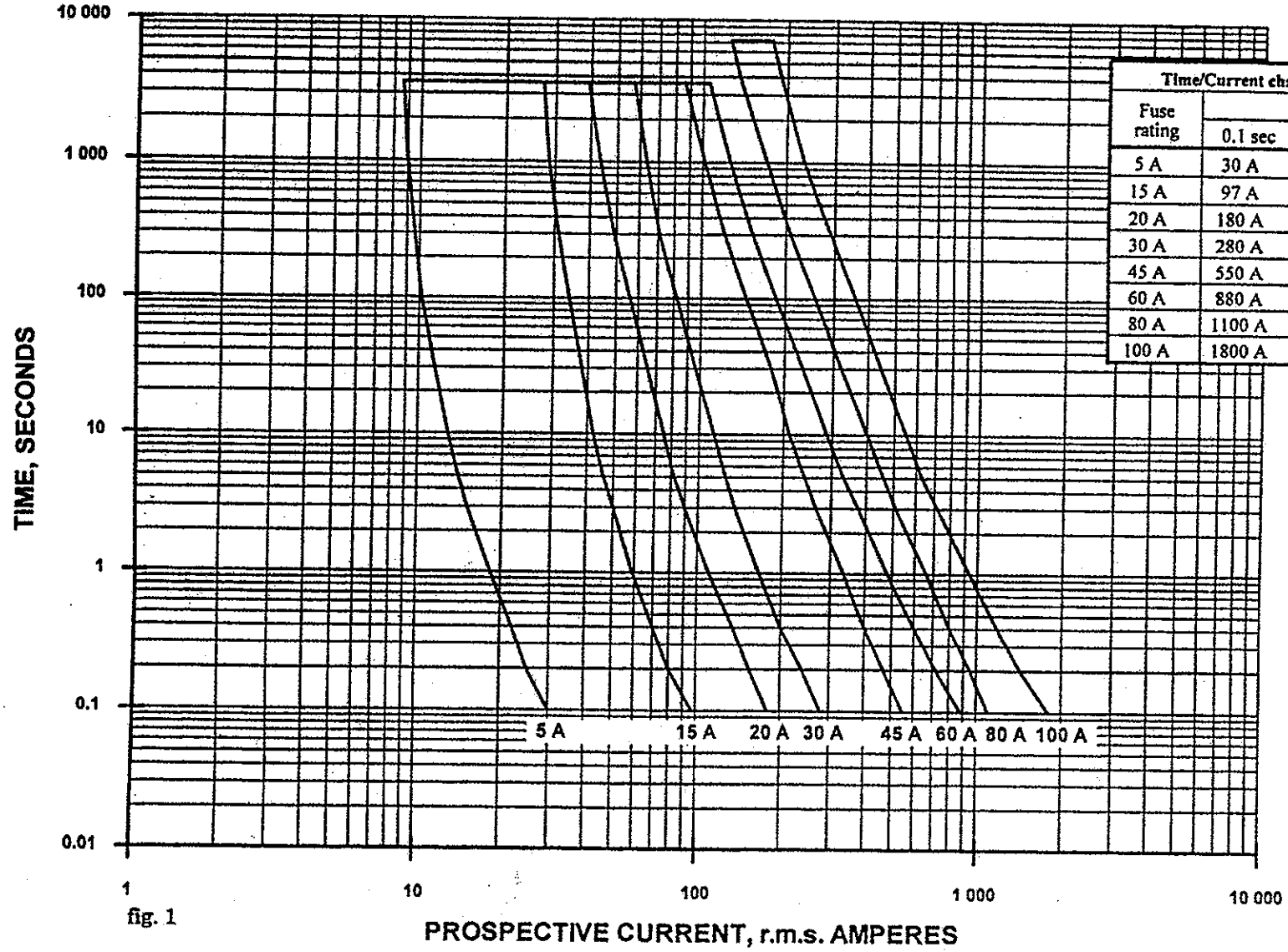
(d) Fuse to SS 167

Rating (amperes)	13
Z_s(ohms)	3.83

NOTE: The circuit loop impedances given in the table should not be exceeded when the conductors are at their normal operating temperature. If the conductors are at a different temperature when tested, the reading should be adjusted accordingly.

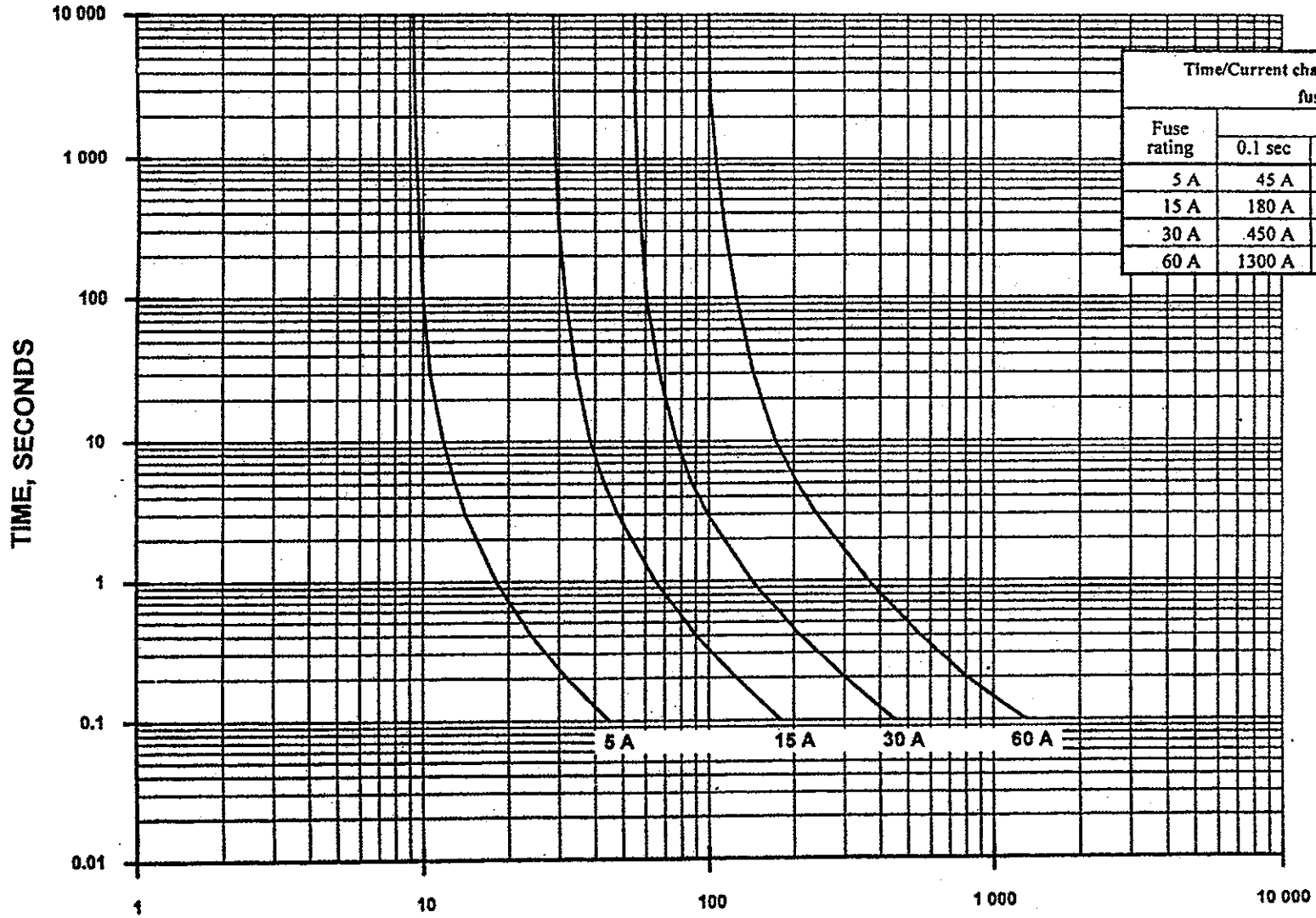
413-02-15 Where the conditions of Clauses 413-02-08 to 413-02-14, for automatic disconnection, cannot be fulfilled by using overcurrent protective devices, then either:

(i) local supplementary equipotential bonding shall be applied in accordance with Clauses



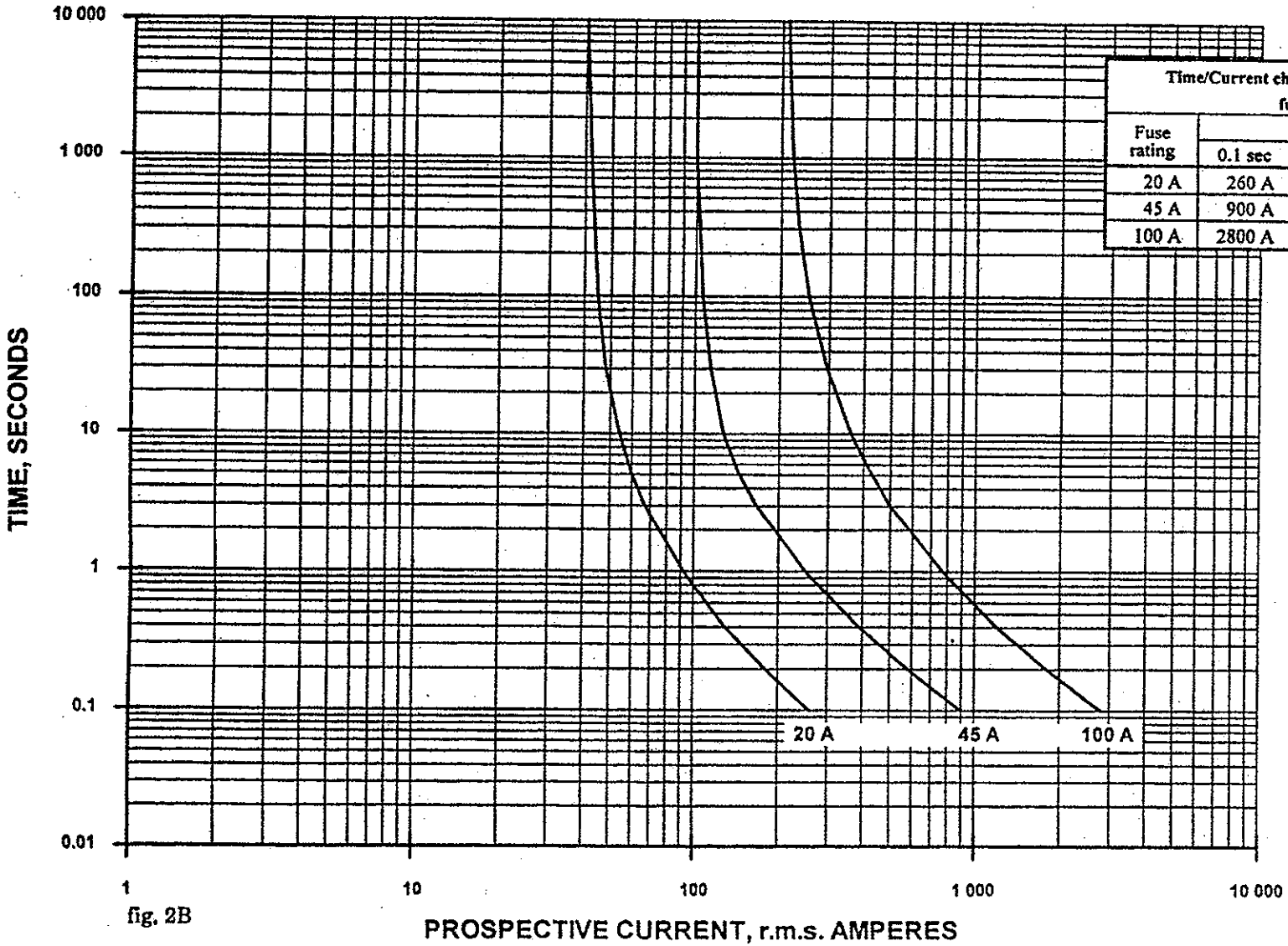
Time/Current characteristics for fuses to BS 1361				
Fuse rating	Current for time			
	0.1 sec	0.2 sec	0.4 sec	5 secs
5 A	30 A	25 A	22 A	14 A
15 A	97 A	80 A	70 A	46 A
20 A	180 A	155 A	135 A	82 A
30 A	280 A	240 A	200 A	125 A
45 A	550 A	470 A	400 A	240 A
60 A	880 A	720 A	600 A	330 A
80 A	1100 A	950 A	800 A	460 A
100 A	1800 A	1400 A	1200 A	630 A

fig. 1



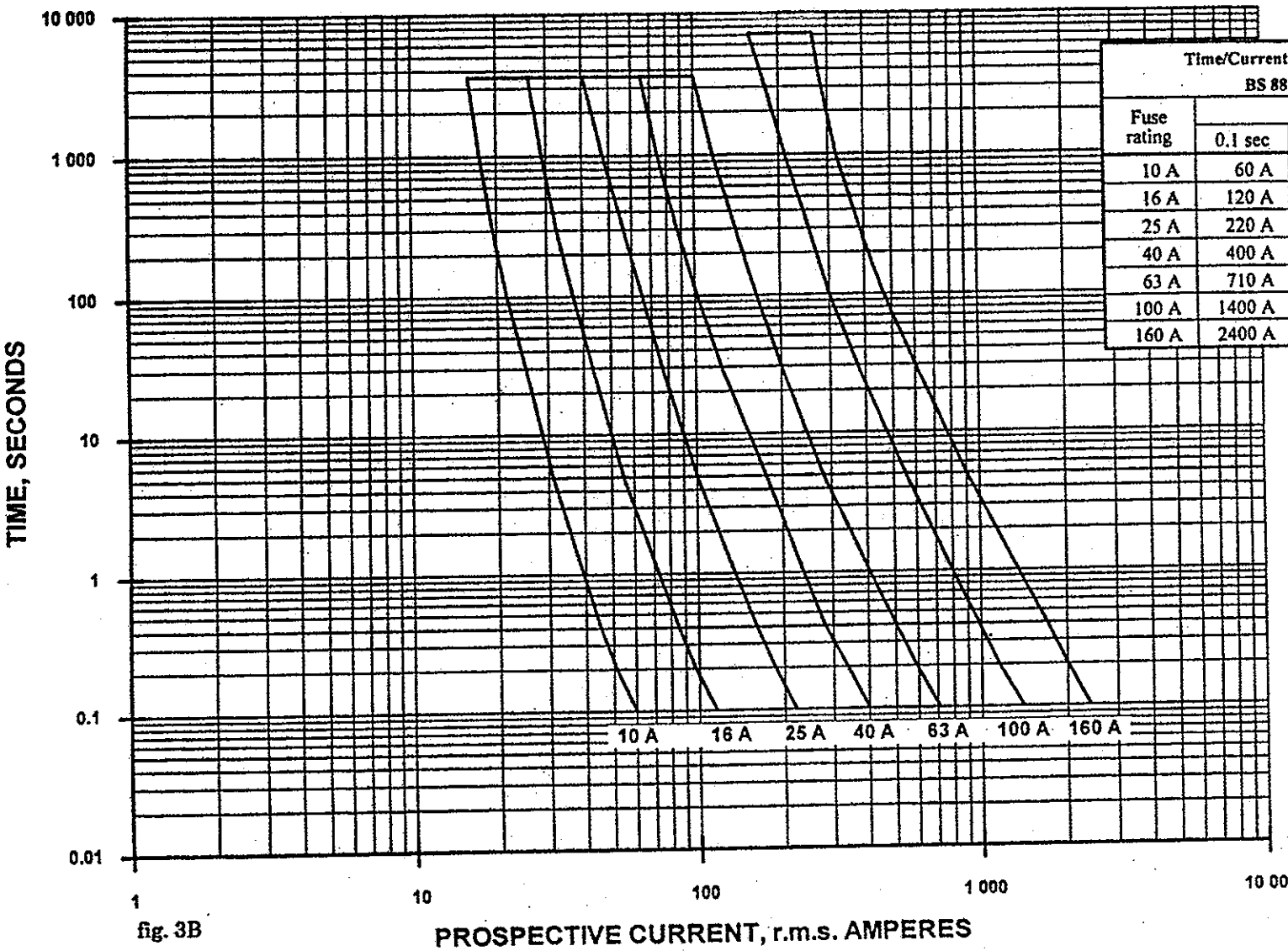
Time/Current characteristics for semi-enclosed fuses to BS 3036				
Fuse rating	Current for time			
	0.1 sec	0.2 sec	0.4 sec	5 secs
5 A	45 A	32 A	24 A	13 A
15 A	180 A	125 A	90 A	43 A
30 A	450 A	300 A	210 A	87 A
60 A	1300 A	800 A	550 A	205 A

fig. 2A



Time/Current characteristics for semi-enclosed fuses to BS 3036				
Fuse rating	Current for time			
	0.1 sec	0.2 sec	0.4 sec	5 secs
20 A	260 A	180 A	130 A	60 A
45 A	900 A	580 A	390 A	145 A
100 A	2800 A	1800 A	1200 A	430 A

fig. 2B



Time/Current characteristics for fuses to BS 88: Part 2 and Part 6

Fuse rating	Current for time			
	0.1 sec	0.2 sec	0.4 sec	5 secs
10 A	60 A	51 A	45 A	31 A
16 A	120 A	95 A	85 A	55 A
25 A	220 A	180 A	160 A	100 A
40 A	400 A	340 A	280 A	170 A
63 A	710 A	590 A	500 A	280 A
100 A	1400 A	1150 A	980 A	550 A
160 A	2400 A	2000 A	1700 A	900 A

fig. 3B

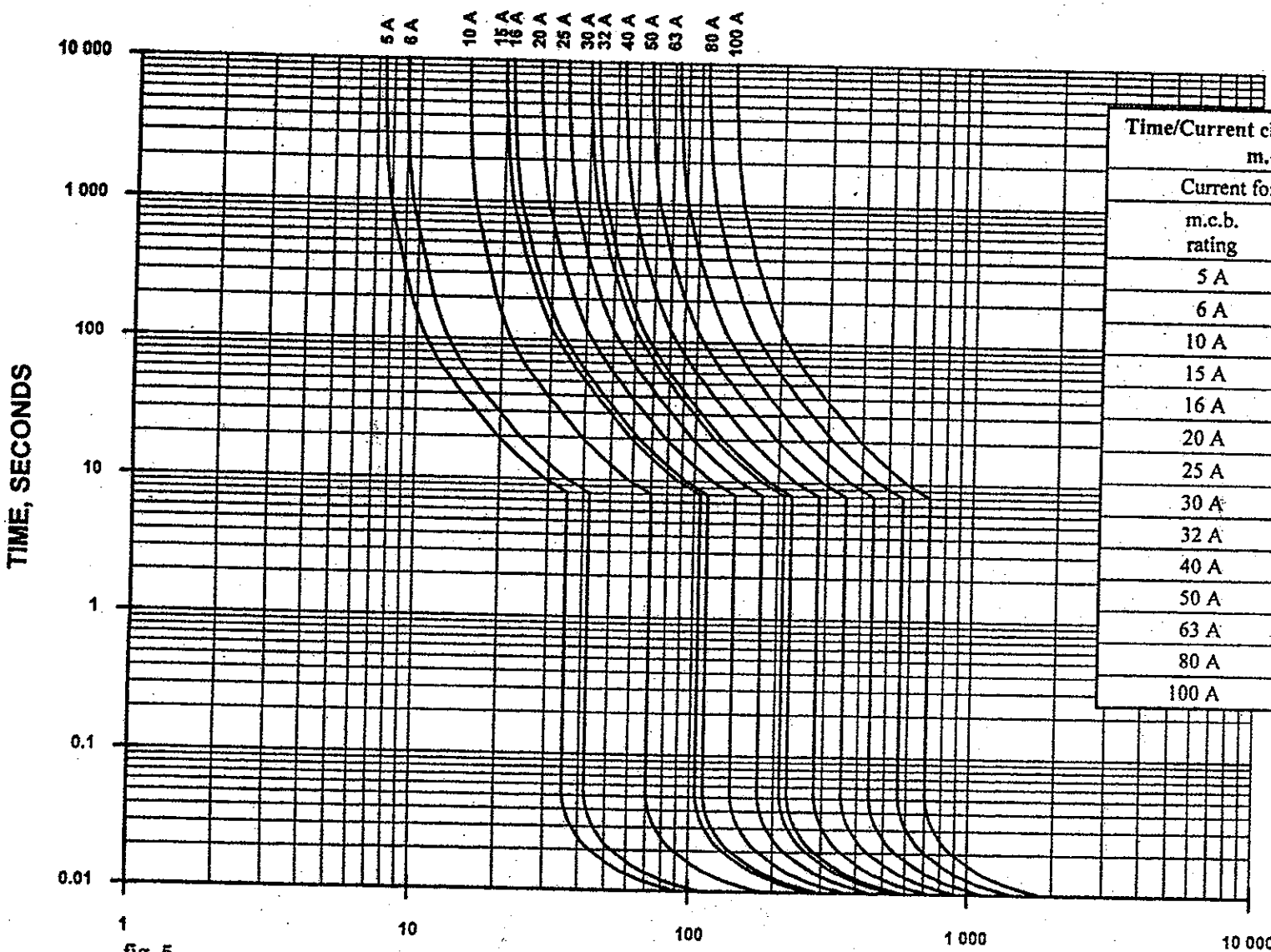
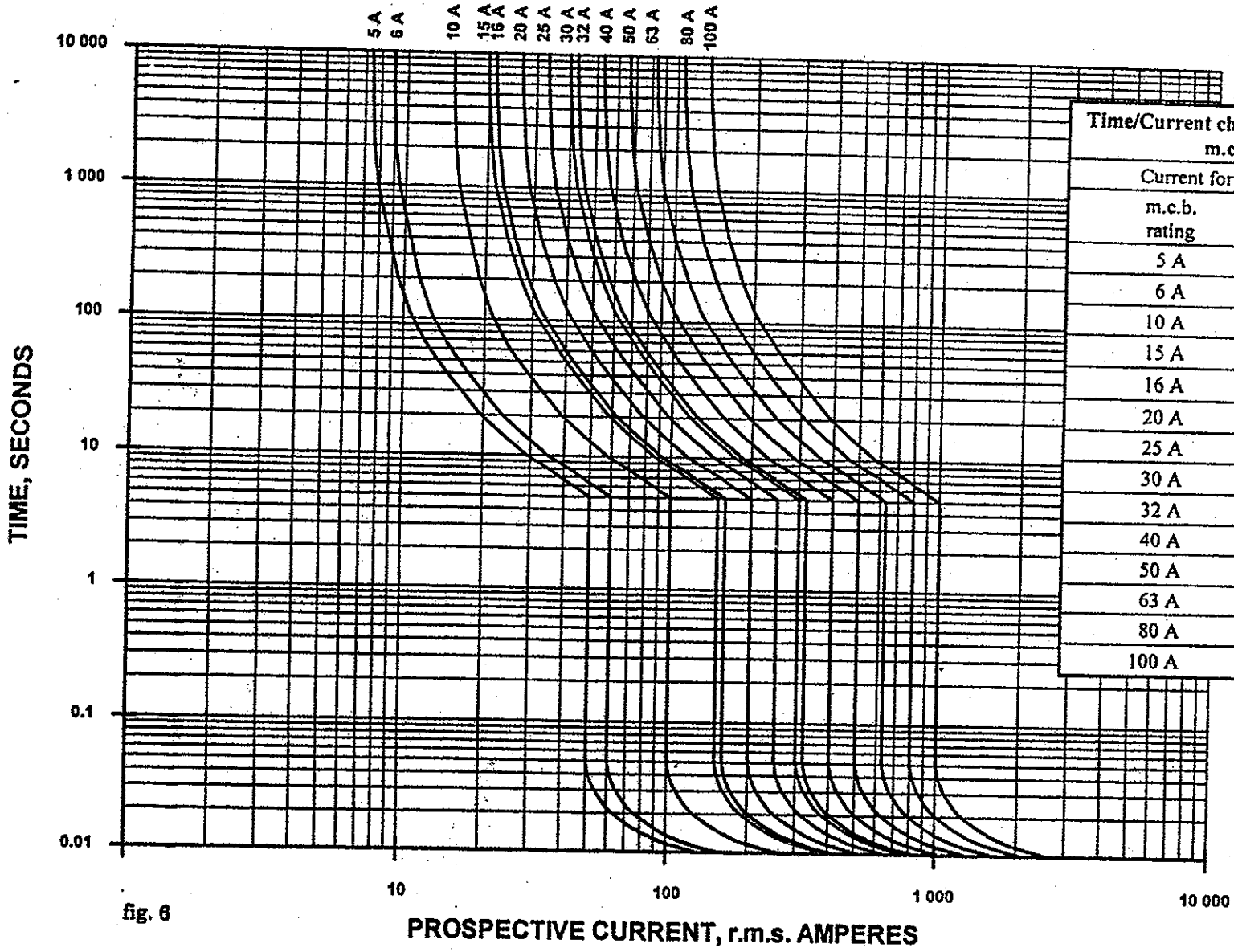


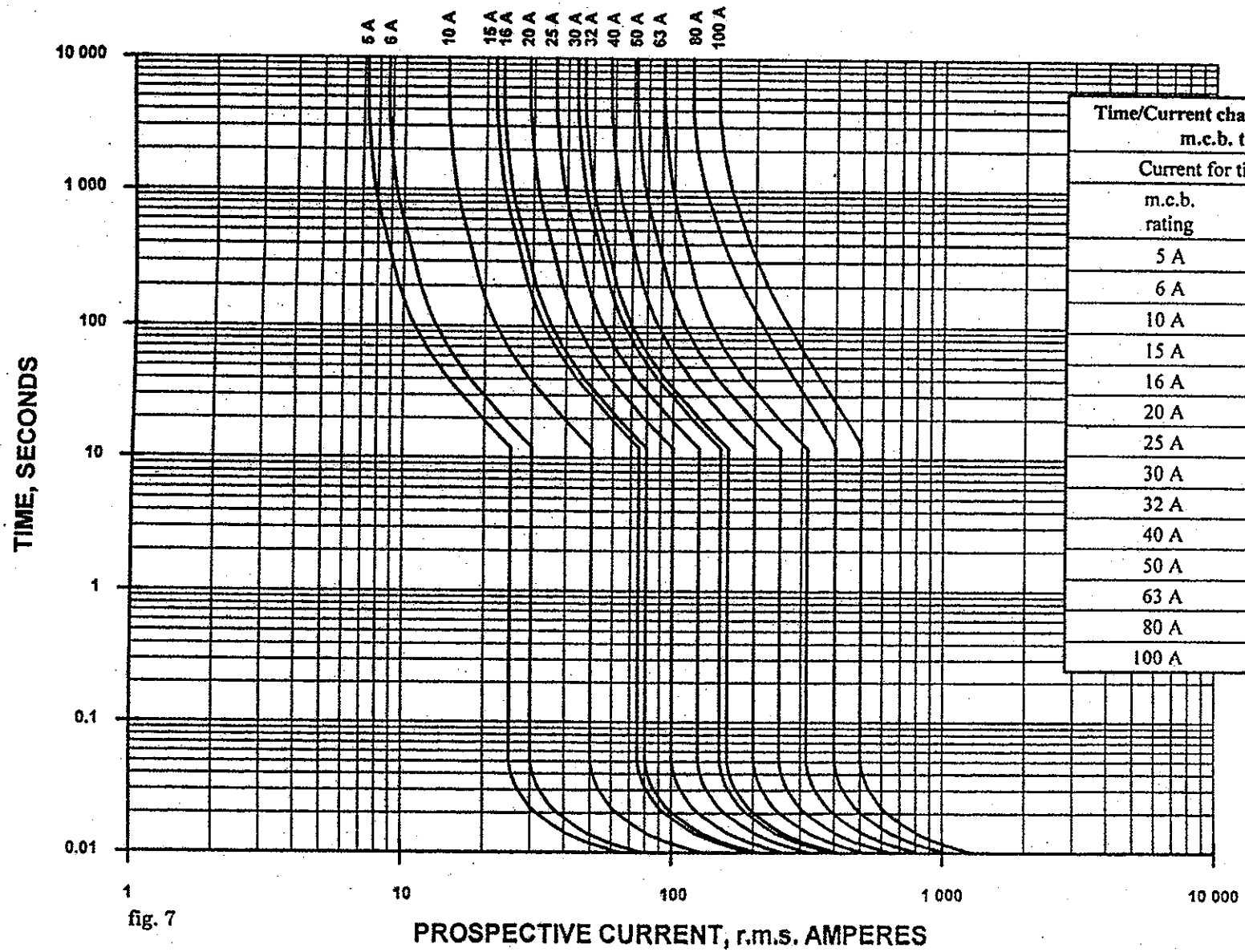
fig. 5

Time/Current characteristics for the Type 2 m.c.b. to BS 3871	
Current for time, 0.1 sec to 5 secs	
m.c.b. rating	Current
5 A	35 A
6 A	42 A
10 A	70 A
15 A	105 A
16 A	112 A
20 A	140 A
25 A	175 A
30 A	210 A
32 A	224 A
40 A	280 A
50 A	350 A
63 A	441 A
80 A	560 A
100 A	700 A



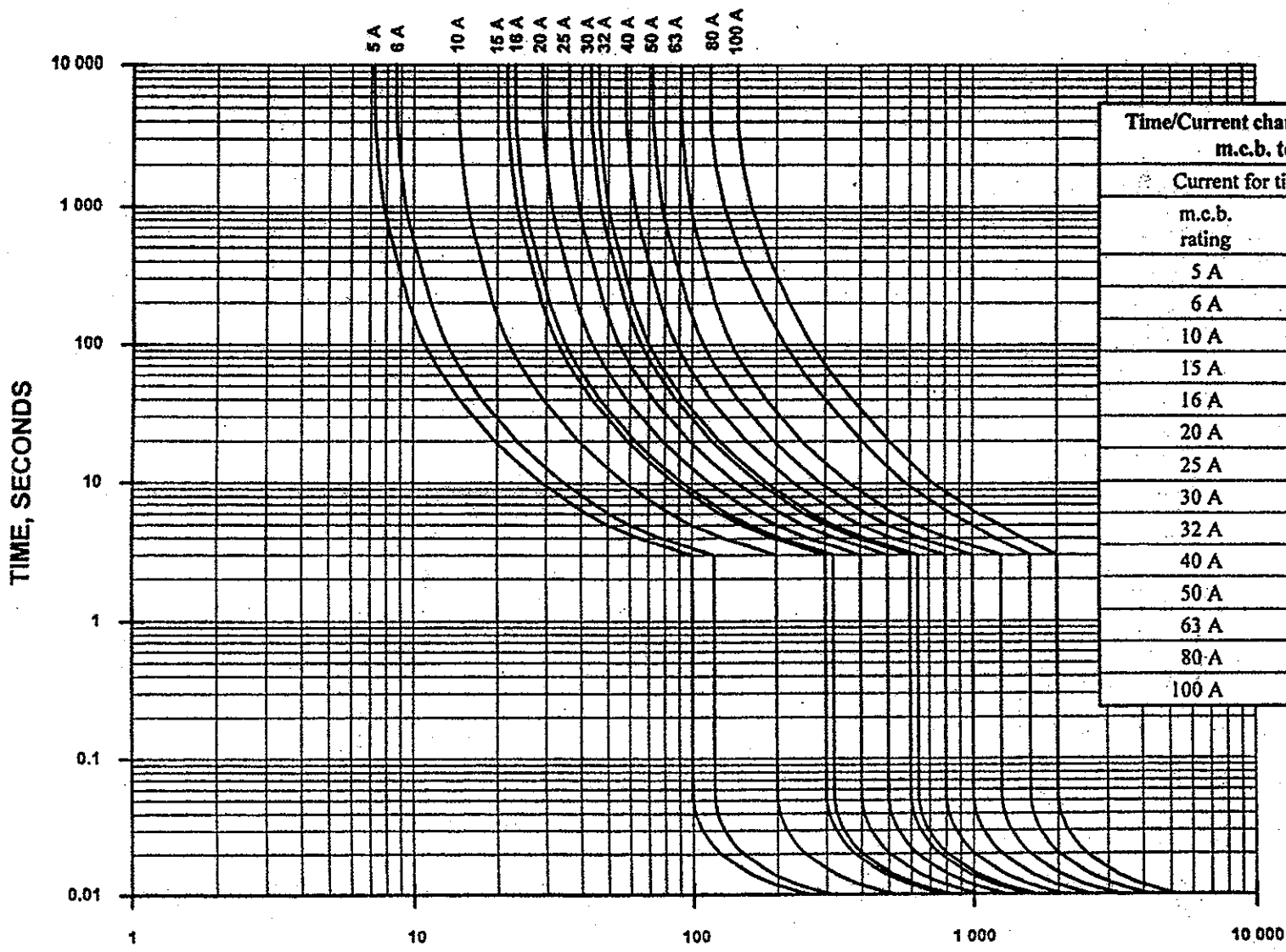
Time/Current characteristics for the Type 3 m.c.b. to BS 3871	
Current for time, 0.1 sec to 5 secs	
m.c.b. rating	Current
5 A	50 A
6 A	60 A
10 A	100 A
15 A	150 A
16 A	160 A
20 A	200 A
25 A	250 A
30 A	300 A
32 A	320 A
40 A	400 A
50 A	500 A
63 A	630 A
80 A	800 A
100 A	1000 A

fig. 6



Time/Current characteristics for the Type B m.c.b. to SS 359	
Current for time, 0.1 sec to 5 secs	
m.c.b. rating	Current
5 A	25 A
6 A	30 A
10 A	50 A
15 A	75 A
16 A	80 A
20 A	100 A
25 A	125 A
30 A	150 A
32 A	160 A
40 A	200 A
50 A	250 A
63 A	315 A
80 A	400 A
100 A	500 A

fig. 7



Time/Current characteristics for the Type D m.c.b. to SS 359	
Current for time, 0.1 sec to 5 secs	
m.c.b. rating	Current
5 A	100 A
6 A	120 A
10 A	200 A
15 A	300 A
16 A	320 A
20 A	400 A
25 A	500 A
30 A	600 A
32 A	640 A
40 A	800 A
50 A	1000 A
63 A	1260 A
80 A	1600 A
100 A	2000 A

fig. 9

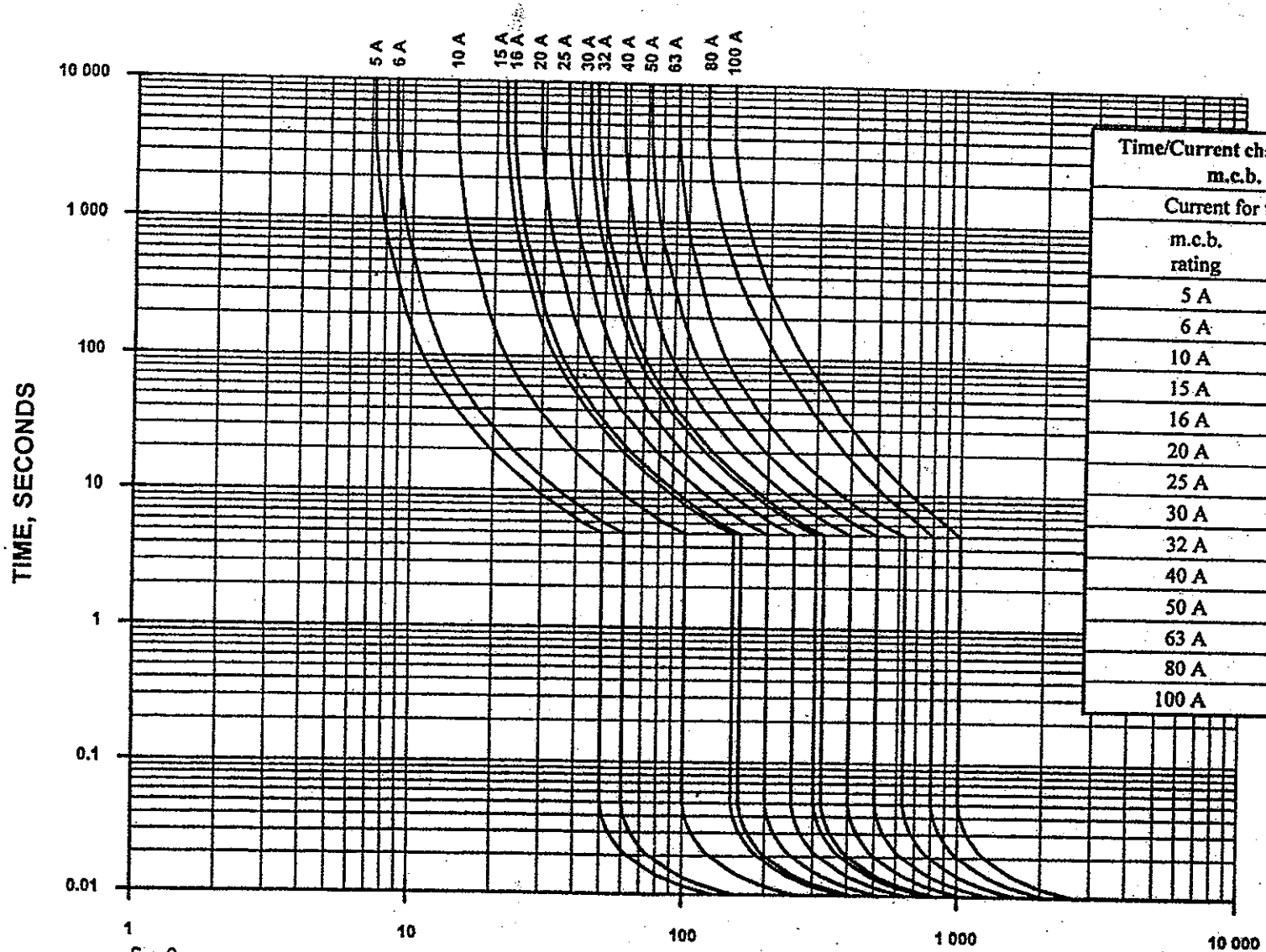


fig. 8

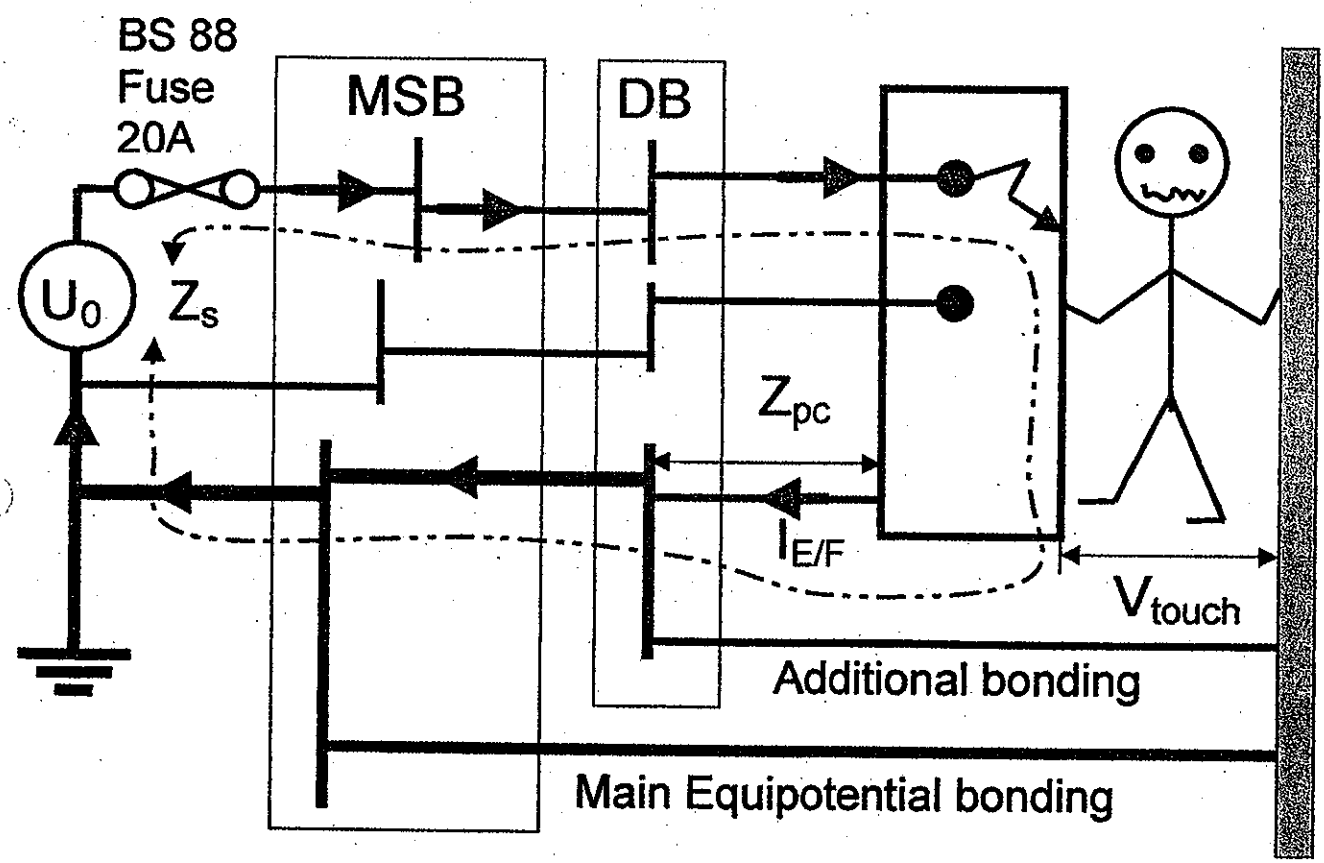
Time/Current characteristics for the Type C m.c.b. to SS 359	
Current for time, 0.1 sec to 5 secs	
m.c.b. rating	Current
5 A	50 A
6 A	60 A
10 A	100 A
15 A	150 A
16 A	160 A
20 A	200 A
25 A	250 A
30 A	300 A
32 A	320 A
40 A	400 A
50 A	500 A
63 A	630 A
80 A	800 A
100 A	1000 A

(6) Irrespective of the value of U_0, for final circuit which supplies a socket-outlet or portable equipment intended for manual movement during use, or hand-held Class I equipment, it shall be permissible to increase the disconnection time to ≤ **5s** of the type and ratings of the O/C protective devices and associated maximum impedances, Z_{pc}, of the CPC shown in Table 41C (L).

The impedance of the pc, Z_{pc}, shall be referred to the point of connection to the main equipotential bonding.

Where additional equipotential bonding is installed in accordance with Clause 413-02-13(ii) then the value of Z_{pc}, specified in this paragraph applies to that portion of the CPC between the point of additional bonding and the socket-outlet, or portable equipment.

The above measure is to **limit** the voltage drop across the CPC which is **the touch voltage** with respect to the extraneous-conductive-part to a value **not exceeding 50V**. e.g.



$V_{touch} = [(Z_{pc})/(Z_s)]_{5sec} \times U_0 = (0.63/2.91)230 =$ **50V**

(7) (413-02-13) For a distribution circuit a disconnection time not exceeding 5 sec is permitted.

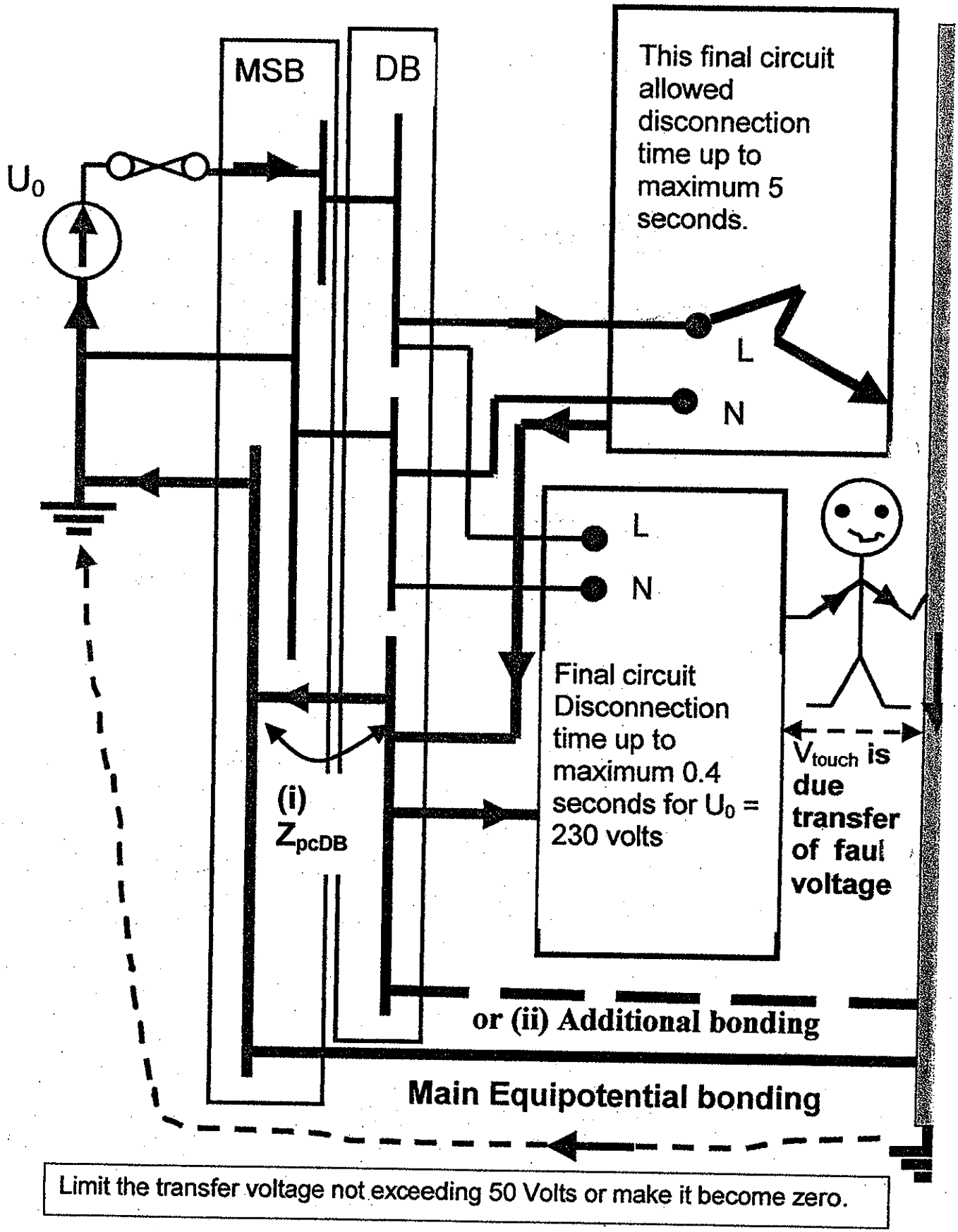
For a final circuit supplying only stationary equipment and for a final circuit for which the requirement of Clause 413-02-09 [i.e. para. (4)] does not apply a disconnection time not exceeding 5 s is permitted. Where the disconnection for such a final circuit exceeds that required by Table 41A (L) and another final circuit requiring a disconnection time according to Table 41A (L) is connected to the same DB or distribution circuit, one of the following conditions shall be fulfilled:

(i) the impedance of the pc between the DB and the point at which the protective conductor is connected to the main equipotential bonding shall not exceed the value give in Table 41C for the appropriate protective device in the final circuit, or, for protective devices not included in Table 41C, $\{50(Z_s)_{5sec}/U_0\}$ ohms i.e. Z_{pcDB},

or

(ii) there shall be equipotential bonding at the DB, which involves the types of extraneous-conductive-parts as the main equipotential bonding according to Clause 413-02-02 and is sized in accordance with Clause 547-02-01, which state as follow:

The main equipotential bonding conductor shall have a cross-sectional area,
(i) ≥ ½ the cross-sectional required for the earthing conductor of the installation, and
(ii) at least ≥ 6 mm^2
(iii) need not exceed 25 mm^2 if the bonding conductor is of copper or a cross-sectional area affording equivalent conductance in other metal.



Limit the transfer voltage not exceeding 50 Volts or make it become zero.

(8) Determination of $(Z_s)_{5sec}$ for use in the above Clause 413-02-13 [i.e. para. (7)]

(i) For circuit-breaker

(a) Calculate in accordance with Clause 413-02-08 [para. (3)]

$$Z_s \leq U_0 / I_a$$

or

(b) use the values specified in Table 41B2 (L).

(ii) For fuse,

(a) use the values specified in Table 41D (L), or

(b) alternatively calculate based on $Z_s \leq U_0 / I_a$, I_a shall be obtained from the manufacturer's data of the fuse.

Interpretation of $Z_{PC} \leq (50Z_s)/U_0$ in Clause 413-02-13

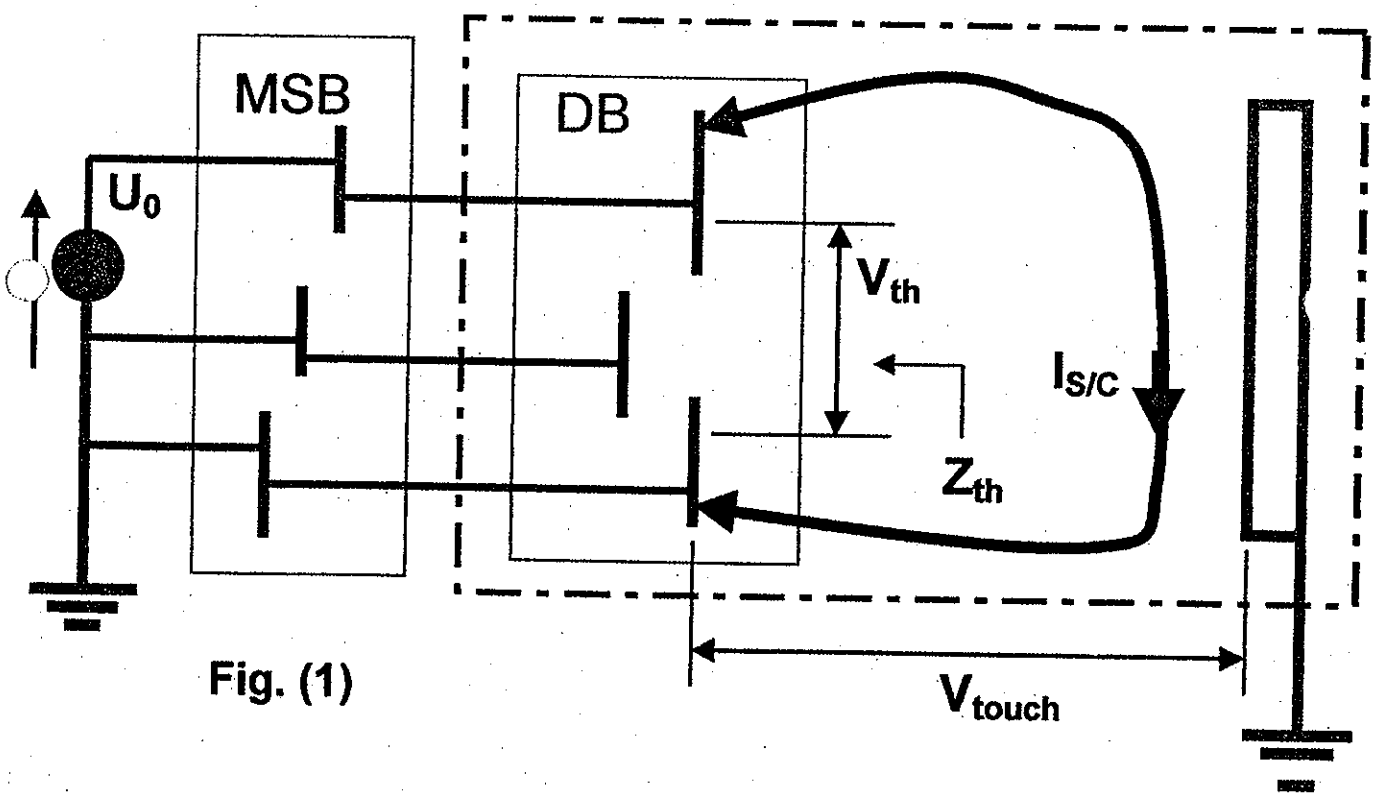


Fig. (1)

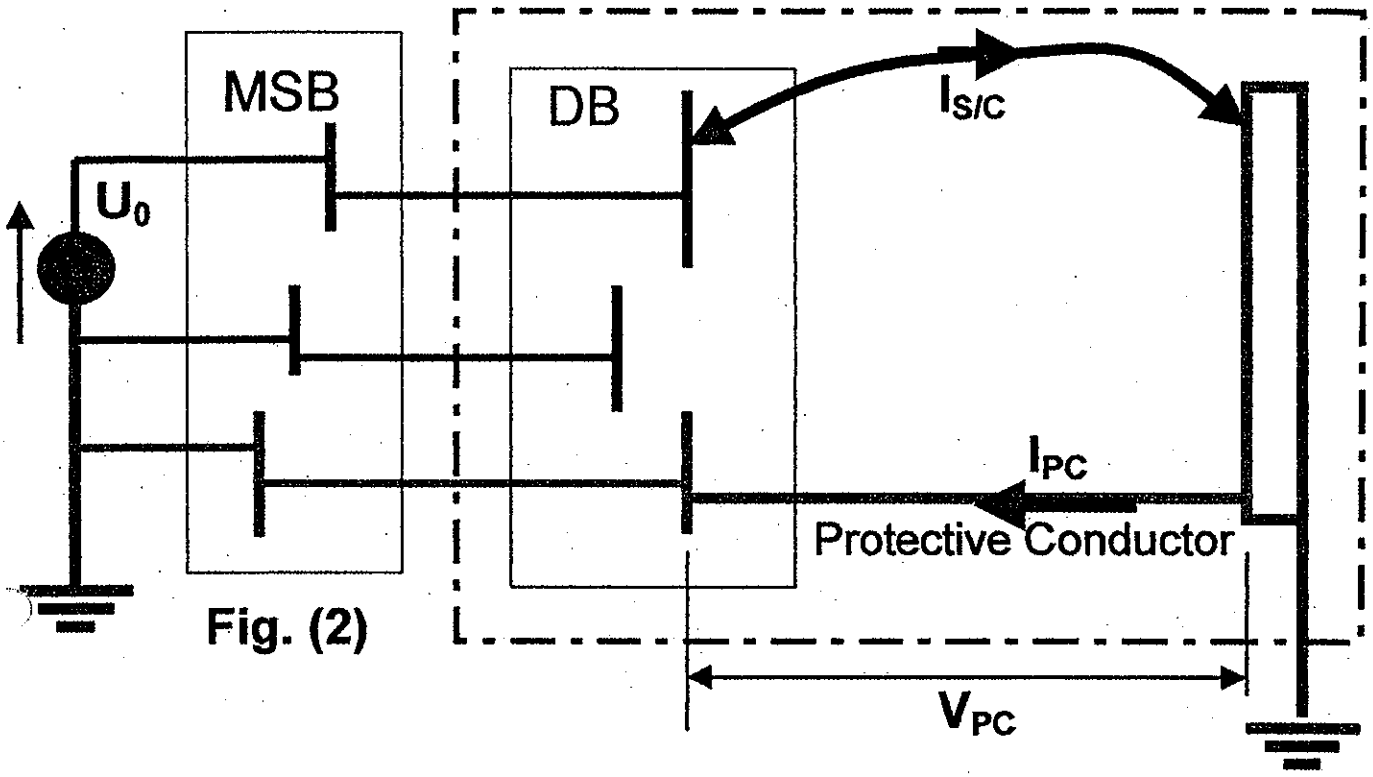

MSB
DB
U_0
$I_{S/C}$
I_{PC}
Protective Conductor
V_{PC}

Fig. (2)

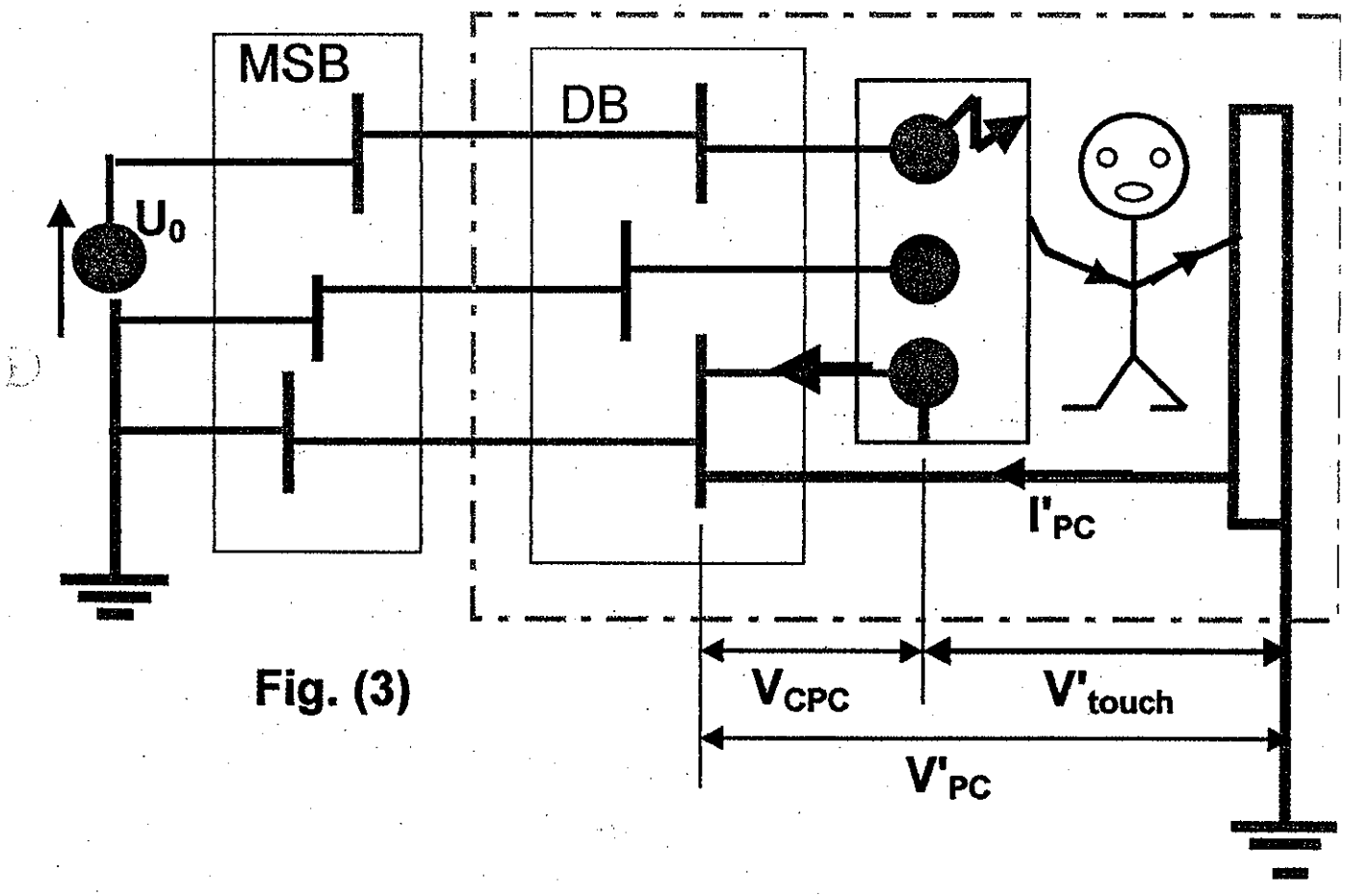

MSB
DB
U_0
I'_{PC}
V_{CPC}
V'_{touch}
V'_{PC}

Fig. (3)

In Fig. (1) :-

According to Thevenin's Theorem, the open circuit voltage across the "L" and "E" terminal is $V_{th} = U_o = 230$ **(Volts)**

The Thevenin's equivalent impedance, $Z_{th} = Z_s$ **(Ohm).**

The maximum short circuit current across L-E terminal by the shorting link of negligible impedance is, $I_{S/C} = V_{th}/Z_{th} = U_0/Z_s$ **(Amp)** and the touch voltage, $V_{touch} = U_0 = 230$ **(V)**

In Fig. (2) :-

Now, a "protective conductor" is used to replace the shorting link in Fig. (1), and is connected from the DB to the extraneous conductive part. Hence, if another conductor of negligible impedance is connected across the "L" terminal and the extraneous conductive part. The maximum short circuit current flow in the "protective conductor" is the same as,

$$I_{S/C} = V_{th}/Z_{th} = U_0/Z_s$$

Because the PC has impedance, Z_{PC}, there is voltage drop across it. However, the magnitude can be limited to a value to prevent harmful electric shock. For example, its magnitude is limited to 25V in Agricultural and Horticultural installation.

The current flow in the PC is, $I_{PC} = 25/Z_{PC}$, which can not exceed the maximum short circuit current, $I_{S/C} = U_0/Z_s$.

Hence, $25/Z_{PC} \leq U_0/Z_s$ or, $Z_{PC} \leq (25\ Z_s) / U_0$

In Fig. (3) :-

The touch voltage received by the live stocks,

$$V_{touch} = V_{PC} - V_{CPC} \quad \text{or,} \quad V_{touch} = 25 - V_{CPC}$$

Hence, the live stock is ensured to receive a touch voltage less than the permissible 25V.

(9) If automatic disconnection cannot be fulfilled by using overcurrent protective devices, then use one of the following requirement (I) or (ii):

(i) local supplementary equipotential bonding shall be applied in accordance with the following requirements.

(a) Disconnection of supply is required within certain maximum time base on thermal effect.

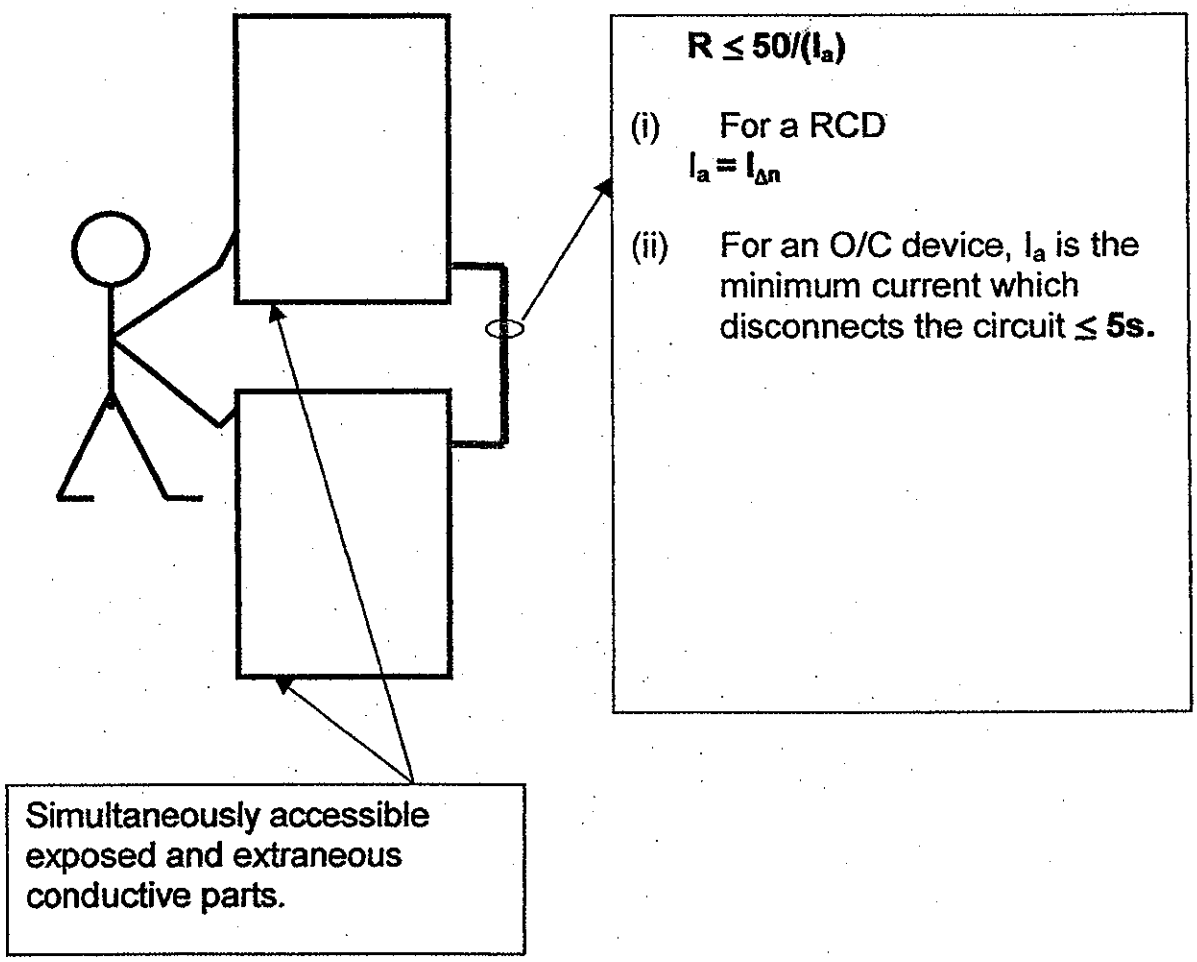
(b) Supplementary equipotential bonding conductors shall connect together

(1) exposed-conductive-parts of equipment in the circuit concerned, **and**

(2) earthing contacts of socket-outlets, **and**

(3) extraneous-conductive-parts, **and**

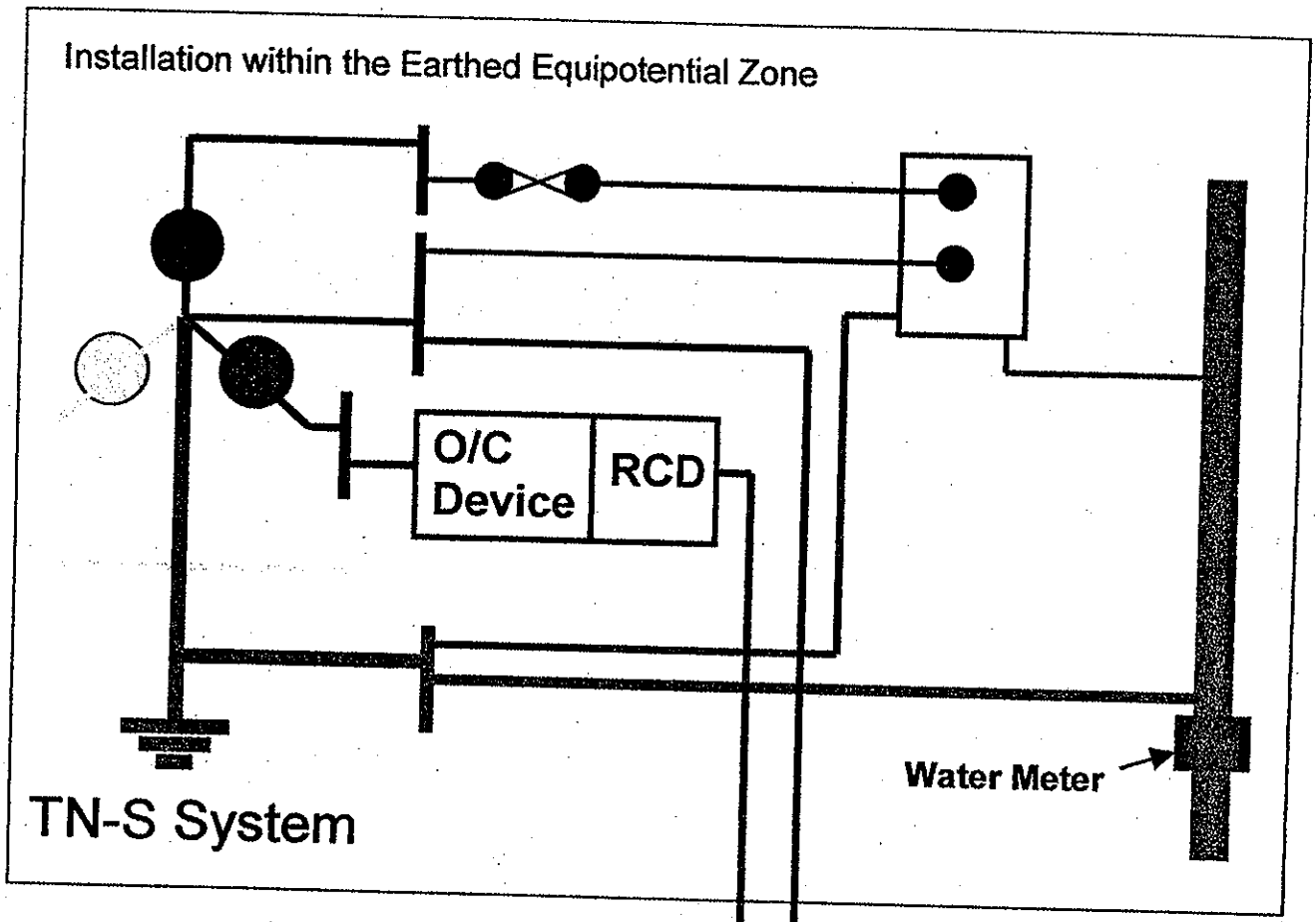
(4) The resistance (R) of the supplementary bonding conductor shall be, $R \leq 50/(I_a)$.

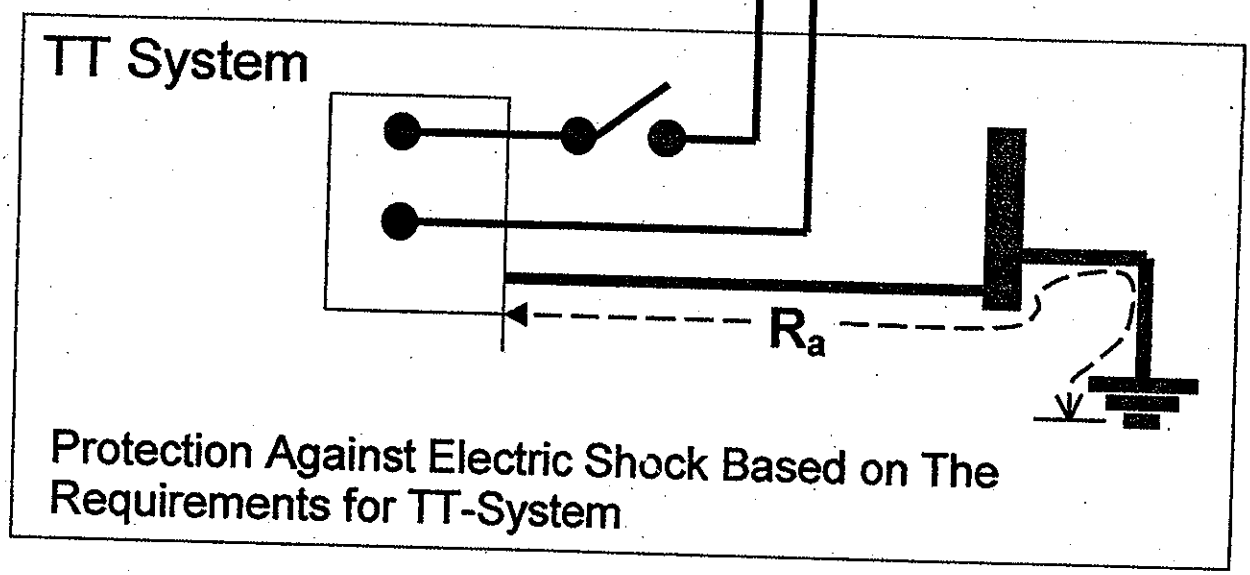


or, (ii) Protection shall be provided by means of RCD and fulfilled the following equation.

$$Z_s I_{\Delta n} \leq 50 \text{ (Volts)}$$

(10) If a RCD is used for automatic disconnection for a circuit which extends beyond the earthed equipotential zone. Then,

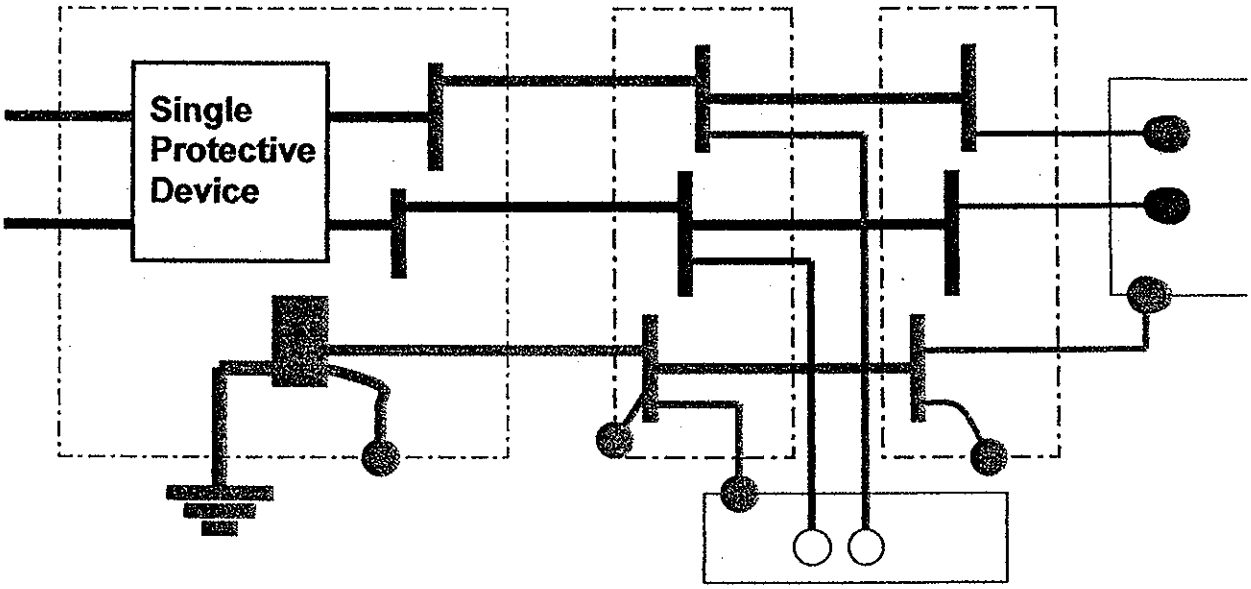




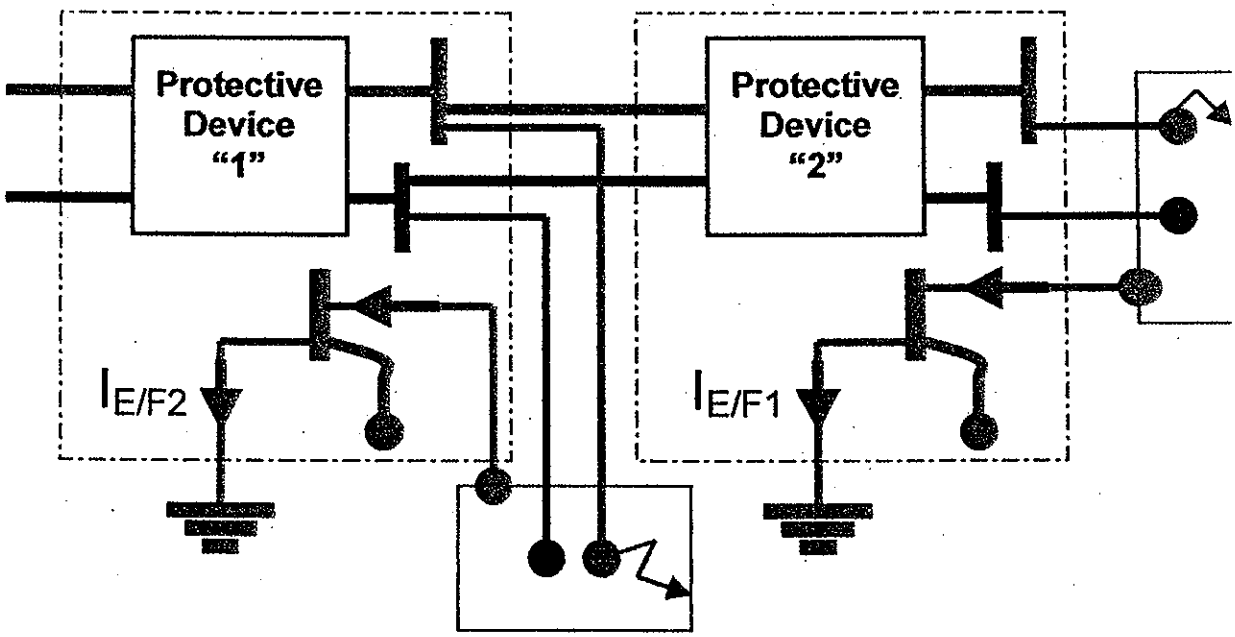
6.1.3 Additional Requirements For TT-System

(1) Earth electrode system

(i) Every exposed-conductive-part which is to be protected by a **single protective device** shall be connected, via the main earthing terminal, to a **common earth electrode**.



(ii) **Several protective devices are in series**, the exposed-conductive-parts may be connected to **separate earth electrodes** corresponding to each protective device.



(2) The protective devices shall

(i) preferably a residual current device.

(ii) an overcurrent device.

(3) The following condition shall be fulfilled for each circuit:

$$R_a I_a \leq 50 \text{ (Volts)}$$

R_a = Sum of the resistances of the earth electrode and the protective conductor(s) connecting it to the exposed-conductive-part.

I_a = current causing the automatic operation of the protective device within 5 sec.

or $I_a = I_{\Delta n}$ for RCD.

6.2 Protection by Use of Class II Equipment or by Equivalent Insulation

(1) Protection shall be provided by one or more of the following.

(i) electrical equipment of the following types, type tested and marked to the relevant standards:

(a) **double or reinforced insulation** (Class II equipment)

(b) low-voltage switchgear and controlgear assemblies having **total insulation**.

(ii) **Supplementary insulation** applied to electrical equipment having basic insulation only. Comply with item (i) above and the following requirement.

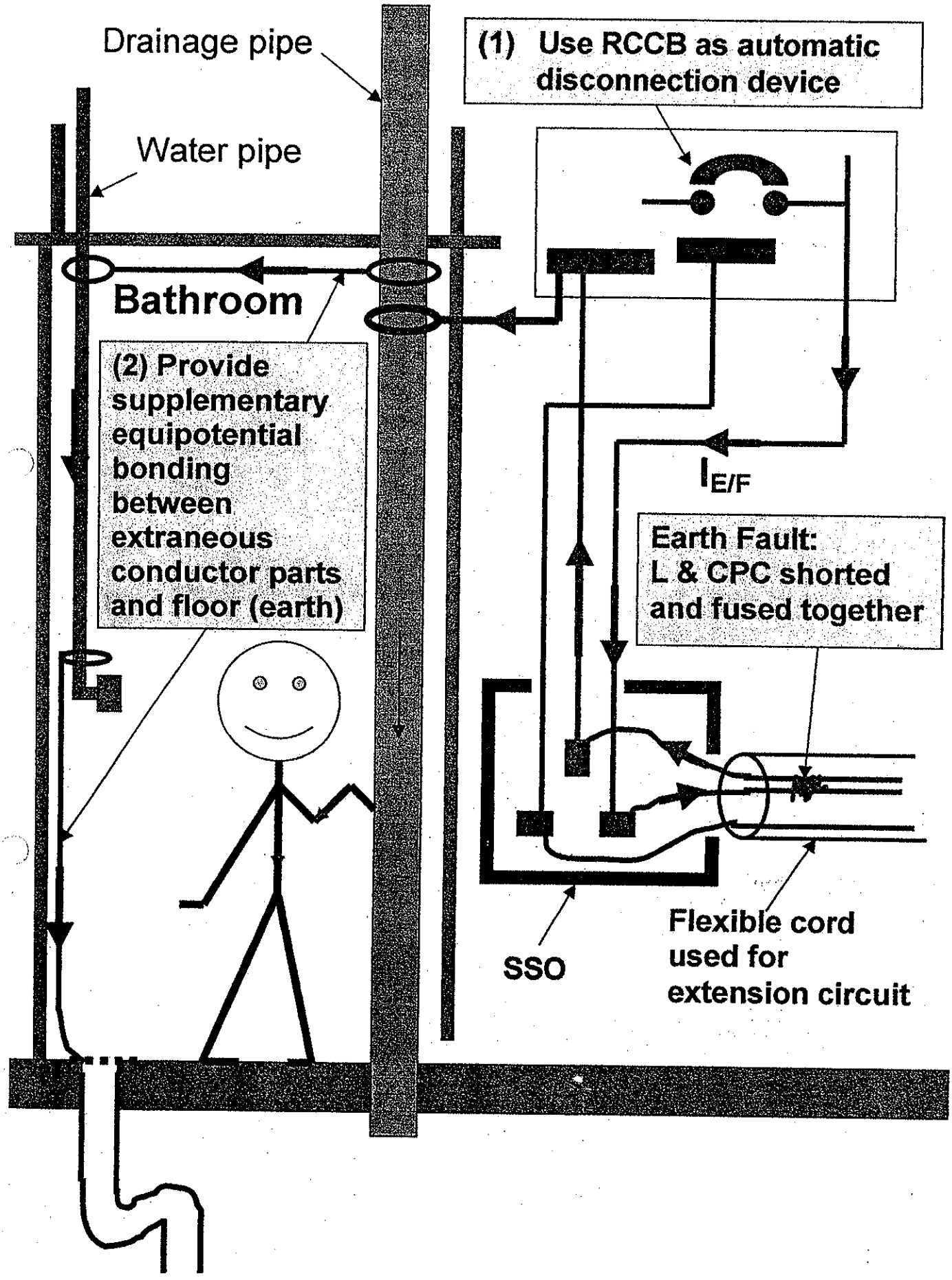
(iii) **Reinforce insulation** applied to uninsulated live parts. Comply with item (i) above and the following requirements.

(2) Installation of equipment:

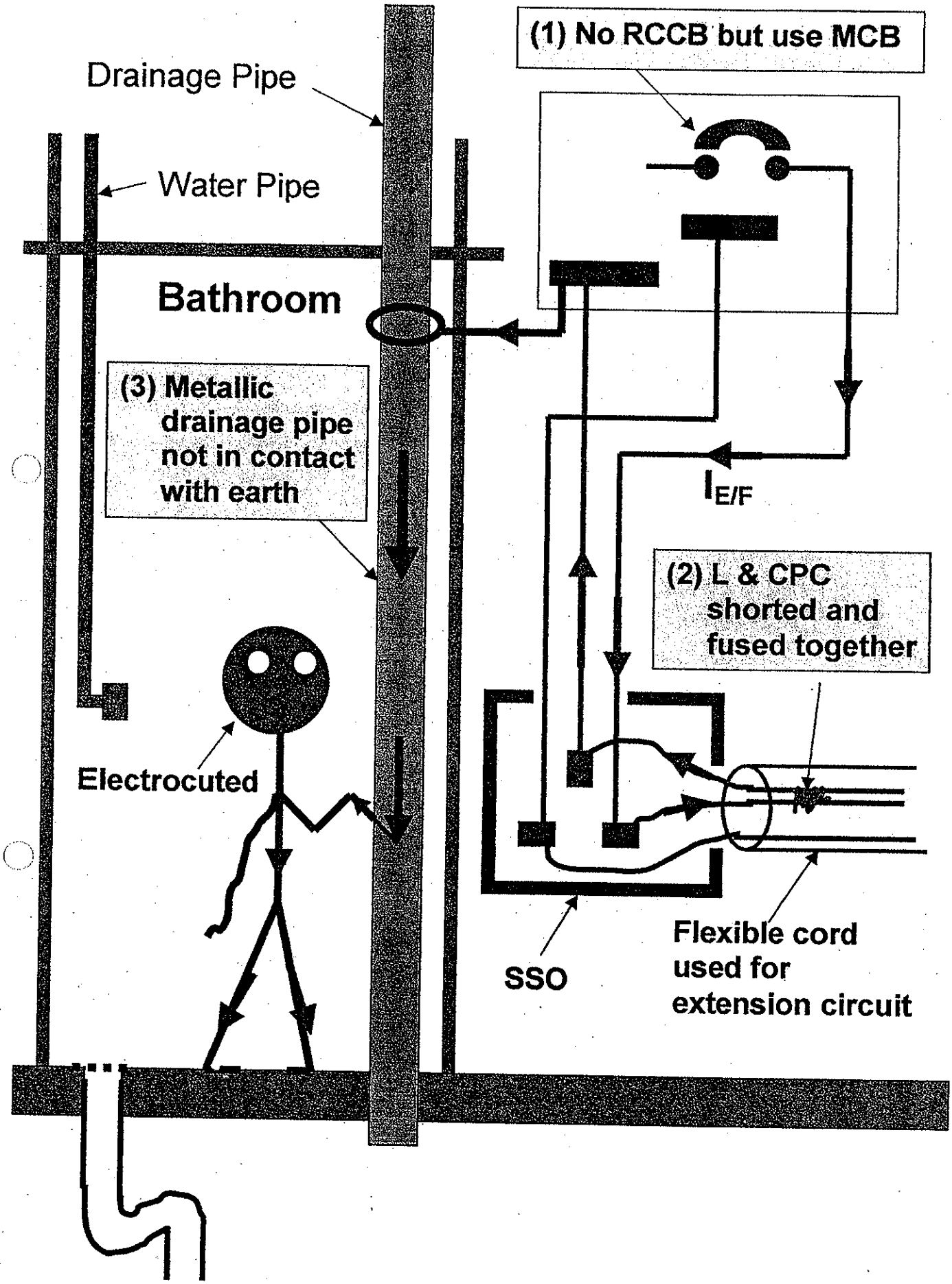
(i) not to impair the protection afforded in compliance with the equipment specification.

(ii) Basic insulation is not the only protection between live parts of the installation and exposed metalwork of that equipment.

Prevent electrocution in a bathroom – Equipotential Bonding



Electrocution in a bathroom – a real deceased case



(3) Enclosure provided shall not adversely affect the operation of the equipment protected.

(4) All conductive parts separated from live parts only by basic insulation shall be contained in an insulating enclosure affording at least IP2X or IPXXB.

(5) The insulating enclosure shall be **capable of resisting mechanical, electrical and thermal stresses** likely to encountered. **Prohibit the use of a coating of paint, varnish or similar product.**

(6) The insulating enclosure shall be tested as follow:

(i) affords a degree of protection at least IP2X or IPXXB.

(ii) capable of withstanding, without breakdown or flashover, an applied voltage test equivalent to that specified in the Singapore or British standard for similar type tested equipment.

(7) It **shall not be pierced by conductive parts**, other than circuit conductors, likely to transmit a potential.

It **shall not contain any screws** of insulating material, because the replacement of which by metallic screws could impair the insulation provided by the enclosure.

Where it has to be pierced by conductive parts (e.g. for operating handles of built-in equipment, and for screw) **protection against indirect contact** shall not impaired.

(8) Where a lid or door in an insulating enclosure can be opened without the use of a tool or key. Every accessible conductive parts shall be installed behind an "insulating barrier" which shall be:

(i) removable only by the use of a tool, **and**
(ii) at least IP2X or IPXXB.

(9) Conductive part enclosed in an insulating enclosure shall not be connected to a protective conductor.

Where a separate circuit runs through an enclosure which serve another item of equipment, any such protective conductor and its terminals and joints shall be insulated as though they were live parts and its terminals shall be appropriately marked.

6.3 Protection By Non-Conducting Location

To prevent simultaneous contact with parts which may be at different potential through failure of the basic insulation of live parts.

This measure is applicable only in special situations which are under effective supervision.

Not applicable to certain installations and locations of increased shock risk covered by Part 6 of the Code.

(1) (413-04-02) A person will not come into simultaneous contact with:

(i) two exposed-conductive-parts, or

(ii) an exposed-conductive-parts and any extraneous-conductive-part.

(2) There shall be no protective conductors, and any socket-outlet shall not incorporate an earthing contact.

A luminaire supporting coupler having a protective conductor contact shall not be used.

(3) The resistance of the floors and walls to the main protective conductor of the installation shall be measured at not less than three points on each relevant surface, one of which shall be not less than 1 m and not more than 1.2 m from any extraneous-conductive-part in the location. The other two measurements shall be made at greater distance.
The measured resistance shall be:

(i) $\geq$ 50 KΩ where the voltage to earth $\leq$ 500 V.

(ii) $\geq$ 100 KΩ where the voltage to earth >500 V but $\leq$ low voltage.

If at any point the resistance is less than the specified value, the floors and walls are deemed to be extraneous-conductive-parts for the purposes of protection against electric shock.

(4) Permanent arrangements shall be made which shall afford protection where the use of mobile or portable equipment is envisaged.

(5) Any potential on extraneous-conductive-parts in the location **CANNOT** be transmitted outside that location.

(6) Clause 413-04-02 [i.e. item (1) above] shall be deemed to be fulfilled if the location has an insulating floor and insulating walls and one or more of the following arrangements applies:

(i) the distance between "separated exposed-conductive-parts" and between exposed-conductive-parts and extraneous-conductive-parts is ≥ **2 m** or, for parts out of the zone of arm's reach ≥ **1.25 m.**

(ii) the interposition of obstacles made of insulating material between exposed-conductive-parts and extraneous-conductive-parts. They are sufficiently effective if they extend the distances to be surmounted to the values stated in item (i) above.

(iii) the insulation or insulating arrangement of extraneous-conductive-parts. The insulation shall be of adequate electrical and mechanical strength.

6.4 Protection By Earth-Free Local Equipotential Bonding

This measure is intended to prevent the appearance of a dangerous voltage between simultaneously accessible parts.

Only applicable under the **effective supervision of a skilled person** in special situations which are earth-free.

A **warning notice** complying with Clause 514-13-02 shall be fixed in a prominent position adjacent to every point of access to the location concerned.

This measure is not applicable to those installations and locations of increased shock risk. (refer to Part 6 of CP5:1998)

(1) An equipotential bonding conductor shall connect together every simultaneously accessible exposed-conductive-part and extraneous-conductive-parts.

(2) The local equipotential bonding conductors shall not be in electrical contact with Earth.

(3) Precautions shall be taken so that persons entering or leaving the equipotential location cannot be exposed to dangerous potential difference, in particular, where a conductive floor insulated from Earth is connected to the earth-free equipotential bonding conductors.

6.5 Protection By Electrical Separation

This measure is intended, in an individual circuit, to prevent shock current through contact with contact with exposed-conductive-parts.

Applicable to the supply of any individual item of equipment by means of a transformer to IEC 742 the secondary is not earthed, or a source affording equivalent safety.

Its use to supply several items of equipment from a single source is recognised in the code only under effective supervision, where specified by a skilled person. Warning notice complying with Clause 514-13-02 shall be fixed in a prominent position adjacent to every point access to the location concerned.

Common Requirement:

(1) (413-06-02) The source of supply shall comply with the following requirements:

(i) It shall be either

(a) an isolating transformer to IEC 742, or

(b) motor-generator set.

(ii) A mobile source of supply fed from a fixed installation shall be selected or installed in accordance with Clause 413-03 i.e. "Protection by use of Class II equipment or by electrical separation".

(iii) Equipment used as a fixed source of supply shall be either:

(a) selected & installed in accordance with Clause 413-03, or

(b) the output is separated from the input and from the enclosure by insulation satisfying Clause 413-03. If such a source supplies several items of equipments, exposed-conductive-parts of that equipment shall not be connected to the exposed-conductive-parts of the source.

(iv) the voltage $\leq$ 500 V

(2) The separated circuit shall comply with the following requirements:

(i) Live part of separated circuit shall be:

(a) not connected to another circuit, and

(b) not connected to earth.

(ii) every part of a flexible cable or cord liable to mechanical damage shall be visible throughout its length,

(iii) a separate wiring system shall be preferably be used for the separated circuit.

Alternatively, the following type of wiring system with overcurrent protection for each circuit:

(a) use multicore cables without metallic sheath, or
(b) insulated conductors in insulating conduit.

(iv) every live part of each separated circuit shall be electrically separated from all other circuits to a standard not less than that provided between the input & output windings of an isolating transformer to IEC 742. The same standard of electrical separation shall also be provided between live parts of relays, contactors etc included in the separated circuit and between them and live parts of other circuit.

Single Equipment:

(3) For a circuit supplying a single item of equipment, exposed-conductive-part of the separated circuit shall be:

(i) not connected to the protective conductor of the source, and

(ii) not connected to any exposed-conductive-part of any other circuit.

Multiple Equipments:

(4) A source of supply complying with Clause 413-06-02 [item (1) above] may supply more than one item of equipment provided that all the following requirements are fulfilled:

(i) Precautions must be taken to **protect** the separated circuit from **damage and insulation failure.**

(ii) every exposed-conductive-part of the separated circuit shall be connected together by an **insulated and non-earthed equipotential bonding conductor**. Such a conductor shall not be connected to a protective conductor or exposed-conductive-part of any other circuit or to any extraneous-conductive-part, and

(iii) every **socket-outlet** shall be provided with a **protective conductor contact** which shall be connected to the equipotential bonding conductor provided in accordance with item (i) above, and

(iv) every **flexible cable** of equipment other than Class II equipment shall embody a **protective conductor** for use as an equipotential bonding conductor, and

(v) it shall be verified that, if two faults to exposed-conductive-parts occur and these are fed by conductors of different polarity, an associated protective device will **meet the requirements of 413-02-04**, and

(vi) **no** exposed-conductive-part of the source shall be **simultaneously accessible** with any exposed-conductive-part in the separated circuit.

Locations Containing a Bath Tub or Shower Basin

FOR BONDING REQUIREMENTS SEE FIGURE D6

DISCONNECTION TIME

601 - 04 - 01

For circuits supplying equipment where such equipment is simultaneously accessible with exposed conductive parts or with other equipment or with extraneous conductive parts. A 0.4 second disconnection time must be achieved

STATIONARY APPLIANCE

601 - 12 - 01

No stationary appliance of which the heating elements can be touched to be installed within reach of person using bath or shower

601 - 07 - 01

No surface metallic enclosures; exposed earthing and bonding conductors

601 - 02 - 01

No electrical equipment to be installed in the interior of a bath tub or shower basin

ELECTRIC SHAVER

601 - 09 - 01

Shavers only connected through unit to BS 3535 and earth terminal of unit to be connected to its circuit protective conductor

NO SOCKET OUTLETS – except SELV

See below

601 - 10 - 02

There shall be no socket outlets and no provision for connecting portable appliances in rooms containing a fixed bath or shower (other than shaver and SELV sockets – see below)

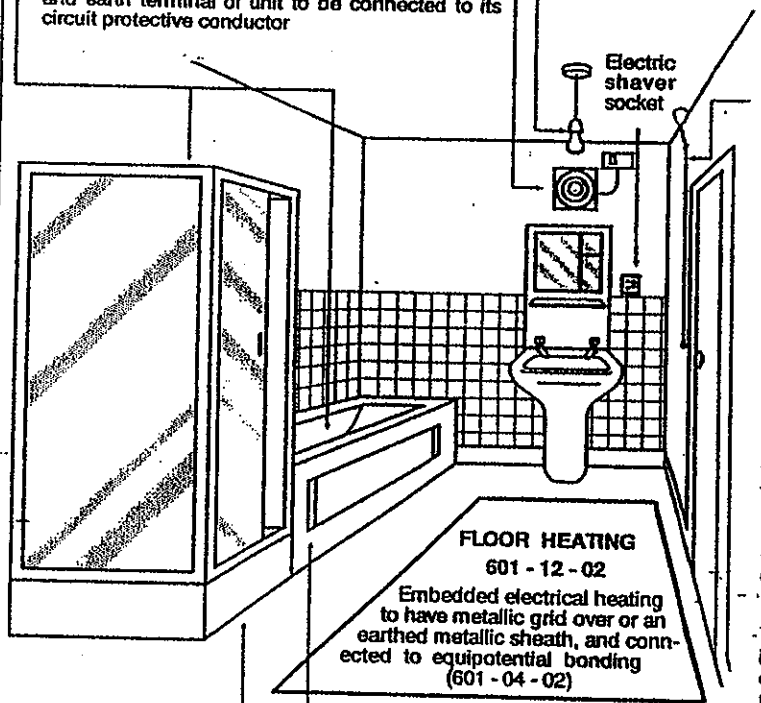
601 - 10 - 01

12V a.c. or d.c. SELV socket outlets may be installed in bathrooms out of reach of a person using the bath if the socket has no accessible metal parts and protection against direct contact with live parts in accordance with 411 - 02 - 09

LAMPHOLDERS

601 - 11 - 01

Parts of a lampholder within a distance of 2.5m from the bath or shower shall be constructed of, or shrouded in, insulating material. Bayonet type (B22) lampholders to have shield to BS 5042 (HO Skirt) or, as an alternative, totally enclosed luminaires may be used



SWITCHES AND CONTROLS

601 - 08 - 01

Every switch, electrical control or adjustment to be situated so as to be normally inaccessible to a person using the bath or shower – this does not apply to:

(i) insulating cords of switches

(ii) mechanical actuators with linkages incorporating insulating components, of remotely operated switches

* (iii) controls incorporated in water heaters and shower pumps complying with British Standards.

(iv) Switches supplied by SELV

(v) shaver supply units to comply with 601 - 09 - 01

* Notwithstanding (iii) above, it is recommended that a local cord-operated switch be provided for maintenance purposes. Cord operated switches which also provide isolation must be double pole, with adequate contact separation and clear mechanical indication of the switch position given only when both poles have achieved full separation. (Neon indicators do not suffice.) Alternatively, switches may be situated outside the bath or shower room

FLOOR HEATING

601 - 12 - 02

Embedded electrical heating to have metallic grid over or an earthed metallic sheath, and connected to equipotential bonding (601 - 04 - 02)

SHOWER CUBICLE

601 - 10 - 03

Where shower cubicles are located in rooms other than locations containing a bath tub or shower basin, any socket outlets shall be situated at least 2.5m from the cubicle

601 - 04 - 03

Bath panel to need a tool to remove it if electrical equipment installed behind

EARTHING REQUIREMENT FOR THE INSTALLATION OF EQUIPMENT HAVING HIGH EARTH LEAKAGE CURRENTS

1 Equipment with High Leakage Current

The following requirements shall apply to every installation supplying the following equipment:

(1) Equipment with leakage current flowing into the earth exceeding 3.5mA will be considered high leakage current, and

(2) Information technology equipment to SS 337 or IEC 950, and

(3) Industrial control equipment where the values of earth leakage current in normal service permitted by appropriate Standards necessitate special precautions being taken in the installation of equipment.

2 General Requirements

2.1 Earthing Arrangement for Functional Purposes

Where a clean (low noise) earth is specified for a particular item of equipment, the **manufacturer of the equipment shall be consulted** in order to confirm that the arrangements described herewith are suitable for functional purposes.

2.2 Earthing Arrangements for Combined Protective and Functional Purposes

The requirements for **protective measures shall take precedence.**

2.3 Exceptional Condition

For equipment complying with SS 337 or IEC 950 and with leakage current not exceeding 3.5mA, **only need to comply with the requirement of paragraph 2.8.**

2.4 Total Leakage Current and Residual Current Device

Where more than one item of stationary equipment having leakage current exceeding 3.5mA in normal service is to be supplied from an installation incorporating residual current device(RCD), the total leakage current does not exceed 25% of the nominal tripping current of the RCD.

Where compliance with this clause cannot be otherwise achieved, the items of equipment shall be supplied through a double-wound transformer or equivalent device as described in item (v) of paragraph 2.5 below.

2.5 High Integrity Protective Connection

The fixed wiring of every final circuit intended to supply an item of equipment having an earth leakage current exceeding 10mA in normal service (and for equipment indicated in paragraph 2.3) shall be provided with a high integrity protective connection complying with one or more of the following arrangements described in item (I) to (vi) below.

Except where paragraph 2.7 applies each protective conductor mentioned in item (I) to (vi) below shall comply with the requirement of paragraph 2.8.

(i) A single protective conductor with a cross-sectional area not less than $10mm^2$.

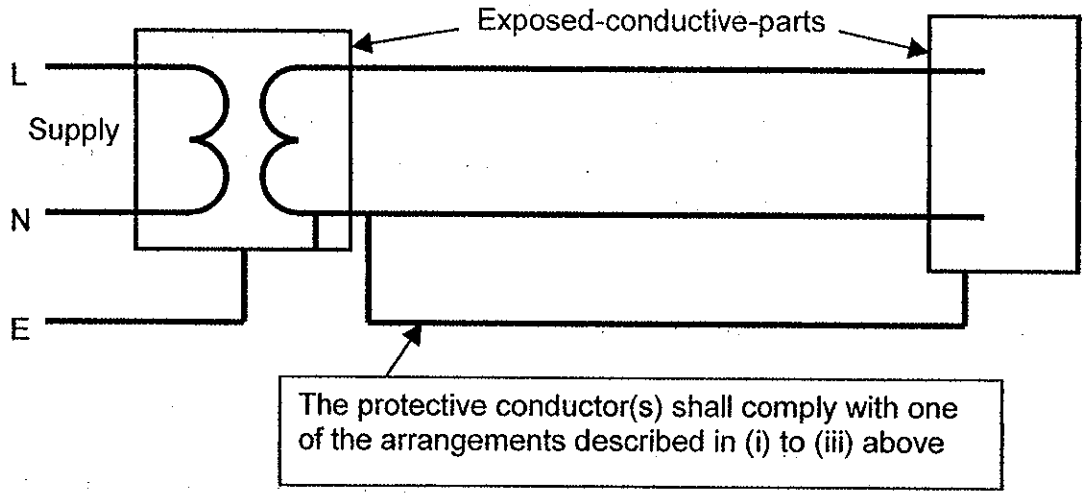
(ii) (ii) Separate duplicated protective conductors, having independent connections complying with Clause 526-01(Connection between conductors and between conductor and equipment), each having a cross-sectional area not less than $10mm^2$.

(iii) Duplicate protective conductors incorporated in a multi-core cable together with the live conductors of the circuit, provided that the total cross-sectional area of all the conductors of the cable is not less than $10mm^2$.

(iv) An earth monitoring device which, in the event of a discontinuity in the protective conductor, automatically disconnects the

supply in accordance with Clause 413-02-01 to 413-02-06 of CP5:1998, Protection by Earthed Equipotential Bonding and Automatic Disconnection of Supply.

(v) Use double-wound transformer.



2.6 Stationary Equipment with Earth Leakage Current Exceeding 3.5mA and up to 10mA

Stationary equipment which is either fixed, or equipment having a mass exceeding 18kg and not providing with handle.

It shall be either is permanently connected to the fixed wiring, or a plug and socket-outlet complying with IEC 309-2.

2.7 Stationary Equipment with Earth Leakage Current Exceeding 10mA

(1) It shall preferably be permanently connected to the fixed wiring of the installation, the permanent connection to the fixed wiring may be by means of a flexible cable. Alternatively, one of the following **precautions** shall be taken.

(i) The equipment may be connected by means of a plug and socket-outlet complying with IEC309-2 provided that the protective conductor of the associated flexible cable is supplemented by a separate contact and protective conductor having a cross-sectional area not less than

4mm^2, or the flexible cable complies with item (iii) of paragraph 2.5 with the second protective conductor connected via a separate contact within the plug.

(ii) An earth monitoring system to BS4444 may be installed which, in the event of a discontinuity in the protective conductor, automatically disconnects the supply in accordance with clause 413-02-01 of CP5:1998. (i.e. Protection by Earthed Equipotential Bonding and Automatic Disconnection of Supply for earthing system TN-S and TT system.)

2.8 Final Circuit Requirement

For a final circuit supplying a number of SSO in a location intended to accommodate several items of equipment, where it is known or is reasonably to be expected that the total earth leakage current in normal service will exceed 10 mA, the circuit shall be provided with a high integrity protective connection complying with one or more of the arrangements described in item (i) to (v) of paragraph 2.5

Alternatively, a ring circuit may be used to supply a number of single socket-outlets. There shall be no spur from the ring and the supply ends of the protective conductor ring shall be separately connected at the distribution board. The minimum size of the protective earth conductor ring shall be 2.5mm^2.

3 Requirement for TT System

(i) Verify that:

$$I_{Leakage} \times (2 \times R_{Electrode}) \leq 50 \text{ (volts)}$$

(ii) Where compliance with (i) above cannot be otherwise achieved the items of equipment shall be supplied through a double-wound transformer or equivalent device described in item (v) of paragraph 2.5 above.

4 Safety Requirement for Low Noise Earthing Arrangement

Low Noise Earth is defined as an earth connection in which the level of conducted or induced interference from external sources does not produce an unacceptable incidence of malfunction in the data processing or similar equipment to which it is connected. The susceptibility in terms of amplitude/frequency characteristics varies depending on the type of equipment.

(i) Each exposed-conductive-part of data processing equipment shall be **connected to the Main Earthing Terminal**.

(ii) This requirement shall also apply to metallic enclosures of class II and class III equipment and to a FELV circuit when this is **earthed for functional reasons**.

The earth conductor which serves a functional purpose only is not required to comply with Section 543 of CP5:1998. (i.e. Cross-sectional area of protective conductors)

ISOLATION AND SWITCHING

1.0 Definition

Switch -- A mechanical switching device capable of making, carrying and breaking under normal circuit conditions, which may include specified operating overload conditions, and also of carrying for a specified time currents under specified abnormal circuit conditions such as those of short-circuit. It may also be capable of making, but not breaking, short-circuit current.

Isolator -- A mechanical switching device which, in the open position, complies with the requirements specified for isolation. An isolator also called a disconnector.

Isolation -- A function to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy.

Circuit Breaker -- A device capable of making, carrying and breaking normal load currents and also making and automatically breaking, under pre-determined conditions, abnormal currents such as short-circuit currents. It is usually required to operate infrequently although some types are suitable for frequent operation.

Origin of an installation -- The position at which electrical energy is delivered to an electrical installation.

2.0 General Requirement

- Non-automatic isolation and switching to prevent or remove hazards.

- A main linked switch or linked circuit breaker shall be installed at the origin of every installation.

- Installation taking more than one source, durable **warning notice** shall be permanently fixed at a conspicuous position near to each main switch that is used to isolate the incoming supply.

- Neither an isolator (disconnector) nor a switch shall break a protective conductor. Except specially required by an installation taking more than one source of energy.

- A common device can be used to satisfy all the requirements for the various functions.

- Every circuit and final circuit shall be provided with a means of switching for interrupting the supply on load.

- Provision shall be made for disconnecting the neutral conductor.

3.0 Isolation

3.1 Definition of Isolation

A function to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy.

3.2 Requirements in an Installation

- Every circuit or group of circuits shall be capable of being isolated from each of the live supply conductors.
- Precautions to be taken against inadvertent or unintentional operation of the isolator.
- Durable warning notice shall be permanently fixed in a conspicuous position for those isolators that are used to supply a single equipment or an enclosure contains live parts.
- Each isolator for used in an installation shall be clearly identified.

3.3 Devices for Isolation

- **Distance** between contacts when in the open position shall be not less than that as stipulated in IEC 947-3 for isolator (disconnector).

- **Position** of the contacts shall be either externally visible or clearly and reliably indicated.

- Prevent **unintentional reclosure** such as due to mechanical shock or vibration.

- Securing an **off-load isolator** against inadvertent and unauthorised operation.

- Multipole isolation can be achieved by the use of either a **single device** or **single-pole devices** which are situated adjacent to each other.

- Neutral link shall be either operated with the tools or/and accessible to skilled persons only.

- A plug and socket-outlet may be used as an isolator.

3.4 Prohibition of Devices for use as Isolator

Semiconductor device cannot be used as isolator.

3.5 Erection of Isolator

- Isolator shall be **interlock** with the associated circuit-breaker, alternatively it shall be so **placed and or guarded** that only skilled persons can operate it.

- Isolator is placed remotely from the equipment to be isolated, Key or handle shall be **non-interchangeable** with any others used for a similar purpose within the installation.
- Isolator shall be provided for every **motor circuit**.

- Isolator shall be provided for every electric **discharge lighting** installation operating normally at an open-circuit voltage exceeding low voltage, one or more of the following shall be provided.

1) An **interlock** on a self-contained luminaire, in additional to the switch normally used for controlling the circuit.
2) An effective **local means of isolation** of the circuit from the supply, in additional to the switch normally used for controlling the circuit.
3) A switch having a **lock** or **removable handle**, or a distribution board which can be locked. All locks and handles used in an installation shall be non-interchangeable.

4.0 Switching off for Mechanical Maintenance

4.1 Purpose

Prevent risk of burns or a risk of injury from mechanical movement when carry out mechanical maintenance. Mechanical maintenance is defined as replacement, refurbishment or cleaning of lamps and non-electrical parts of equipment, plant and machinery.

4.2 Devices for Switching Off For Mechanical Maintenance

- manually operated.
- with externally visible contact gap or a clearly and reliably indicated OFF or OPEN position.
- prevent unintentional reclosure.
- capable of cutting off the full load current.

4.3 Erection of Devices For Mechanical Maintenance

- inserted in the main supply circuit or inserted in the control circuit to provide a degree of safety equivalent to that of interruption of the main supply.

- suitably located for operation.

- durably mark for identification.

- prevent unintentionally or inadvertently reactivated. (wit exception)

5.0 Emergency Switching

5.1 Definition

An operation intended to remove, as quickly as possible, danger, which may have occurred unexpectedly.

5.2 Requirement In an Installation

- provided for every part of an installation where emergency switching is foreseen.
- operation of the emergency switching must not introduce a further hazard or interfere with the complete operation necessary to remove the hazard.
- emergency stopping shall be provided where mechanical movement of electrically actuated equipment may give rise to danger.
- Every fixed or stationary appliances: (1) may gives rise to danger, and (2) connected to the supply other than by means of plug and socket-outlet.

5.3 Devices For Emergency Switching

- Capable of cutting off the full load current.
- Manually operated.
- Operating means (e.g. handle or push button) shall be (1)clearly identifiable, (2) preferably coloured red and (3) latching type.
- A single switching device or a combination of several items of equipment operated by a single action. (remote control)
- Fireman's emergency switch.

5.4 Prohibition of Device for Use as Emergency Switching

Plug and Socket-outlet.

5.5 Erection of Emergency Switching Device and Circuit Arrangement

- Readily accessible
- Circuit-breaker or a contactor operated by remote control shall open on de-energisation of the coil.
- Operating means automatically resets is permitted where both that operating means and the means of re-energisation are under the control of one and the same person.

6.0 Functional Switching (control)

6.1 Definition

An operation intended to switch 'ON' or 'OFF' or vary the supply of electrical energy to all or part of an installation for normal operating purposes.

6.2 Requirements and Arrangement of Circuit

- Part of a circuit which may require to be controlled independently of other parts of the installation.
- Not necessary to control all the live conductors.
- All current-using equipment requiring control shall be controlled by an appropriate functional switching device.
- A single functional switching device may control several items of equipment intended to operate simultaneously.
- Functional switching devices which are used for change-over of supply from alternative sources shall (1) switch all live conductors, (2) prevent paralleling of the sources except special case and (3) not switch the protective conductor except specifically design for it.

6.3 Devices for Functional Switching

- Semiconductor switching devices.
- Switched socket-outlet
- Switch complying with SS227.

6.4 Prohibition of Devices For Use as Functional Switching

- Off load isolators (disconnectors)
- Fuses
- Links
- Plugs and socket-outlets without incorporation of a switch.

Equipment Selection – Common Rules

Equipment Selection – Common Rules

Chapter 51 of the Wiring Regulations deals with the common rules for selection and erection of equipment and is made up of five principal sections:

- compliance with Standards,
- operational conditions and external influences,
- accessibility,
- identification and notices, and
- mutual detrimental influences.

The requirements embodied in Chapter 51 are common rules and as such must be applied to every installation irrespective of its location and environment.

SELECTION AND ERECTION OF EQUIPMENT

1.0 Compliance with Standards

- Singapore Standard.
- Foreign national standard based on an IEC Standard – not result in a lesser degree of safety than that afforded by compliance with the Singapore Standard.
- Person responsible for specifying the installation shall confirm that the equipment provides the same degree of safety as that afforded by the CP5.

2.0 Operational Conditions and External Influences

- Voltage.
- Current – design current, current flow under abnormal condition.
- Frequency – affect the characteristic of the equipment.
- Power – suitable for the duty demand.
- Compatibility – (1) No harmful effects and (2) Do not impair the supply.
- External influences – appropriate design and correct mode of installation.

3.0 Accessibility

Facilitate operation, inspection, maintenance and access to each connection.

4.0 Identification and Notices

- Conduit – Orange colour to BS 1710.
- Protective conductor – Colour combination GREEN and YELLOW is reserved exclusively.
- Non-flexible cable and conductor – colour identification in accordance with table 51A (L).
- Flexible cables and flexible cords – Table 51B.
- Protective device.

4.1 Diagram

A legible diagram, charts or table.

- Type and composition of each circuit.
- Method used for compliance with clause 413-01-01 and the data required by clause 413-02-04.
- Information necessary for the identification of each device performing the functions of protection, isolation and switching, its location.
- Any circuit or equipment vulnerable to a test.
- Symbol used shall comply with SS 202.

4.2 Warning Notices – Voltage

- A voltage exceeding 250V, which is not normally been expected, is presence within an item of equipment or enclosure.
- Live parts between which a voltage exceeding 250V exists are housed in separate enclosures or items of equipment, which can be reached simultaneously by a person.

4.3 Warning Notice – Isolation

For live parts which are not capable of being isolated by a single device. The location of each isolator (disconnector) shall be indicated.

4.4 Notice – Periodic Inspection and Testing

To be fixed in a prominent position at or near the origin of every installation.

4.5 Warning Notice – Earthing and Bonding Connections

"Safety Electrical Connection – Do Not Remove" shall be fixed near

- The point of connection of every earthing conductor to an earth electrode.
- The point of connection of every bonding conductor to an extraneous-conductive-part.
- The main earth terminal, where separate from main switchgear.

WARNING NOTICES

CAUTION 400 VOLTS

CAUTION

400 Volts between this equipment and adjacent socket

CAUTION

Enclosure contains circuits with voltages at
400 Volts
230 Volts
24 Volts

4.6 Mutual Detrimental Influence

- Avoid any harmful influence between the electrical installation and any non-electrical installation envisaged.

- Equipment carrying current of different types or at different voltages is grouped in a common assembly, all the equipment belonging to any one type of current or any one voltage shall be effectively segregated.

SELECTION AND ERECTION OF WIRING SYSTEM

1.0 Selection of Type of Wiring System

1.1 Cables and Conductors For Low Voltage System

- Conductor shall be of copper –
  (1) for conductor size 10 mm sq or less,
  (2) domestic installation.

- Busbar trunking system – IEC 439-2.

- Conductor for use as an overhead lines for LV circuit – appropriate BS.

- Flexible cable & flexible cord for fixed wiring – comply with CP5:1998.

1.2 Cables For A.C. Circuits – Electromagnetic Effect

- Prohibit the use of single-core cables armoured with steel wire or tape.

- Enclose in ferromagnetic enclosure – All the phase, neutral and protective conductors of the same circuit are contained in the same enclosure.

- Prevent eddy current flow in the ferromagnetic material.

1.3 Electromechanical Stress

Correct method of installation to withstand the force.

1.4 Conduit And Conduit Fittings

- Steel conduit and fitting.
- Flexible steel conduit
- Steel conduit fittings with metric threads.
- Non-metallic conduits and fittings.

1.5 Trunking, Ducting and Fittings

- SS 249
- Non-metallic type, it shall be made of insulating material complying with the ignitability characteristic 'P' of BS 476 Part 5.

1.6 Lighting Track Systems

- Comply with IEC 570.

1.7 Methods of Installation of Cables and Conductors

- Appendix 4, Table 4A.
- Specified by a suitable qualified electrical engineer and subject to the concurrence of the supply authority.
- Non-sheathed cables for fixed wiring shall be enclosed in conduit, ducting or trunking.

2.0 SELECTION AND ERECTION IN RELATION TO EXTERNAL INFLUENCES

Influences from sources external to the installation which may affect the design and safe operation of the installation.

A – Environmental conditions.

B – Type of utilisation of premises.

C – Type of building construction.

2.1 Ambient Temperature (AA)

- Suitable for the highest and lowest local ambient temperature.
- Installed or handled only at temperatures within the allowable limits.

2.2 External Heat Source

- Shielding.
- Away from the heat source.
- Design to withstand the additional temperature rise.
- Reducing the current-carrying capacity.
- Local reinforcement or substitution of insulating material.

2.3 Presence of Water (AD) or High Humidity (AB)

- Design to withstand it.
- Water from the wiring system shall be able to escape safely.

2.4 Presence of Solid Foreign bodies (AE)

- Minimise the ingress of solid foreign bodies.
- Prevent the accumulation of dust which can affect the heat dissipation from the wiring system.

2.5 Presence of Corrosive or Polluting Substances (AF)

- Suitably protected against it.
- Use materials resistant to such subtances.
- Metals liable to initiate electrolytic action shall be segregated apart.
- Materials liable to cause mutual or individual deterioration or hazardous degradation shall be segregated apart.

2.6 Impact (AG)

- Design minimise mechanical damage.
- Subjected to Medium Severity (AG2) or High Severity (AG3), protected by

  (1) the mechanical characteristic of the system, OR

  (2) the location selected, OR

  (3) the provision of additional local or general mechanical protection, OR

- Cable buried in the Ground.

  (1) Cable used shall be of a construction incorporating an EARTHED ARMOURED or METAL SHEATH or BOTH.

  (2) Installed in a conduit or duct.

- Wiring system buried in a floor – e.g. protected by conduit.

- Cable passed through a timble joist within a floor, ceiling construction or through a ceiling support (e.g. under floorboard).

  (1) Installed at least 50 mm measured vertically from the top, or bottom as appropriate, of the joist or batten. OR

  (2) Cable shall incorporate an EARTHED METALLIC SHEATH as protective conductor. OR

  (3) Installed in EARTHED steel conduit SECURELY supported. OR

  (4) Provide equivalent mechanical protection SUFFICIENT to prevent penetration of the cable by nails, screws, and the like.

- Conceal within a wall or partition at a depth of less than 50 mm from the surface.

  (a) Shall comply with the requirements (1), (2) and (3)

  (1) Cable shall be installed within 150 mm of the top of the wall or partition.

  (2) Cable shall be installed within 150 mm of an angle formed by two adjoining walls or partition.

  (3) Cable installed outside the above mentioned zones only in straight runs either HORIZONTALLY or VERTICALLY to the point locate outside the zone. OR

  (b) Cable shall incorporate an EARTHED metallic covering. OR

  (c) Cable shall be installed in EARTHED metallic conduit, trunking or ducting system as a protective conductor. OR

  (d) Provide equivalent mechanical protection SUFFICIENT to prevent penetration of the cable by nails, screws, and the like.

2.7 Vibration (AH)

Design to withstand such vibration.

2.8 Other Mechanical Stresses (AJ)

- Minimise damage to the sheath and insulation of the cable. – e.g. drawing cable through a conduit or ducting system.

- At least supported by SUITABLE MEANS at APPROPRIATE INTERVALS to prevent damaged to the conductor, cable or termination by its own weight.

- No mechanical strain on the termination of the conductor.

- Avoid excessive tensile and torsional stresses to the conductors and connections of flexible wiring system.

2.9 Presence of Flora and/or Mould Growth (AK)

- Selected accordingly.

- Adopt special protective measure.

2.10 Presence of Fauna (AL)

- Selected accordingly.
- Adopt special protective measure.

3.0 CURRENT-CARRYING CAPACITY OF CONDUCTORS

3.1 Conductor Operating Temperature

Indicated in Appendix 4 of CP5:1998.

3.2 Conductors In Parallel

- Connected in the SAME PHASE of the supply
- Same construction.
- Same material.
- Same cross sectional area.
- Approximately the same length.
- No branch circuit.
- Appropriate phase disposition.

3.3 Cable Connected to Bare Conductor Busbar

Insulation and/or sheath of the cable shall be suitable for the maximum operating temperature of the bare conductor or busbar. (e.g. 90 degree C).

3.4 Cables in Thermal Insulation

- Totally surrounded by thermally insulating material over a length of MORE than 0.5m, current-carrying capacity = 0.5 x current-carrying capacity of that cable clipped direct to a surface and open (REFERENCE METHOD 1).

- Cable with conductor of size up to 10 sq. mm and totally surrounded by thermal insulation for less than 0.5m, the current-carrying capacity shall be taking into consideration of the derating factor of Table 52A.

Table 52A
Cable surrounded by thermal insulation

Length in insulation (mm)	Derating Factor
50	0.89
100	0.81
200	0.68
400	0.55

3.5 Metallic Sheaths and / or Non-magnetic Armour of Single-Core Cable

- Solid bonding – Bonded to earth at both ends for all the cables in the same circuit
  OR

- Single point bonding

  (a) For cable with conductor size exceeding 50 sq. mm.

  (b) With a non-conducting outer sheath.

  (c) Armour or metallic sheath shall be bonded together at one point to earth.

  (d) Un-bonded ends shall be insulated with suitable insulation.

  (e) At full load current, voltage from armour and / or metallic sheath to Earth:

    (1) Shall not exceed 25 Volts.

    (2) Do not cause corrosion.

    (3) Do not cause danger or damage to property under short circuit condition.

4.0 CROSS SECTIONAL AREAS OF CONDUCTORS

4.1 Phase Conductor in A.C. Circuits and Live Conductors in D.C. Circuits

Not less than that as specified in Table 52C.

4.2 Neutral Conductors For Polyphase Circuit

- Serious imbalance is unlikely to occur in normal service:

  (1) Multicore cables incorporating a reduced neutral conductor comply with SS or BS may be use. OR

  (2) For single core cables area used, N-conductor shall have a x-area appropriate to the expected value of the N-current.

- Imbalance may occur in normal service:

  N-conductor shall have a x-area adequate for the maximum current likely to flow in it in order to comply with Table 52B.

- For discharge lighting circuits:

  N-conductor shall have a x-area not less than that of the phase conductor (s).

5.0 VOLTAGE DROP IN CONSUMER'S INSTALLATION

- Voltage at the terminals of any fixed current-using equipment shall be greater than the lower limit as specified in the SS relevant to the equipment.

- Voltage drop between the origin of the installation (supply terminal) and a socket outlet or the terminals of the fixed equipment does not exceed 4% of the nominal voltage of the supply.

- During the starting period of a motor or other high inrush current equipment, the voltage variations are within the limits specified in the SS or manufacturer's recommendation.

6.0 ELECTRICAL CONNECTIONS

6.1 Connection Between Conductors and Between A Conductor And Equipment

Provide durable electrical continuity and adequate mechanical strength.

6.2 Selection of Means of Connection

(a) Material
(b) Number & shape of wire (e.g. screwless terminal)
(c) X-area
(d) Number of conductors
(e) Temperature attained – insulation not impaired under normal service.
(f) Soldered connection – consider creep, mechanical stress & temperature rise under fault current conditions.
(g) Adequate locking – vibration or thermal cycle.

6.3 Enclosed Connections

- Enclosure shall provide adequate mechanical protection and protection against relevant external influences.

- Types of enclosure:

  (a) Accessory complies with SS or BS.

  (b) Equipment enclosure complies with SS or BS.

  (c) Material of the enclosure complies with the relevant glow wire test requirements of IEC 695-2-1.

  (d) Building material used for the enclosure complies with BS 476 Part 4.

  (e) Building structure complies the ignitability characteristic 'P' as specified in BS 476 Part 5.

6.4 Accessibility of Connections

- For inspection.
- Exception:

  (a) Compound-filled or encapsulated joint.

  (b) Connection between a cold tail and a heating element. (e.g. a ceiling and floor heating system, a pipe trace-heating system).

  (c) Joint made by welding, soldering, brazing or compression tool.

7.0 SELECTION AND ERECTION TO MINIMISE THE SPREAD OF FIRE

7.1 Risk of Spread of Fire

- Minimised by selection of an appropriate material. AND
- Erection in accordance with Section 527.
- For non-combustible building material which is used to enclose the wiring system shall have ignitability characteristic 'P' as specified in BS 476 Part 5.

7.2 Sealing of The Wiring System Penetration

- Remaining openings shall be sealed according to the degree of fire resistance required of the element concerned.

- For conduit, cable ducting, cable trunking, busbar or busbar trunking penetrate elements of building construction having specified fire resistance, their internal and external space shall be sealed so as to maintain the degree of fire resistance of the respective element.

- Sealing material used shall:

  (a) be compatible with the material of the wiring system with which it is in contact

  (b) permit thermal movement of the wiring system.

  (c) be removable without damage to existing cable.

  (d) Resist relevant external influences.

7.3 Erection Conditions

- During erection – provide temporary sealing arrangements.

- During alteration – reinstate sealing material as soon as possible.

7.4 Verification

- Visual inspection.

- Details shall be recorded.

8.0 PROXIMITY TO OTHER SERVICES

8.1 Proximity to Electrical Services

- Low voltage circuit shall be separated from an extra-low voltage circuit.

- Low voltage circuit can be contained within the same wiring system under any of the following method of installation:

  (a) Multicore cable:

  (1) Each conductor is insulated for the highest voltage present. OR

  (2) Enclosed within an earthed metallic screen of current-carrying capacity equivalent to that of the largest conductor enclosed within the screen. OR

  (3) Cables are insulated for their respective system voltages and installed in separate compartment of a cable ducting or cable trunking system, or have an earthed metallic covering.

- Fire alarm and emergency lighting circuits shall be segregated from all other cables and from each other in accordance with SS CP 19 and SS CP 10.

8.2 Proximity to Non-Electrical Services

- Wiring system shall be suitably protected against any hazards arises due to other services.

- Protection against indirect contact. (Section 413)

- Wiring system shall be protected against deleterious effects due to other services which produce:

  (a) Heat, smoke or fume.

  (b) Water, steam or gas.

- Segregated from or bonded to the fixed metalwork of other services.

- Only cable forms part of lift installation can be installed in the lift (or hoist) shaft.

9.0 SELECTION AND ERECTION IN RELATION TO MAINTANABILITY INCLUDING CLEANING

- Reinstatement of the protective measures to the original degree of protection.

- Provision for the safe and adequate access to all parts of the wiring system which may require maintenance.

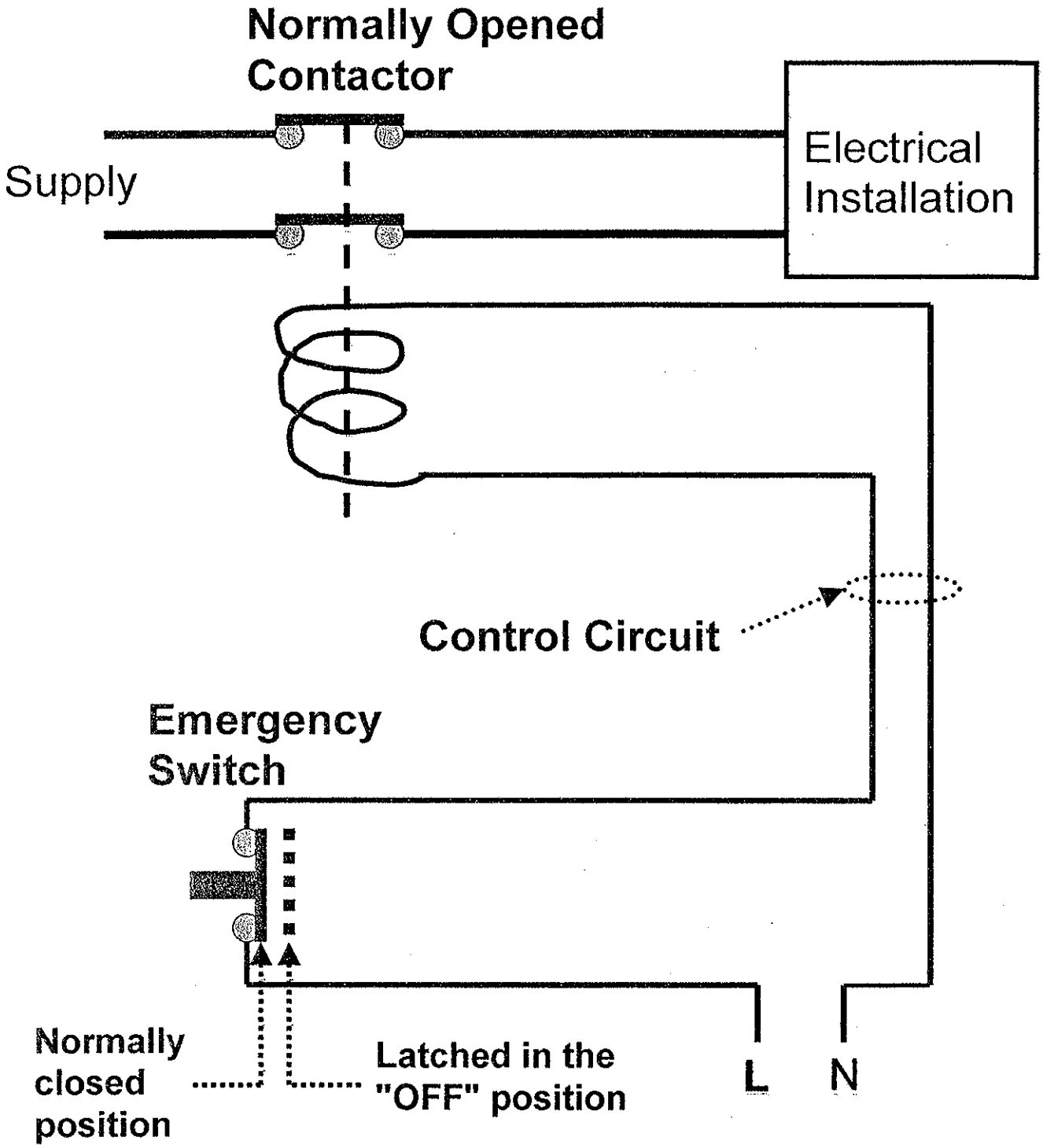


Fig (A1) Control Circuit Failed-Safe

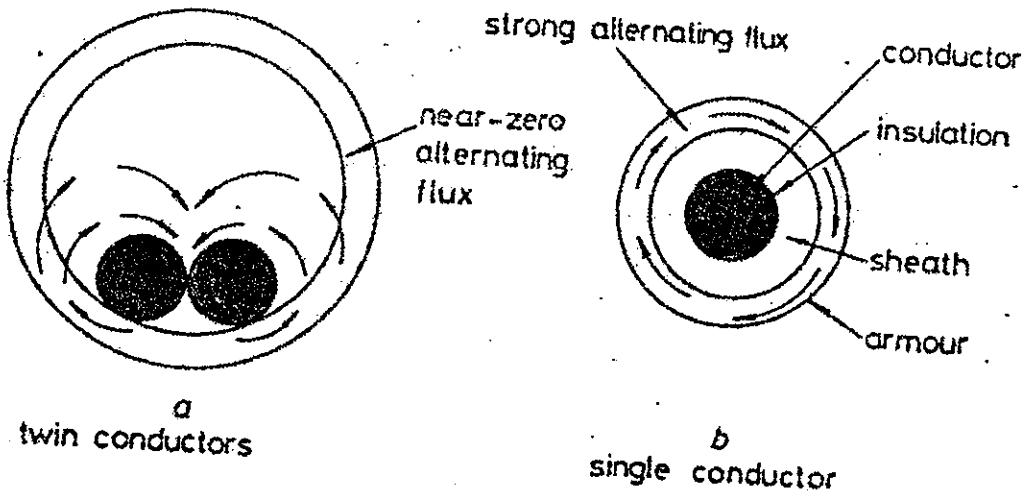


Fig. 5.3 *Iron losses in the steel armour of a cable carrying alternating current*
a Twin conductors: ampere-turns cancel
b Single conductor: strong magnetic flux set up in armour

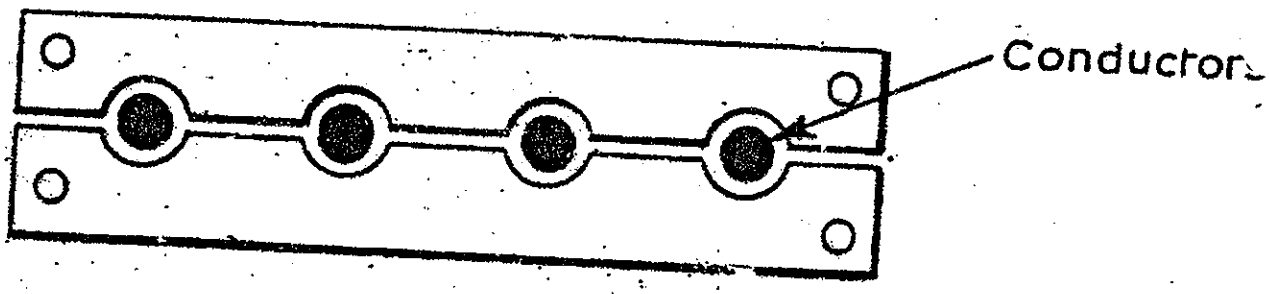


Figure 3.1 Means of preventing appreciable eddy currents in ferrous gland plate.

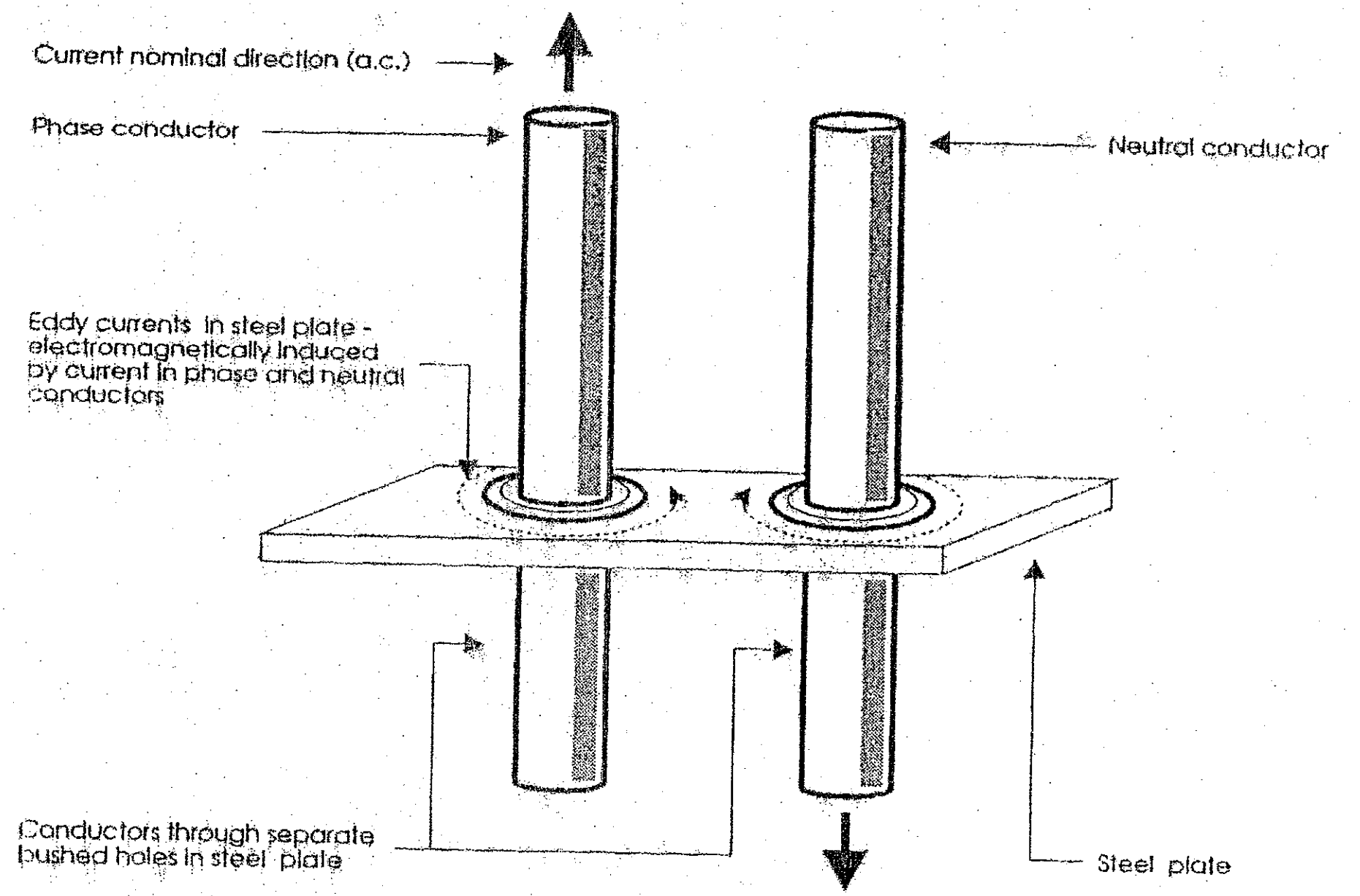


Figure 10.19: The eddy-current effect

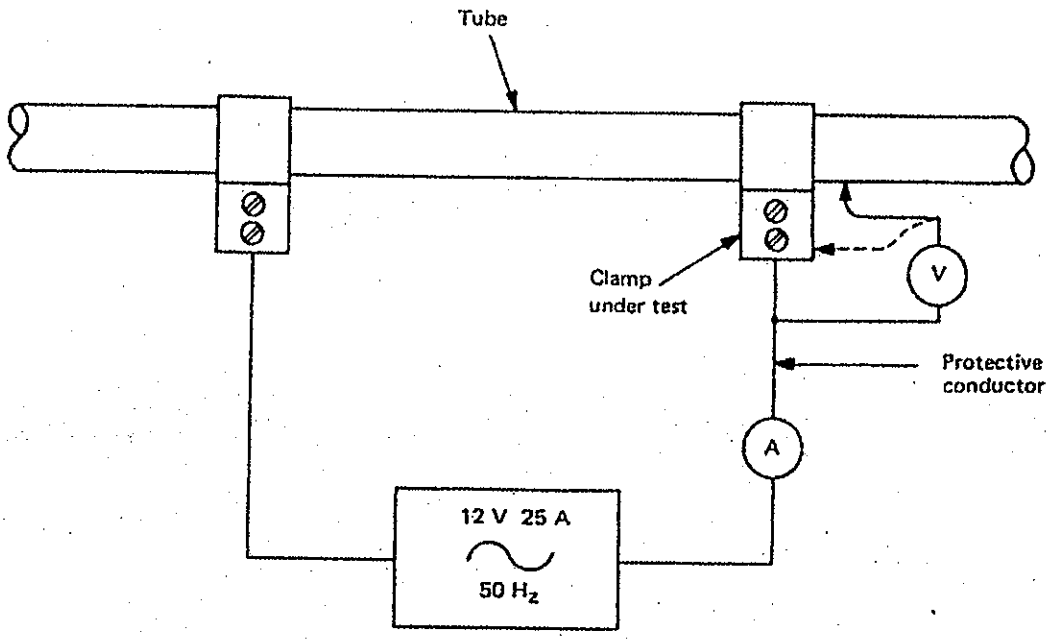
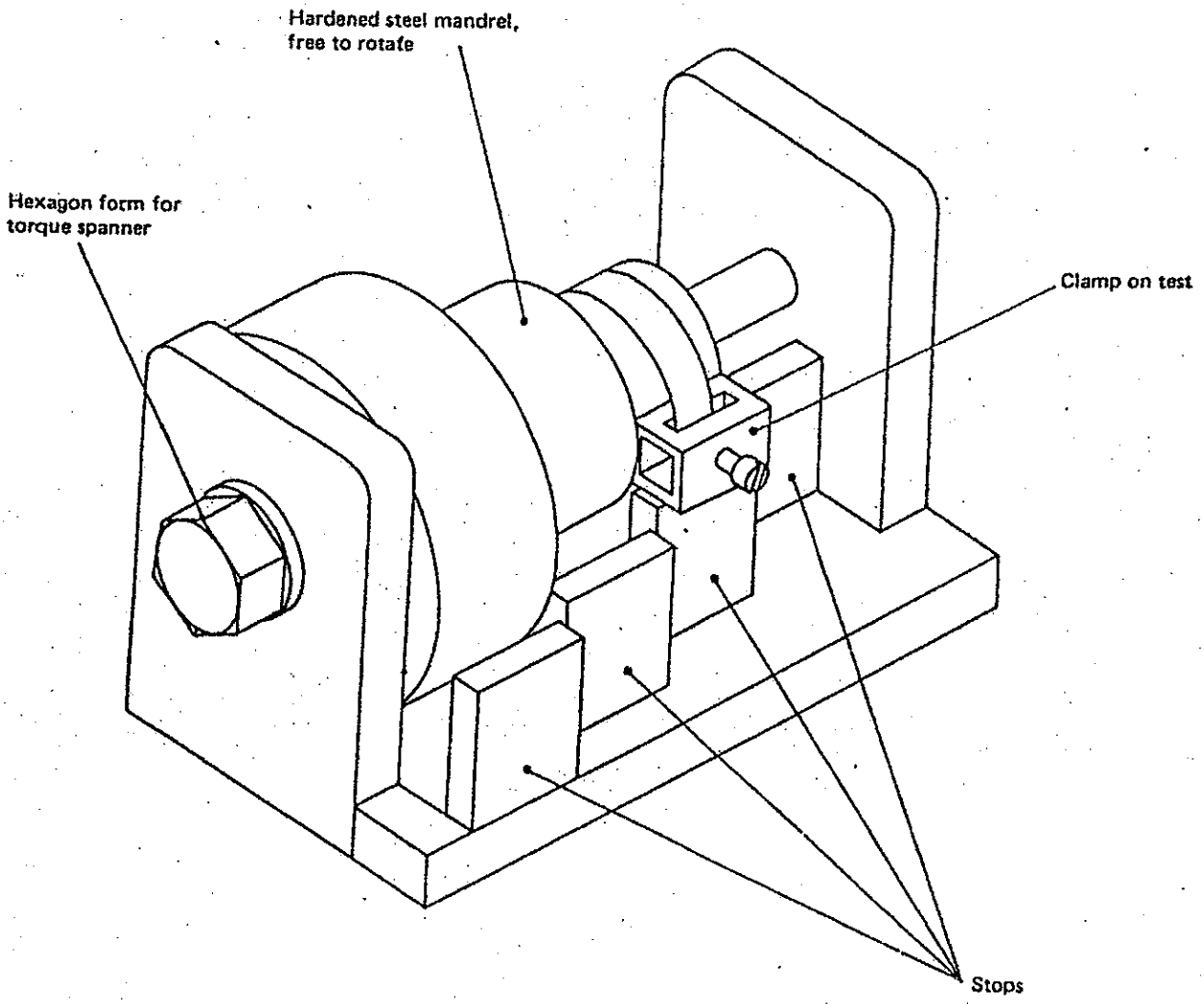


Figure 1. Arrangement for the measurement of electrical resistance



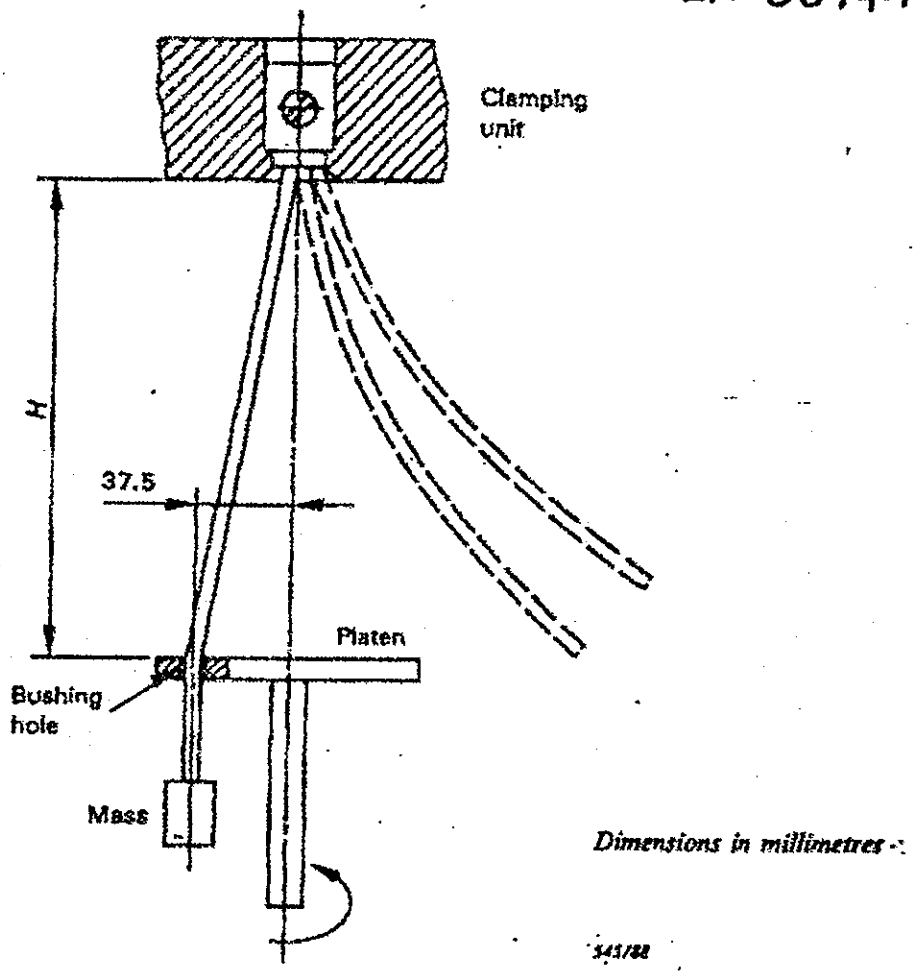


FIG. 1. — Test equipment for flexion test.

Each conductor is subjected to circular motions according to the following procedure:

The end of the conductor under test shall be passed through an appropriate size bushing in a platen positioned at a height *H* below the equipment terminal, as given in Table V. The other conductors shall be bent in order not to influence the result of the test. The bushing shall be positioned in the horizontal platen concentric with the conductor. The bushing shall be moved so that its centre-line describes a circle of 75 mm diameter about its centre in the horizontal plane at 10 rpm ± 2 rpm. The distance between the mouth of the terminal and the upper surface of the bushing shall be within 13 mm of the height *H* in Table V. The bushing is to be lubricated to prevent binding, twisting or rotation of the insulated conductor. A mass as specified in Table V is to be suspended from the end of the conductor. The test shall consist of 135 continuous revolutions.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

Immediately after the flexion test, each conductor under test shall be submitted in the test equipment to the test of Sub-clause 8.2.4.4 (pull-out test).

CONCEALED ELECTRICAL WIRING

1 Introduction

The method of installation of electrical wire concealed in the wall shall depend on the depth at which the wire is installed. Regulation 15 of the Electricity (Electrical Installations) Regulations with revised edition 2004 has stipulated the requirement.

2 Requirement

(1) Automatic Disconnection Device

Concealed electricity cables shall be controlled by a high-sensitivity direct-acting residual current circuit breaker.

(2) Concealed wiring installed in an electrical installation at a depth of less than 50 mm from the surface

The type of wiring shall be either:

(i) Metallic sheathed cable. or

(ii) Non-metallic sheathed cable or Non-sheathed cable shall be installed inside metallic conduit or trunking.

(3) Concealed wiring installed in an electrical installation at a depth of 50 mm or more from the surface

The type of wiring shall be:

(i) A sheathed and polyvinylchloride insulated cable; or

(ii) Any other electricity cable approved by the Authority.

3 Example of Concealed Wiring

Picture 1 shows the high impact UPVC conduit is laid within the floor and with an up right turn. The portion of the up right turn is to be laid within the lower part of the wall. The end of the UPVC conduit shall be joined to the metallic conduit which is to be concealed in the wall.

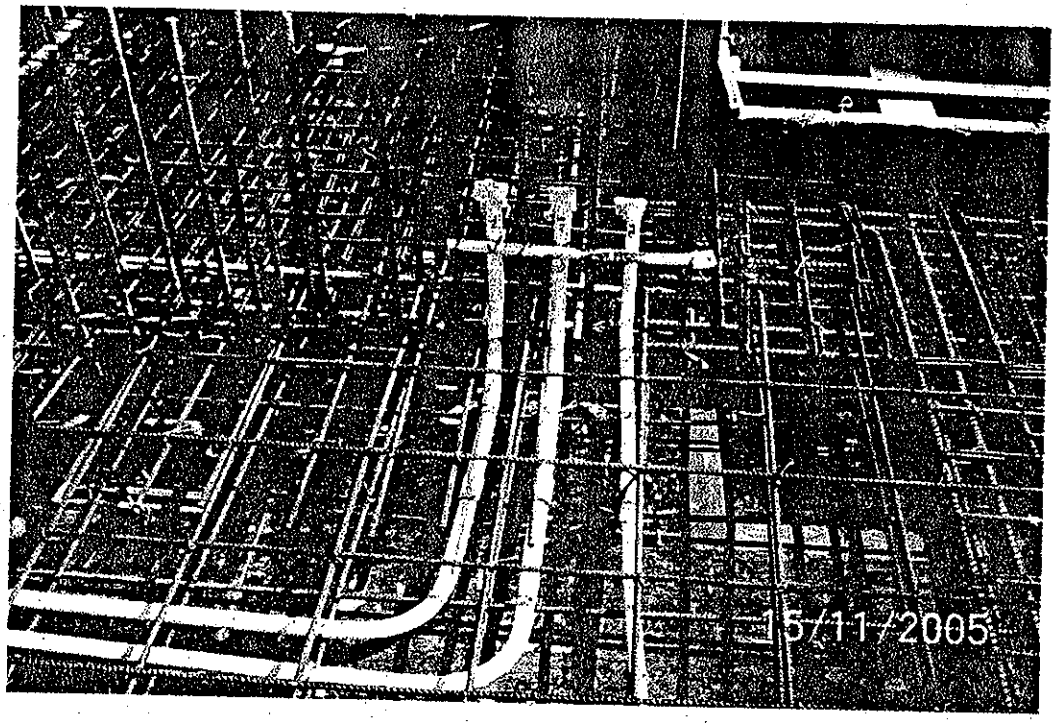


Fig (2) shows the conceal UPVC conduits and metallic conduit which have emerge from the floor and lay within the wall. The four pieces of white colour UPVC conduit on the left in the picture are for signal cables. The other two metallic conduits on the right are for low voltage electrical cables. Noticed that the electrical metallic conduits are joined to its lower portion of UPVC conduits.

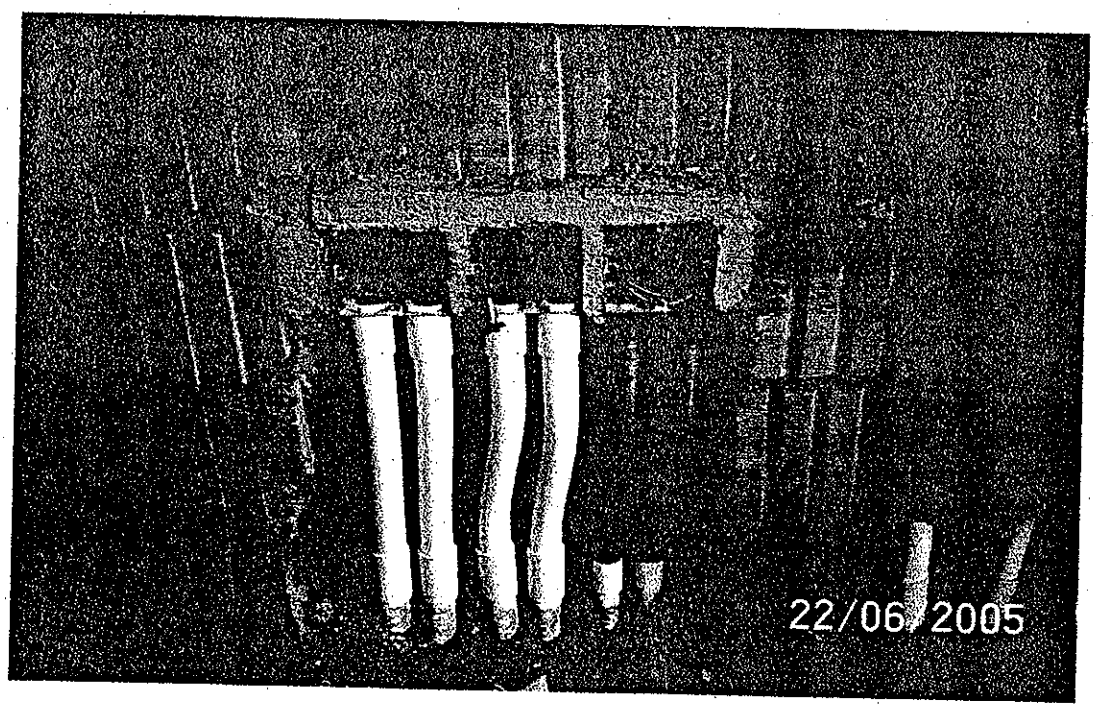


Fig (3) is another picture which show the left two electrical metallic conduits are joined to its lower UPVC conduits. The provision of short length of UPVC conduit, which lay through the floor, will provide flexibility for the joining of metallic conduit which is not flexible.

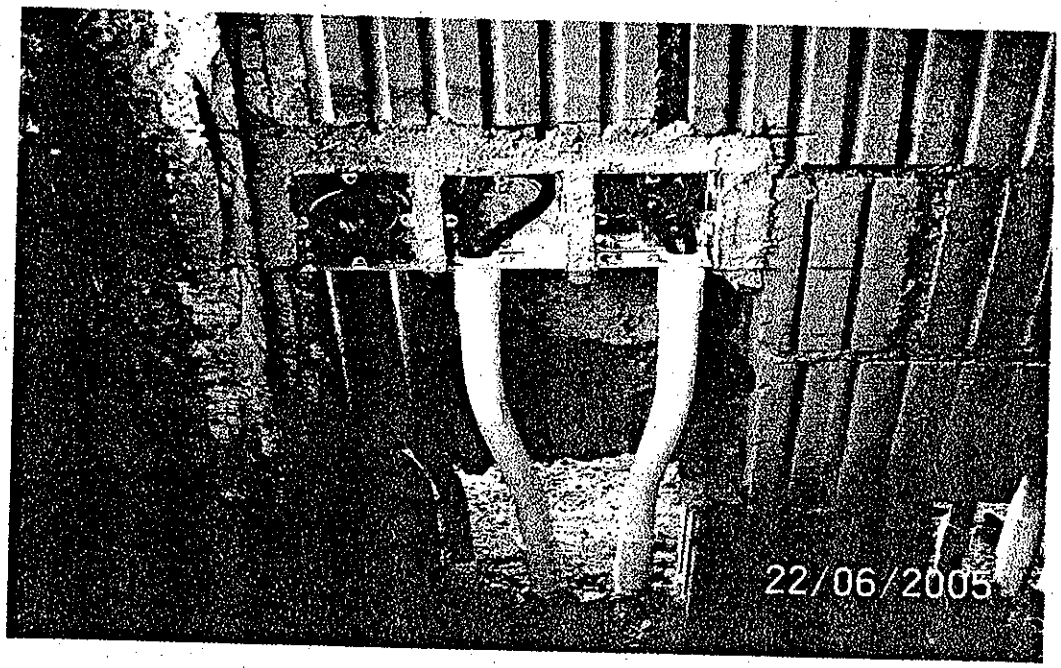


Fig (4) shows the two short length of UPVC conduits (white colour conduit) which lay through the floor slab with its lower portion which are joined to the electrical metallic conduit.

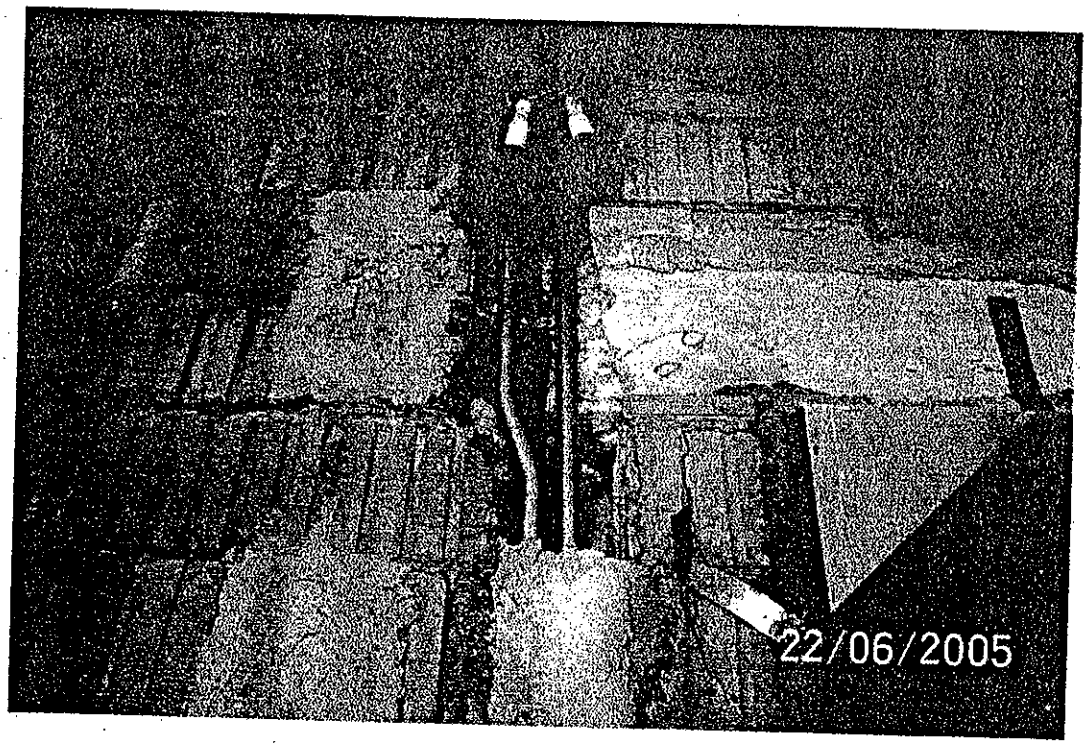
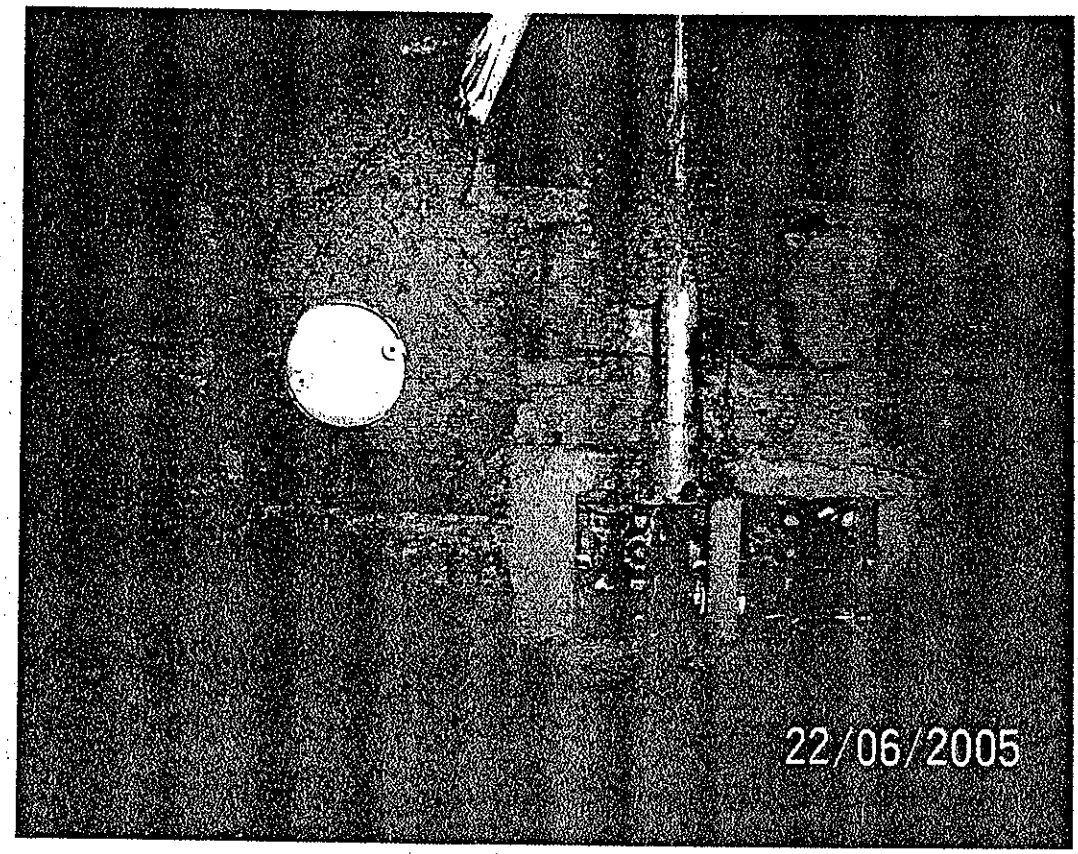


Fig (5) shows the metallic outlet box which is joined to the metallic conduit and need to be earthed.



4 Conclusion

In the Singapore Standard, Code of Practice CP5: 1998, Clauses 522-06-06 and 522-06-07 have stipulated the requirement for a cable to be concealed within a wall or partition of less than 50 mm from the surface. However, the requirement as stipulated in the Regulation shall be fully complied with for concealed wiring installed in an electrical installation.

SWIMMING POOLS

1 Scope

Requirements apply to:

(1) Basins of swimming pool, and

(2) Paddling pool, and

(3) Their surrounding zones where the risk of electric shock is increased by a reduction in body resistance and contact of the body with earth potential.

2 Assessment of General Characteristic

(1) **Zone A** is the interior of the basin, chute or flume and includes the portions of essential apertures in its walls and floor which are accessible to persons in the basin.

(2) **Zone B** is limited:

by the vertical plane 2 m from the rim of the basin, and

by the floor or surface expected to be accessible to person, and

by the horizontal plane 2.5 m above that floor or surface except where the basin is above ground, when it shall be 2.5 m from the level of the rim of the basin.

Where the building containing the swimming pool contains diving boards, spring boards, starting blocks or a chute, Zone B includes also the zone limited by – the vertical plane spaced 1.5 m from the periphery of diving boards, spring boards and starting blocks, and within that zone, by the horizontal plane 2.5 m above the highest surface expected to be occupied by persons, or to the ceiling or roof if they exist.

(3) **Zone C** is limited:

by the vertical plane circumscribing Zone B, and the parallel vertical plane 1.5 m external to Zone B, and

by floor or surface expected to be occupied by persons and the horizontal plane 2.5 m above that floor or surface.

3 Protection Against Electric Shock

(1) Where SELV is used, protection against direct contact shall be provided by one of the following requirement:

(i) barrier or enclosure affording at least the degree of protection IP2X or IPXXB, or

(ii) insulation capable to withstand a test voltage of 500 V d.c. for 60 seconds.

(2) Create a zone of equipotential bonding:

Local supplementary equipotential bonding shall be provided connecting all extraneous-conductive-parts in Zone A, B and C together, with the protective conductors of all exposed-conductive-parts situated in these zones. Where there is a metal grid in a solid floor it shall be connected to the local supplimentary equipotential bonding.

This requirement is not to be applied to equipment supplied by SELV circuits.

4 Application of Protective Measures Against Electric Shock

(1) Application of SELV:

In Zones A and B , only the protective measure against electric shock by SELV (Clause 411-02 of CP5:1998) at a nominal voltage not exceeding 12 V a.c. r.m.s. or 30 V d.c. shall be used, the safety source being installed outside the Zone A, B and C, except that:

(i) Where floodlights are installed, each floodlight hall be supplied from its own transformer (or an individual secondary winding of a multi-secondary transformer), having an open circuit voltage not exceeding 18V.

(ii) automatic disconnection of supply by means of a residual current device having a rated residual operating current not exceeding 30 mA and an operating time not exceeding 40 ms at a residual current of 150 mA as specified in SS97, may be used to protect socket-outlets installed in accordance with the following paragraph.

(2) The following protective measures **shall not be used**:

(i) protection by means of obstacles. (Clause 412-04 of CP5:1998)

(ii) protection by means of placing out of reach (Clause 412-05 of CP5:1998)

(iii) protection by means of non-conducting location (Clause 413-04 of CP5:1998)

(iv) protection by means of earth-free local equipotential bonding. (Clause 413-05 of CP5:1998)

5 Selection and Erection of Enclosures

5.1 Degree of Protection

Equipment shall have the following minimum degree of protection:

(i) in Zone A - IPX8.

(ii) in Zone B - IPX5.

- IPX4 for swimming pools where water jets are not likely to be used for cleaning purposes.

(iii) in Zone C - IPX2 for indoor pools

- IPX4 for outdoor pools

- IPX5 for swimming pools where water jets are likely to be used for cleaning purposes.

5.2 Wiring System in Zone A and B

(1) In Zone A and B, a surface wiring system shall not employ metallic conduit or metallic trunking or an exposed metallic sheath or an exposed earthing or bonding conductor.

(2) Zone A and B shall contain only wiring necessary to supply equipment situated in those zones.

(3) Accessible metal junction boxes shall not be installed in Zone A and B.

5.3 Switchgear, Controlgear and Accesaries

(1) In Zone A and B, switchgear, controlgear and accessaries shall not be installed except for swimming pools where it is not possible to locate socket-outlets outside Zone B, when socket-outlets complying with IEC 309-2 may be installed if they are:

(i) more than 1.25m outside the border of Zone A, and

(ii) at least 0.3m above the floor, and

(iii) protected by either:

a residual current device complying with the relevant Singapore Standard and with Clause 412-06-02, or

electrical separation (Clause 413-06) with the safety isolating transformer placed outside Zone A, B and C.

Note: Clause 412-06-02 state that

The use of RCD is recognised as reducing the risk of electric shock where the following conditions are complied with:

(a) One of the following protective measure shall be applied:

(i) Protection by insulation of live parts (Clause 412-02 & 471-04)

(ii) Protection by a barrier or an enclosure (Clause 412-03 & 471-05)

(iii) Protection by obstacles (Clause 412-04 & 471-06)

(iv) Protection by placing out of reach (Clause 412-05 & 471-07)

(b) The RCD shall have a rated residual operating current not exceeding 30 mA and an operating time not exceeding 40 ms at a residual current of 150mA, as provided by SS 97.

(2) In Zone C, a socket-outlet, switch or accessory is permitted only if it is:

(i) Protected individually by electrical separation. (Clause 413-06), or

(ii) Protected by SELV (Clause 411-02), or

(iii) Protected by a residual current device complying with the appropriate SS and having the characteristics specified in Clause 412-06-02, or

(iv) A shaver socket complying with IEC 742.

This requirement does not apply to insulation cords of cord operated switches complying with SS 227.

5.4 Other Equipment

(1) Socket-outlets shall comply with IEC 309-2 (Plugs, socket-outlets and couplers for industrial purposes, Part 2: 1989, Dimension and interchangeability requirements for pin and contact-tube accessories)

(2) In Zone A and B only current-using equipment specifically intended for use in swimming pools shall be installed.

(3) In Zone C, equipment shall be protected by one of the following:

(i) individually by electrical separation (Clause 413-06)

(ii) SELV (Clause 411-02)

(iii) A RCD having the characteristics specified in Clause 412-06-02.

This requirement does not apply to instantaneous water heaters complying with the relevant requirements of SS 146.

LOCATIONS CONTAINING A BATH TUB OR SHOWER BASIN

1 Protection Against Electric Shock

No electrical equipment shall be installed in the interior of a bath tub or shower basin.

1.1 Protection Against Both Direct and Indirect Contact

Where SELV is used:

(1) Safety source shall be installed out of reach of a person using the bath or shower.

(2) The equipment shall incorporate protection against:

(i) Direct contact by insulation, capable of withstanding a test voltage of 500 V d.c. for 60 seconds, or

(ii) Barrier, or

(iii) Enclosure.

1.2 Protection Against Indirect Contact

Supply source is NOT SELV

(1) For circuit supplying equipment in a room containing a fixed bath or shower, where the equipment is simultaneously accessible with exposed-conductive-parts of other equipment or with extraneous-conductive-parts, the characteristic of the protective devices and the earthing arrangements shall be such that, in the event of an earth fault, disconnection occurs within 0.4 seconds.

Note: The wet-floor of the bathroom is extraneous-conductive-parts where a person taking a bath has direct contact with it. The water pipe is connected to the electrical installation by equipotential bonding conductor or is joint to an electric water heater. The water pipe will become an exposed-conductive-part in the bathroom with respect to the floor and both are simultaneously accessible which may give rise to hazardous electric shock in the event of an earth fault occur at the water heater or any other part of the electrical installation. Local equipotential bonding within the bathroom will reduce the risk of electric shock.

(2) Except for equipment supplied from a SELV circuit, in a room containing a fixed bath or shower, supplementary equipotential bonding shall be provided between simultaneously accessible exposed-conductive-parts of equipment, between exposed-conductive-parts and imultaneously accessible extraneous-conductive-parts, and between simultaneously accessible extraneous-conductive-parts.

(3) Where electrical equipment is installed in the space below a bath:

(i) The space shall be accessible only by the use of a tool, and

(ii) Requirement of pargraph (2) above shall extend to the interior of that space.

2 Application of Protective Measures Against Electric Shock

2.1 Protection Against Direct Contact

Prohibit the use of:

(1) Protection by Means of Obstacles.

(2) Protection by Placing Out of Reach.

2.2 Protection Against Indirect Contact

Prohibit the use of:

(1) Protection by Non-Conducting Location.

(2) Protection by Means of Earth-Free Local Equipotential Bonding.

3 Selection and Erection of Equipment

3.1 Wiring System

Surface wiring system shall not use:

(i) Metallic conduit, or

(ii) Metallic trunking, or

(iii) Exposed metallic cable sheath, or

(iv) Exposed earthing or bonding conductor.

3.2 Devices for Isolation and Switching

(1) Every switch or other means of electrical control or adjustment shall not be so situated as to be normally inaccessible to the person using a fixed bath or shower.

(2) The requirement does not apply to:

(i) the insulating cords of a cord-operated switches which comply with SS 227.

(ii) mechanical actuators, with linkages incorporating insulating components, of remotely operated witches.

(iii) controls and switches of water heaters and shower pumps which comply with the relevant requirements of the appropriate Singapore or British or IEC Standard.

(iv) switches supplied by SELV at a nominal voltage not exceeding 12 V a.c. r.m.s. or d.c.

(v) a shaver supply unit complying with IEC 742 or such a unit incorporated in a luminaire. The earthing terminal of the shaver supply unit shall be connected to the protective conductor of the final circuit from which the supply is derived.

3.3 Transformers

In a room containing a fixed bath or shower, provision for the connection of an electric shaver shall be only by means of shaver supply unit complying with IEC 742 or such a unit incorported in a luminaire. The earthing terminal of the shaver supply unit shall be connected to the protective conductor of the final circuit from which the supply is derived.

3.4 Plugs and Socket-Outlets

(1) Where a socket-outlet which forms part of a SELV circuit is installed in a room containing a fixed bath or shower, the norminal voltage shall not exceed 12 V a.c. r.m.s. or d.c. and the socket-out shall have no accessible metallic parts.

(2) Except as permitted by paragraph 3.3 and 3.4-(1), in a room containing a fixed bath and in a shower room there shall be no socket-outlet and no provision for connecting portable equipment.

(3) Where a shower cubicle is located in a room other than a bathroom or a show room, any socket-outlet not provided in conformance with paragraph 3.3 and 3.4-(1) shall be installed at least 2.5 m from the shower cubicle.

3.5 Luminaires

(1) In a room containing a fixed bath or shoer cubicle, parts of a lampholder within a distance of 2.5 m from the bath or shower cubicle shall be constructed of, or shrouded in, insulating material.

(2) Bayonet lampholders type B22 shall be fitted with protective shield complying with SS 125.

(3) Totally enclosed luminaires.

3.6 Other Fixed Equipment

(1) No stationary appliance having heating elements which can be touched shall be installed within reach of a person using a bath or shower.

(2) The sheath or a silica glass sheathed element is regarded as part of the element.

SECTION 601

LOCATIONS CONTAINING A BATH TUB OR SHOWER BASIN

601-01 Scope

601-01-01 The particular requirements of this section shall apply to bath tubs, shower basins and their surroundings, where the risk of electric shock is increased by a reduction in body resistance and contact of the body with earth potential.

Special requirements may be necessary for a location containing a bath for medical treatment.

Protection for safety

601-02 Protection Against Electric Shock

601-02-01 No electrical equipment shall be installed in the interior of a bath tub or shower basin.

601-03 Protection Against Both Direct And Indirect Contact.

601-03-01 Where SELV (Clauses 411-02 and 471-02) is used, the safety source shall be installed out of reach of a person using the bath or shower and, notwithstanding the provision of the second paragraph of Clause 411-02-09 the equipment shall incorporate protection against direct contact by insulation (Clause 412-02), capable of withstanding a test voltage of 500 V d.c. for 60 seconds, or by barriers or enclosures (Clause 412-03).

601-04 Protection Against Indirect Contact

601-04-01 Except for SELV, for a circuit supplying equipment in a room containing a fixed bath or shower, where the equipment is simultaneously accessible with exposed-conductive-parts of other equipment or with extraneous-conductive-parts, the characteristics of the protective devices and the earthing arrangements shall be such that, in the event of a fault to earth, disconnection occurs within 0.4 second.

601-04-02 Except for equipment supplied from a SELV circuit, in a room containing a fixed bath or shower, supplementary equipotential bonding shall be provided between simultaneously accessible exposed-conductive-parts of equipment, between exposed-conductive-parts and simultaneously accessible extraneous-conductive-parts, and between simultaneously accessible extraneous-conductive-parts.

601-04-03 Where electrical equipment is installed in the space below a bath, that space shall be accessible only by the use of a tool and, nevertheless, the requirement of Clause 601-04-02 shall extend to the interior of that space.

Application of protective measures against electric shock

601-05 Protection Against Direct Contact

601-05-01 The following protective measures against direct contact shall not be used:

(i) protection by means of obstacles (Clause 412-04)

(ii) protection by placing out of reach (Clause 412-05).

601-06 Protection Against Indirect Contact

601-06-01 The following protective measures against indirect contact shall not be used:

(i) protection by non-conducting location (Clause 413-04)

(ii) protection by means of earth-free local equipotential bonding (Clause 413-05).

Selection and erection of equipment

601-07 Wiring Systems

601-07-01 Surface wiring systems shall not employ metallic conduit or metallic trunking or an exposed metallic cable sheath or an exposed earthing or bonding conductor.

Switchgear and controlgear

601-08 Devices For Isolating And Switching

601-08-01L Every switch or other means of electrical control or adjustment shall be so situated as to be normally inaccessible to a person using a fixed bath or shower. This requirement does not apply to:

(i) the insulating cords of cord-operated switches which comply with SS 227.

(ii) mechanical actuators, with linkages incorporating insulating components, of remotely operated switches.

(iii) controls and switches of water heaters and shower pumps which comply with the relevant requirements of the appropriate Singapore or British or IEC standards.

(iv) switches supplied by SELV at a nominal voltage not exceeding 12 V a.c. r.m.s. or d.c.

(v) a shaver supply unit complying with Clause 601-09-01.

601-08-02 A switch which forms part of a SELV circuit shall have no accessible metal parts.

Other equipment

601-09 Transformers

601-09-01L In a room containing a fixed bath or shower, provision for the connection of an electric shaver shall be only by means of a shaver supply unit complying with IEC 742 or such a unit incorporated in a luminaire. The earthing terminal of the shaver supply unit shall be connected to the protective conductor of the final circuit from which the supply is derived.

Accessories

601-10 Plugs And Socket-outlets

601-10-01 Where a socket-outlet which forms part of a SELV circuit is installed in a room containing a fixed bath or shower, the nominal voltage shall not exceed 12 V a.c. r.m.s. or d.c. and the socket-outlet shall have no accessible metallic parts.

Typical Requirements for Bonding in Locations Containing a Bath Tub or Shower Basin

Note:

In the illustration the only accessible extraneous conductive parts are the towel rail, taps and the bath or wash basin if metal.

The illustration shows the towel rail to be water heated, i.e. an extraneous conductive part thus:

547 - 03 - 02

Requires the supplementary bond to be of a conductance not less than half that of the protective conductor connected to the exposed conductive part (the heater) if the bond is mechanically protected, and 4mm^2 minimum if no mechanical protection is provided.

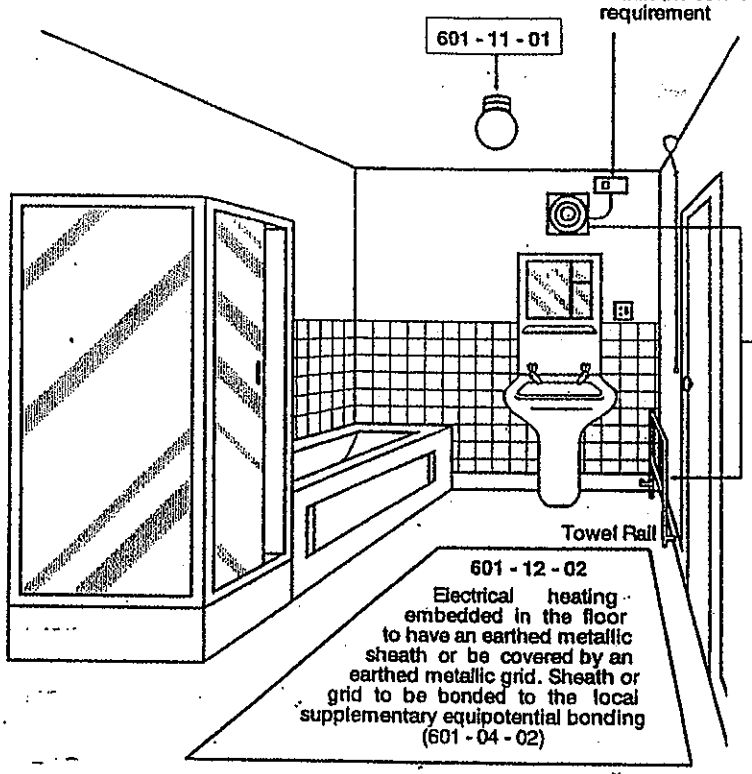
If the towel rail is electrically heated it is an exposed conductive part thus:

547 - 03 - 01

Requires the supplementary bond to be of a conductance not less than half that of the smallest protective conductor connected to the exposed conductive part if the bond is mechanically protected, and 4mm^2 minimum if no mechanical protection is provided

547 - 03 - 05

Where a fixed appliance such as a fan heater is supplied by a short length of flexible cord the cpc within the cord can be deemed to satisfy the bonding requirement



601 - 04 - 02

Supplementary bond between exposed conductive part and extraneous conductive part (simultaneously accessible).

See Regulation 547 - 13 - 02 for conductor size

Tests

These must be carried out to ensure supplementary equipotential bonding is connected to the taps or bath or basin

601 - 04 - 02

Irrespective of impedance test results, this Regulation requires supplementary equipotential bonding as follows:-

(1) between simultaneously accessible exposed conductive parts of equipment, e.g. heaters, electric towel rails, electric showers, etc.

(2) between exposed conductive parts and simultaneously accessible extraneous conductive parts

(3) between simultaneously accessible extraneous conductive parts

601-10-02 Except as permitted by Clauses 601-09-01 and 601-10-01, in a room containing a fixed bath and in a shower room there shall be no socket-outlet and no provision for connecting portable equipment.

601-10-03 Where a shower cubicle is located in a room other than a bathroom or a shower room, any socket-outlet not provided in conformance with Clauses 601-09-01 or 601-10-01 shall be installed at least 2.5 m from the shower cubicle.

Current-using equipment

601-11 Luminaires

601-11-01L In a room containing a fixed bath or shower cubicle, parts of a lampholder within a distance of 2.5 m from the bath or shower cubicle shall be constructed of, or shrouded in, insulating material. Bayonet lampholders Type B22 shall be fitted with a protective shield complying with SS 125. Alternatively, totally enclosed luminaires shall be used.

601-12 Other Fixed Equipment

601-12-01 No stationary appliance having heating elements which can be touched shall be installed within reach of a person using a bath or shower. For the purpose of this clause the sheath or a silica glass sheathed element is regarded as part of the element.

601-12-02 *(Reserved for future use)*

Swimming pools

Hot air saunas

SECTION 602

SWIMMING POOLS

602-01 Scope

602-01-01 The particular requirements of this section shall apply to basins of swimming pools and paddling pools and their surrounding zones where the risk of electric shock is increased by a reduction in body resistance and contact of the body with earth potential.

Special requirements may be necessary for swimming pools for medical use.

602-02 **Assessment Of General Characteristics** (see Figures 602A and 602B)

Zone A is the interior of the basin, chute or flume and includes the portions of essential apertures in its walls and floor which are accessible to persons in the basin.

Zone B is limited:

by the vertical plane 2 m from the rim of the basin, and

by the floor or surface expected to be accessible to persons, and

by the horizontal plane 2.5 m above that floor or surface except where the basin is above ground, when it shall be 2.5 m above the level of the rim of the basin.

Where the building containing the swimming pool contains diving boards, spring boards, starting blocks or a chute, Zone B includes also the zone limited by - the vertical plane spaced 1.5 m from the periphery of diving boards, spring boards and starting blocks, and within that zone, by the horizontal plane 2.5 m above the highest surface expected to be occupied by persons, or to the ceiling or roof if they exist.

Zone C is limited:

by the vertical plane circumscribing Zone B, and the parallel vertical plane 1.5 m external to Zone B, and

by the floor or surface expected to be occupied by persons and the horizontal plane 2.5 m above that floor or surface.

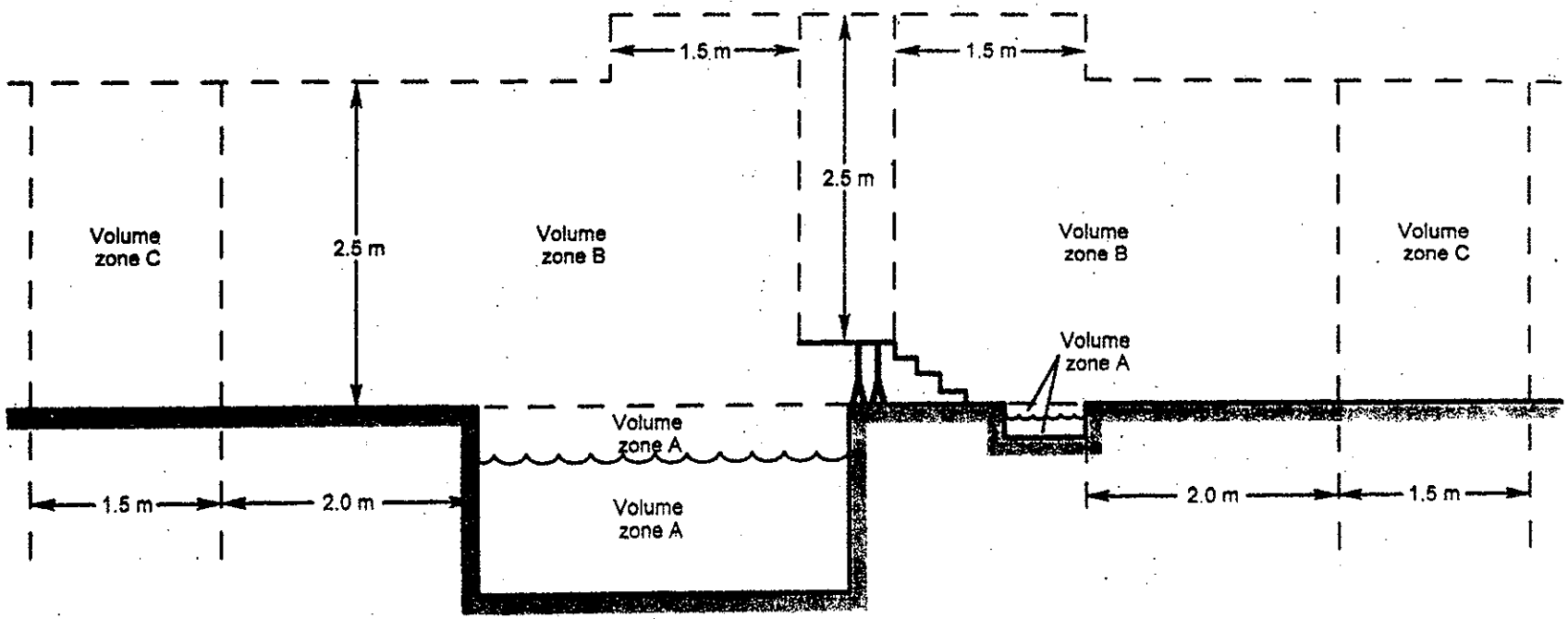
Protection for safety

602-03 **Protection Against Electric Shock**

602-03-01 Where SELV is used, irrespective of the nominal voltage, protection against direct contact shall be provided by:

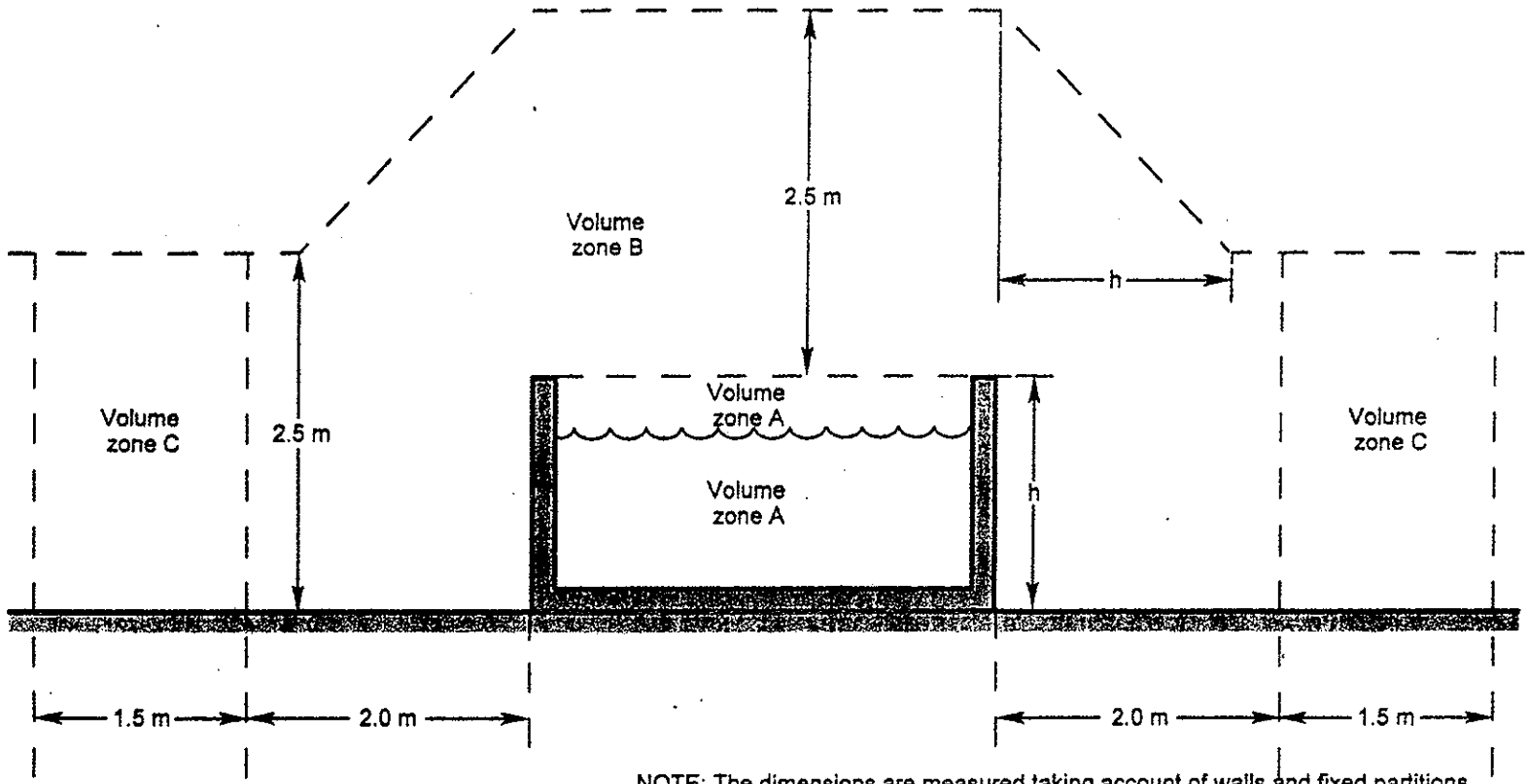
(i) barriers or enclosures affording at least the degree of protection IP2X or IPXXB, or

(ii) insulation capable of withstanding a test voltage of 500 V d.c. for 60 seconds.



NOTE: The dimensions are measured taking account of walls and fixed partitions

Figure 602A - Zone dimensions of swimming pools and paddling pools



NOTE: The dimensions are measured taking account of walls and fixed partitions

Figure 602B - Zone dimensions for basin above ground level

602-07 Switchgear, Controlgear And Accessories

602-07-01L In Zones A and B, switchgear, controlgear and accessories shall not be installed except for swimming pools where it is not possible to locate socket-outlets outside Zone B, when socket-outlets complying with IEC 309-2 may be installed if they are :

(i) more than 1.25 m outside outside the border of Zone A, and

(ii) at least 0.3 m above the floor, and

(iii) protected by either :

a residual current device complying with the relevant Singapore Standard and with Clause 412-06-02, or

electrical separation (Clause 413-06) with the safety isolating transformer placed outside Zones A, B and C.

602-07-02L In Zone C, a socket-outlet, switch or accessory is permitted only if it is:

(i) protected individually by electrical separation, (Clause 413-06), or

(ii) protected by SELV (Clause 411-02), or

(iii) protected by a residual current device complying with the appropriate Singapore Standard and having the characteristics specified in Clause 412-06-02, or

(iv) a shaver socket complying with IEC 742.

This requirement does not apply to the insulating cords of cord operated switches complying with SS 227.

602-08 Other Equipment

602-08-01L Socket-outlets shall comply with IEC 309-2.

602-08-02 In Zones A and B, only current-using equipment specifically intended for use in swimming pools shall be installed.

602-08-03L In Zone C, equipment shall be protected by one of the following:

(i) individually by electrical separation (Clause 413-06)

(ii) SELV (Clause 411-02)

(iii) a residual current device having the characteristics specified in Clause 412-06-02

This requirement does not apply to instantaneous water heaters complying with the relevant requirements of SS 146.

SECTION 603

HOT AIR SAUNAS

603-01 Scope

603-01-01L The particular requirements of this section shall apply to locations in which hot air sauna heating equipment according to IEC Publication 335-2-53 (Safety of Household and Similar Electrical Appliances Part 2 : Particular requirements for electric sauna heating appliances) is installed.

603-02 Classification Of Temperature Zones

603-02-01 The assessment of the general characteristics of the location shall take due consideration of the classification of the four temperature zones which are illustrated in Figure 603A.

Protection against electric shock

603-03 Protection Against Both Direct And Indirect Contact

603-03-01 Where SELV is used, irrespective of the nominal voltage, protection against direct contact shall be provided by one or more of the following:

(i) insulation (Clause 412-02), capable of withstanding a test voltage of 500 V d.c. for 60 seconds

(ii) barriers or enclosures (Clause 412-03), affording at least the degree of protection IP24 or IPX4B.

Application of protective measures against electric shock

603-04 Protection Against Direct Contact

603-04-01 The following protective measures against direct contact shall not be used:

(i) protection by means of obstacles (Clause 412-04).

(ii) protection by placing out of reach (Clause 412-05).

603-05 Protection Against Indirect Contact

603-05-01 The following protective measures against indirect contact shall not be used:

(i) protection by non-conducting location (Clause 413-04).

(ii) protection by means of earth-free local equipotential bonding (Clause 413-05).

Selection and erection of equipment

603-06 Common Rules

603-06-01 All equipment shall have at least the degree of protection IP24.

603-06-02 In temperature Zone A only the sauna heater and equipment directly associated with it shall be installed.

In temperature Zone B there is no special requirement concerning heat resistance of equipment.

In temperature Zone C equipment shall be suitable for an ambient temperature of 125°C.

In temperature Zone D only luminaires and their associated wiring, and control devices for the sauna heater and their associated wiring shall be installed. The equipment shall be suitable for an ambient temperature of 125°C.

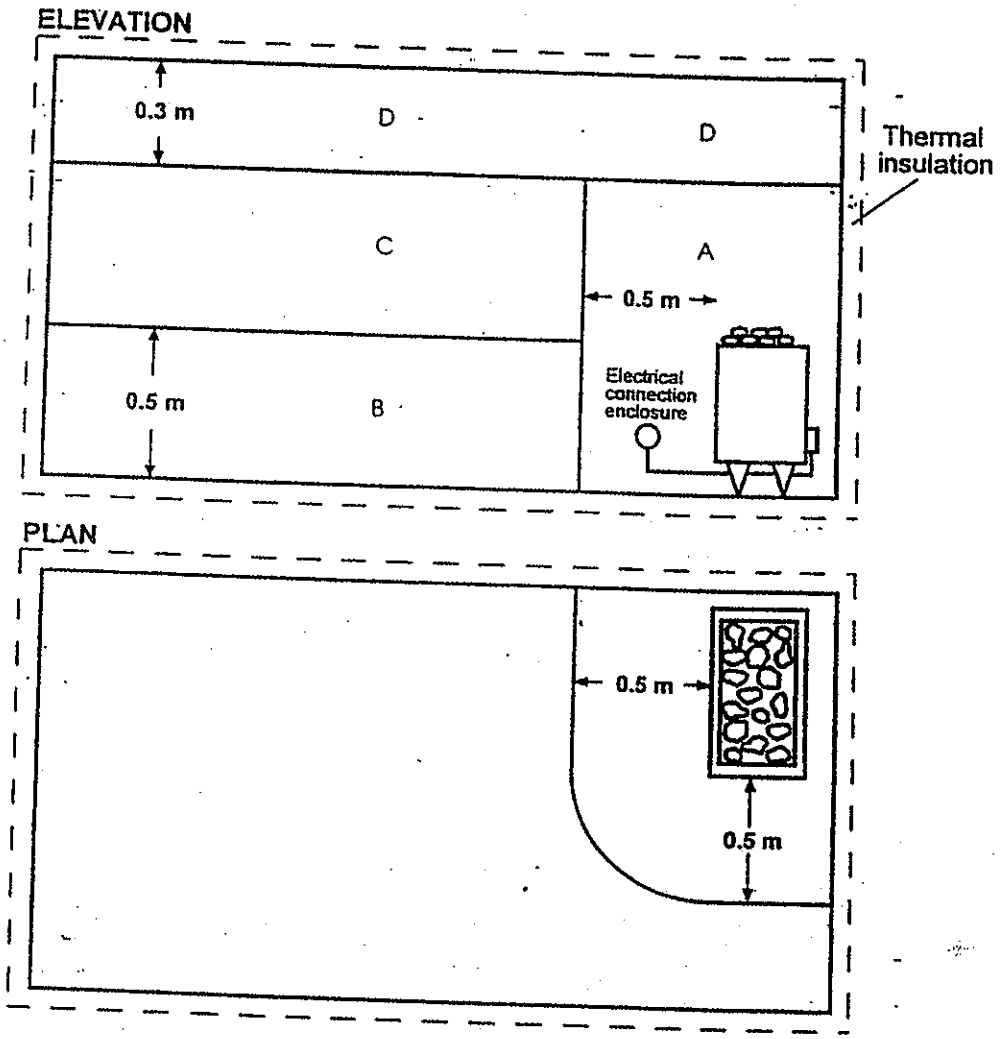


Figure 603A - Zones of ambient temperature

603-07 **Wiring Systems**

603-07-01L Only flexible cords complying with IEC 245 or BS 6141 having 150°C rubber insulation shall be used and shall be mechanically protected with material which complies with Clause 413-03-01.

603-08 **Switchgear, Controlgear And Accessories**

603-08-01 Switchgear not built into the sauna heater, other than a thermostat and a thermal cut-out shall be installed outside the hot air sauna.

603-08-02 Except as permitted in Clauses 603-06-02 and 603-08-01 accessories shall not be installed within the hot air sauna.

603-09 **Other Fixed Equipment**

603-09-01 Luminaires shall be so mounted as to prevent overheating.

Code of Practice for Temporary Electrical Installation at Construction and Building Sites (CP88: Part 1: 2001)

1 What is Temporary Electrical Installation?

Temporary Electrical Installation (TEI) is referring to electrical installation which is use for building operation and work of engineering construction building. Any electrical installation set up for the provision electricity supply during the execution of the following works:

(a) New building construction;
(b) Repair, alteration, extension or demolition of buildings;
(c) Engineering construction.
(d) Earth works;
(e) Other similar works.

2 Exceptional Electrical Installations

CP88: Part 1 is not applicable to the electrical installation for the provision of electricity supply to the following sites/environments:

(a) Offices, meeting rooms, canteens, dormitories, toilets & etc of a construction site, where the Singapore Standard CP5 shall apply.
(b) Those part of the temporary electrical installation which is operating at a voltage exceeding 1000V.
(c) Temporary electrical installations which is installed in compressed air environment (e.g. tunnel construction work) and potentially explosive atmosphere.

3 Related Code of Practice

The general requirements of SS CP5 shall be read in conjunction with CP88: Part 1.

Because of variations in local circumstances of construction sites, the requirements of this code is given in general terms, the implementation of the code of practice shall be supplemented by the advice of a Licensed Electrical Worker.

4 Statutory Requirement for the Operation of TEI

All TEIs for building operation and work of engineering construction are required to be licensed by the Energy Market Authority.

5 Definitions of Terms

5.1 Cable Coupler

It enables the connection at will of two flexible cables. It consist of two parts:

(i) A connector
(ii) A Plug.

5.2 Earth Monitoring System

A system for proving a means of maintaining a high degree of confidence in the **measured impedance of a protective conductor** forming part of the earthing arrangements of an electrical installation.

5.3 Generating Set

A generating set is an internal combustion engine driving a rotating a.c. electrical generator together with its associated control panel, switchgear and ancillary equipment, whether integrally mounted or otherwise.

5.4 Plug

A device provided with contact pins, which is intended to be attached to a flexible cable, and which can be engaged with a socket-outlet or with a connector.

5.5 Protective Conductor Proving System

A system provides a means of maintaining a high degree of confidence in the continuity of a protective conductor within the installation.

5.6 Readily Accessible

Capable of being reached quickly, for operation, renewal, or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

5.7 Skilled Person

A person who is licensed as an electrical worker under the Electrical Worker Licensing Act.

5.8 Site

An Area where a building operation or work of engineering construction takes place.

5.9 Socket-Outlet

A device provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug. A luminaire track system is not regarded as a socket-outlet system.

5.10 Supplies

All references throughout the CP88: Part 1, refer to alternating current (a.c.) supplies related to a frequency of 50 Hz unless otherwise stated. AC voltage and current are in terms of r.m.s. values unless otherwise stated.

6 Source of Supply

(i) Public electricity supply network – 50 Hz, 400V 3-phase or 230V single-phase.

(ii) Generating sets –

(a) Three-phase – 50Hz at 400V between phases and **230 between phases and earth.**
(b) Single phase – 50 Hz at 230V between phase & earth.
(c) At a voltage level and frequency approved by the LEW responsible for the design and installation of the TEI.

(iii) Reduced voltage – 110V single-phase from a **double-wound transformer** having the centre tap of the secondary winding earthed so that the nominal voltage to earth is only 55V.

(iv) Extra low voltage – 50V single-phase from a double-wound transformer having the centre tap of the secondary winding earthed so that the nominal voltage to earth is only 25V.

6.1 Operation between Public Supply System and Generator set

(1) No parallel operation, unless otherwise approved by the public electricity supplier.

(2) In a service area where electricity supply is taken from a generating set, no electricity supply from the public system shall be introduced into the same service area.

6.2 Supply for Equipment

The following voltages shall not be exceeded.

S/No	Equipment	Supply
1	-Fixed plant -Movable plant fed via a trailing cable -site buildings/offices -workshops -canteens -quarters -fixed flood lighting -site lighting	3-phase 400V or single-phase 230V
2	-Portable electric hand-held tools -Portable hand-lamps.	Single-phase 230V
3	Portable electric hand-held tools and Portable hand-held lamps used underground such as any shaft, tunnel, caisson or cofferdam.	Single-phase 110V, centre point earthed.
4	Portable electric hand-held tools and Portable hand-held lamps used in confined locations such as the inside of boilers, tanks or pipes, or in other similar situations.	Single-phase 50V, centre point earthed.

6.3 Earthing System for Single Generating Set

The earthing system is **TN-S system.**

6.4 Earthing System for Multiple Generating Sets

(1) Share a common earthing system.

or

(2) Have separate earthing systems and the electrical installations connected to different earthing system are segregated effectively from one another or

effectively bonded to prevent dangerous potential rise between conducting parts which a person can come into simultaneous contact.

6.5 Earthing System for Multiple Supplies Taken from Public Supply System

Earthing system same as paragraph 6.4

6.6 Design, Selection & Installation of Protective Conductors

In accordance with SS CP5.

7 Installation of Generating Set

7.1 General

(1) Generating set shall be suitably barricaded to prevent access by non-authorised person.

(2) Adequate clearance around generating set to facilitate operation & maintenance work.

(3) Readily accessible to the generating set.

(4) Readily accessible to any switch or control for stopping and starting the engines.

(5) Generating set **shall not be installed**

(i) in damp situation or exposed to weather **unless suitably protected.**

(ii) in hazardous area, unless the equipment and method of installation comply with "BS 5345-CP for selection, installation and maintenance of electrical apparatus for use in potentially explosive atmosphere (other than mining applications or explosive processing and manufacturing)", and the additional requirements of any relevant authority.

(6) Fuel and its container shall be stored in a safe manner.

7.2 Earthing Arrangement of Generating Set

(A) Earthing system requirement:

(1) Share a common TN-S system.

(2) Main Earthing Terminal or Bar shall be of adequate rating and connected to the earth electrode system via Earthing Conductors.

(3) The star-point of a 3-phase generator winding or the mid-point of a single-phase centre-tapped generator winding shall be solidly earthed through adequately rated conductors to the earthing system of the installation.

(B) Bonding system requirement:

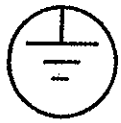
The following parts of the generating set shall be bonded together to form the "generator bonding system" which shall be connected effectively to the "main earthing terminal".

(1) Engine frame.

(2) Generator frame.

(3) All metal enclosure for electrical equipment & wiring.

(4) Earthing terminals of socket-outlet.

(5) The main frame terminal (marked )

7.3 Protection Against Direct Contact of Live Parts

In accordance with SS CP5.

7.4 Labeling of Generating Set

Information such as:

(1) Name of the manufacturer.
(2) Model number, serial number of the set.
(3) Type of fuel or fuel-oil mixture.
(4) Rated output in Watts or kilowatts at a stated power factor.
(5) Voltage & frequency.
(6) Output terminal markings (unless all outputs are socket-outlets)

(7) The frame terminal: symbol marked 

(8) The word **"NOT WEATHER PROFF"** shall be on the set if it is intended for undercover or weather protected usage.

(9) On a set intended for out door use without further protection against weather/environment, the IP classification of its electrical equipment.

(10) A **danger sign** made of **durable material** with the word "DANGER" with the specification as specified in Annex D shall be **displayed at a prominent location near the generating set.**

8 Protection for Safety

8.1 General

Switchgears shall be readily accessible and shall incorporate:

(1) Means of isolation; and

(2) Means of overcurrent and earth fault protection; and

(3) Means of earth leakage protection (except extra-low voltage installations i.e. not exceeding 50V a.c.)

8.2 Protective Device for Incoming Supply

(1) Incoming supply up to 300A – Circuit breaker with **RESIDUAL CURRENT DEVICE.**

(2) Incoming supply exceeding 300A – Circuit breaker incorporating **OVERCURRENT** and **EARTH FAULT protective device.**

8.3 Prohibited use of Fuse for Final Circuits

FUSES SHALL NOT BE USED FOR PROTECTING FINAL CIRCUITS IN ANY PART OF THE INSTALLATION.

Note: Except for those SSO incorporated with fuse protection.

8.4 Protection Against Direct Contact

One or more of the following as indicated in SS CP5.

(1) Protection by insulation of live parts;
(2) Protection by barrier or enclosure;
(3) Protection by obstacles;
(4) Protection by placing out of reach.

8.5 Protection Against Indirect Contact for Low Voltage System

(1) By the use of Residual Current Device (RCD) and the setting will be based on the following:

(a) For TN-S system:

$$Z_s I_{\Delta N} \leq 25 \text{ Volts}$$

(b) For TT system:

$$R_a I_{\Delta N} \leq 25 \text{ Volts}$$

Where Z_s is the earth fault loop impedance.

$I_{\Delta N}$ is the **rated residual operating current** of the protective device in Ampere.

R_a is the sum of the resistance of the "earth electrode" and the "protective conductors" connecting it to the "exposed-conductive-part.

(2) Protection by RCD for Final Circuit

Final circuits are to be protected by one or more RCD. The type of tripping sensitivities of residual current device to be used for the final circuit of the following rating shall be:

(a) Final circuits of rating ≤ 63A at 400V 3-phase or 230V 1-phase:

Use Residual Current Circuit Breaker (**RCCB** complying with SS97) with the tripping current, $I_{\Delta N}$ not exceeding 30 mA and a tripping time within 0.1 second.

(b) Final circuits of rating ≤ 100A at 400V 3-phase or 230V 1-phase:

Use **RCCB** (complying with SS97) with a $I_{\Delta N} \leq 300$mA.

(c) Final circuits of rating > 100A at 400V 3-phase:

Use **RCD** with $I_{\Delta N} \leq 500$mA.

(3) Protective Conductor Proving and Earth Monitoring System

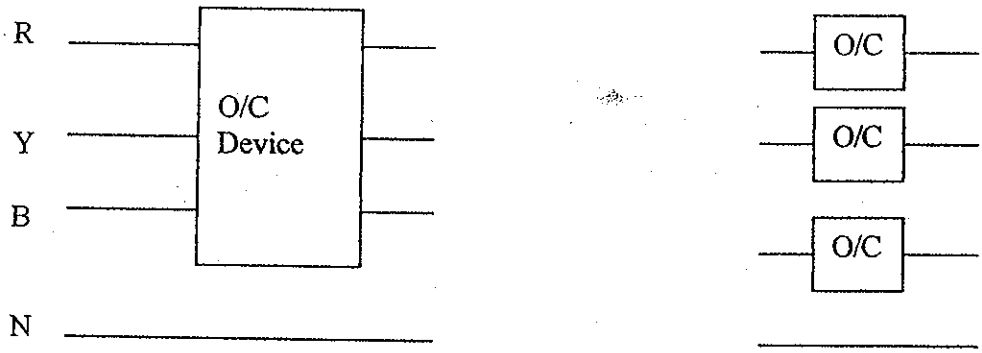
Where flexible cables supplying power at mains voltage (e.g. 400v and 230V) to a **moveable plant** are liable to become damaged or discontinuous, a protective conductor proving and/or earth monitoring system shall be used to detect the failure of the circuit protective conductor. Refer Annex B.

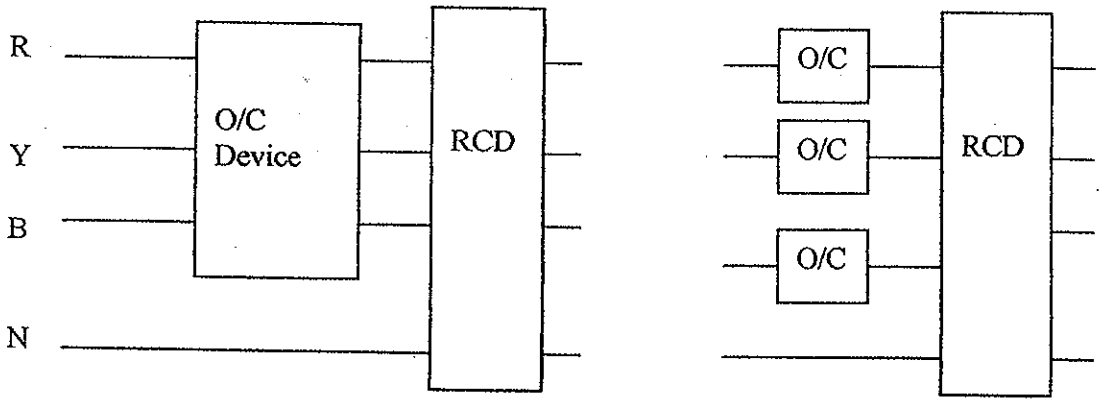
(4) Earth Leakage Protection for Transportable Electrical Equipment

Refer to SS CP16.

8.6 Protection Against Indirect Contact for Reduced Voltage System

(1) Automatic disconnection device installed in each phase conductor can be an Overcurrent Device (O/C) or RCD.





(2) All exposed-conductive-parts shall be connected to Earth.

(3) The earth fault loop impedance at every point of utilisation, including socket-outlets, shall be such that the disconnection time ≤ 5 seconds.

(4) Where the O/C device is a **circuit breaker** which is use for automatic disconnection of supply under earth fault condition.

Table 1 – Maximum earth fault loop impedance (Z_s) for a disconnection time 5 second and U_0 of 55 volts (single-phase)

MCB Type to SS 359 & BS EN 60898	1	B	2	C & 3	D
Rating amperes (I_n)	$U_0 / 4\ I_n$	$U_0 / 5\ I_n$	$U_0 / 7\ I_n$	$U_0 / 10\ I_n$	$U_0 / 20\ I_n$
6	2.29	1.83	1.31	0.92	0.46
10	1.38	1.10	0.79	0.55	0.28
16	0.86	0.69	0.49	0.34	0.17
20	0.69	0.55	0.39	0.28	0.14
25	0.55	0.44	0.31	0.22	0.11
32	0.43	0.34	0.25	0.17	0.09
40	0.34	0.28	0.20	0.14	0.07
50	0.28	0.22	0.16	0.11	0.06
63	0.22	0.18	0.13	0.09	0.04
80	0.17	0.14	0.10	0.07	0.03
100	0.14	0.11	0.08	0.06	0.03

(5) Protection Against Lightning

Refer to CP 33 if it is necessary.

9 Selection and Erection of Equipment

9.1 Type of Cable Covering

(1) All cables to be **laid in the ground** shall be **armoured cables**.

(2) Except cables installed overhead, all other **cables for submains or final circuits** operating at voltages **exceeding 63V to earth** (3-phase 110V system) or **55V to earth** (single-phase system) and **routed outdoor shall be of armoured construction** and buried where possible.

(3) All cables which are to be moved in normal use shall be **flexible cables**. Where trailing cables are required by nature of the work, they shall be of the **armoured type complying with BS 6708** having an over-sheath of heavy-duty oil-resisting and flame-retardant compound.

(4) Elevated cables shall be fully insulated **having a sheath of PVC** or an **oil-resisting and flame-retardant** or **heat resisting** sheath. Overhead cables exposed to sunlight shall have a suitable non-metallic covering which is resistance to the effect of sunlight.

(5) Except for situations (e.g. switch rooms or control room) where the risk of mechanical damage is slight, armoured cables where an over-sheath of PVC or an oil-resisting and flame retardant compound or cables with adequate mechanical protection shall be used.

9.2 Flexible Cords

(1) Flexible cords shall be of the circular type having heat resisting, oil resisting and flame-retardant rubber-sheath complying with **IEC 60245 Part 1** or PVC insulated and PVC sheathed complying with **SS 358 : Part 5**.

(2) **Flexible cords for portable hand-lamps** shall be of the circular type having screened Type EM2 rubber-sheath complying with **BS 6500**.

(3) Flexible cords of portable electrical equipment shall **not exceed 3 m** in length or **such length as supplied** by the original equipment manufacturer.

(4) Flexible cords of conductor size smaller than 1.0 mm^2 (32/0.20 mm) shall not be used.

9.3 Installation of Cables

(1) Cables, other than those supplying power to portable electrical equipment or mobile plant, shall be fixed on site so that they are clear of building operation or engineering construction work and is not hazard **to persons working on the site**.

(2) All cables are to be installed **without obstruction to the use of passageway, walkway, ladder, stairs** and the like.

(3) Where submains cables inside a building or under a covered area are to be suspended or supported from the ceiling or wall, **cable trays, bracket** or **other suitable support** shall be provided. The cable supports shall not cause damage to the cable insulation or subject the cables to undue mechanical stress.

(4) Where cables are to be laid on the ground or the floor of a structure, the cables shall be of the "armoured type complying with **BS 6708** having an over-sheath of heavy duty oil-resisting and flame-retardant compound" or "PVC insulated, steel wire armoured and PVC sheathed complying with **SS 443**" and shall be laid in such a manner that **the risk of mechanical damage is prevented**.

(5) Elevated flexible cables used indoor shall be provided with suitable mechanical protection and securely supported in such a manner as not to damage the sheath of the flexible cables and not subject the cables or their terminations to undue mechanical stress.

(6) No flexible cord shall be used as submain or final circuit for the purpose of distribution of electricity supply.

(7) Cables buried direct in the ground shall be marked by cable covers and shall be buried at a minimum depth of 300mm to avoid being damaged by any disturbance on the ground. The cable route for all supply cables and submains buried underground shall be marked on site drawings.

(8) Cables passing under roadways or accessways for transport and mobile plant shall be laid at a minimum depth of 600mm. A cable marker shall be installed at both ends of each crossing.

(9) Overhead cables shall be so placed and at such height as to be out of reach of any source of mechanical damage reasonably to be foreseen in the area where they are erected.

(10) Overhead (O/H) cables shall be installed at a height such that a clear vertical distance between the lowest part of the O/H cables and the highest point of vehicles, mobile cranes or other mobile plant likely to pass underneath them is 2 m minimum but under no circumstances shall be clear height to ground of the O/H cables be less than 5 m where they cross roadways or accessways.

(11) O/H cables shall be supported by catenary wires or proper cable support in a manner such that the cables are not subjected to undue mechanical stress. The catenary wires or metallic cable support shall be effectively bonded to earth.

(12) Poles supporting O/H cables shall be so located or arranged that the risk of mechanical or vehicular damage is prevented. Poles shall be sufficiently sized with adequate mechanical strength and properly anchored.

(13) Metal pole of minimum diameter 100 mm with adequate mechanical strength shall be used. Poles made of wood or plastic material shall not be used for this purpose.

(14) All cables shall be installed so that they are at least 150 mm clear of piped services such as steam, gas and water and shall not be located directly below and parallel to these pipes.

(15) All armoured cable terminations shall be provided with cable glands and earth tags for bonding to associated gland plate and adjacent cables in order to maintain satisfactory earth loop impedance. The armour of the cable shall not however be relied on as circuit protective conductor for the cable.

(16) All joints shall be mechanically and electrically sound and fully insulated.

9.4 Switchgear and Controlgear

9.4.1 Enclosure for Low-Voltage Assembly

(1) The enclosure of each assembly shall be

- robustly constructed
- adequate strength
- rigidity

(2) Except for socket-outlet assembly, the enclosure for outdoor installation shall have:

- a degree of protection **IP44**
- a roof so designed to **prevent stagnation of water** on its surface.
- A roof shall **extend at least 76 mm** beyond the main body of the enclosure.

(3) The enclosure shall be so placed, installed and safeguarded:

- to **prevent damage by external influences** that may affect the design and safe operation of the equipment; and
- shall be provided with **adequate and safe means of access** and working space for operation and maintenance purposes.

9.4.2 Switchboard and Distribution Board

(1) Provide means for isolation and switching of the incoming supply. **Isolating switches and circuit breakers** used for this purpose shall be suitable for **securing in the OFF position.**

(2) Every switchboard and distribution board shall be erected to **satisfy the requirement of "Protection for Safety" as stipulated in paragraph 8.**

10 Socket-Outlet Assembly

10.1 Enclosure for Socket-Outlet (S/O) Assembly

(1) Enclosure shall be fabricated from:

(a) Galvanised sheet steel of minimum **1.5 mm thickness** finished in **epoxy powder coating**; or

(b) Aluminium sheet of minimum **2 mm thickness** finished in **epoxy powder coating**; or

(c) Self-extinguishing, non-hygroscopic polycarbonate thermoplastic with high impact strength (6 joule), high resistance to UV rays, high resistance to chemical elements and high resistance to abnormal heat and fire (glow wire test according to SS 145 Part 2)

(2) The enclosure for S/O shall have a degree of protection of **minimum IP44 to SS IEC 60529**.

(3) It can be floor standing or wall mounting.

The standing socket-outlet assembly shall be:

(a) Fitted with supports to afford a minimum clearance of 150 mm from the ground; and

(b) Provided with handles and lifting lugs.

(4) Every cable connection to and from the S/O enclosure shall be by means of plugs and socket-outlets. The plugs and socket-outlet shall be of the appropriate type apecified in the following paragraphs.

10.2 Single-phase Socket-Outlet Assembly fed from Single-Phase Source (Fig 1)

(1) Fed from a **32 A single-phase 230 V source**.

(2) A **32 A double-pole MCB** shall be provided to control the incoming supply.

(3) A fixed plug rated at 32 A single-phase 230V shall be provided to receive the incoming supply.

(4) A maximum of 6 number of 16 A "2-pole and earth socket-outlets" shall be provided.

Each S/O shall be controlled by a double-pole 16 A MCB not exceeding 16 A current rating.

All socket-outlets shall be protected by RCCB complying with SS97 having **$I_{\Delta N} \leq 30$ mA**

10.3 Single-Phase Socket-Outlet Fed from Three-Phase Source (Fig 2)

(1) Supply source is 32 A 3-phase 400V.

(2) A 32 A 4-pole MCB shall be provided to control the incoming supply.

(3) A fixed plug rated at 32 A 3-phase 400V shall be provided to receive the incoming supply.

(5) A maximum of 9 number of 16 A "2-pole and earth socket-outlets" shall be provided.

Each S/O shall be controlled by a double-pole MCB not exceeding 16 A current rating.

All socket-outlets shall be protected by RCCB complying with SS97 having **$I_{\Delta N} \leq 30$ mA.**

10.4 3-Phase Socket-Outlet Assembly (Fig 3)

(1) Supply source is 32 A 3-phase 400V.

(2) A 32 A 4-pole MCB shall be provided to control the incoming supply.

(3) A fixed plug rated at 32 A 3-phase 400V shall be provided to receive the incoming supply.

(4) A maximum of 3 number of 16 A "4-pole and earth socket-outlets" shall be provided.

Each S/O shall be controlled by a TP&N MCB not exceeding 16 A current rating.

All socket-outlets shall be protected by RCCB complying with SS97 having **$I_{\Delta N} \leq 30$ mA.**

10.5 3-phase and Single Phase Socket-Outlet Assembly (Fig 4)

(1) Supply source is 32 A 3-phase 400V.

(2) A 32 A 4-pole MCB shall be provided to control the incoming supply.

(3) A fixed plug rated at 32 A 3-phase 400V shall be provided to receive the incoming supply.

(4) A maximum of 2 number of 16 A "4-pole and earth socket-outlets" and a maximum of 3 number of 16 A 2-pole and earth socket outlet shall be provided.

Each S/O shall be controlled by a TP&N MCB / 2-pole MCB of current rating not exceeding 16 A.

All socket-outlets shall be protected by RCCB complying with SS97 having $\mathbf{I_{\Delta N} \leq 30\ mA.}$

11 Plugs, Socket-Outlet and Cable Couplers

(1) To comply with IEC 60309.

(2) Likely to be exposed to weather, they shall be contained in a weatherproof enclosure unless they are of the weatherproof type (minimum IP44 to SS IEC 60529)

(3) Plugs of one voltage system shall not be capable of entering socket-outlets of other voltage system.

(4) Devices for **110 V single-phase** operation shall be of the **3-pin** type with the numbered hour position **4H**. (Numbered hour position indicates the position of earth contact-tube in relation to the keyway.)

(5) Devices for use with **230 V single-phase** system shall be of the **3-pin** type with the numbered hour position **6H**.

(6) Devices for use with 400 V 3-phase system shall be of 5-pin type, 3-pole, neutral and earth, and numbered hour position 6H.

(7) Where several voltages are used in the temporary installation, all plugs, socket-outlets and cable couplers shall be identified by different colours as given in Table 2.

Operating Voltage (V)	Colour
55	White
110	Yellow
230	Blue
400	Red

(8) Connection of flexible cables or flexible cords to socket-outlets shall be by means of plugs.

(9) Where heavy electrical plants such as rail-mounted tower cranes requires the use of plugs and socket-outlets as a convenient form of connection at mains,

such plugs and socket-outlets shall be **mechanically interlocked**. Electrical interlock can be used as an additional feature.

12 Cables for SOA Connection

An extension cable may be used to connect portable equipment to a socket-outlet assembly and such extension cable shall comply with the following conditions:

(a) the cable shall be appropriately sized and provided with suitable mechanical protection.

(b) the cable shall be connected to an **industrial plug** of appropriate rating on one end and a **switched industrial socket-outlet** at the other end to facilitate emergency switching; and

(c) the industrial plug and switched socket-outlet shall be as specified in paragraph 11.

13 Earthing Arrangement and Protective Conductor

(1) They shall be selected and erected to comply with the requirement of **SS CP5**.

(2) Attention shall also be paid to the need for **equipotential bonding of extraneous metallic parts**.

(3) Protective earthing of **metalwork** – Metal work not belong to the installation including scaffolding which is liable to come into fortuitous contact and become live in the event of a failure of insulation of the installation shall be **effectively earthed at all times**.

(4) Earthing of **portable appliances and tools** – Exposed metalwork of all portable appliances and tools **shall be connected to the circuit protective conductors** in the flexible cables or flexible cords **unless they are double-insulated** as specified in SS 236 or of extra-low voltage system.

(5) Earthing of metal sheath and armour of cables – They **cannot be used as circuit protective conductor** but they must be **effectively earthed**.

(6) **Metal sheath and/or armour of flexible or trailing cables** – They shall not be the sole **circuit protective conductor** but **in addition to the earth cores** of the cables.

(7) Earthing of metal enclosure for switchboard and distribution boards – Constructional precautions shall be taken to ensure electrical continuity between the exposed conductive parts of the switchboard and the distribution boards and between these parts and the protective circuits of the installation.

14 Other Equipment

(1) Light fixtures

(i) **Weatherproof** type for light fixture:

(a) used **outdoor**

(b) likelihood that it is subjected to **water splashing.**

(iii) provided with **suitable guards** if exposed to risk of mechanical damage.

(2) Portable hand-lamps

(i) It supplied through flexible cords shall be of the **moulded composition** or other type designed for the purpose and equipped with handle.

(ii) It shall equipped with substantial guard attached to the lampholder or the handle.

(3) Prohibited use of lamp-holders fitted with pin contacts

The use of **lampholders fitted with pin contacts** intended to be penetrated into tough rubber sheath or polychloroprene sheath cable **is prohibited.**

15 Electrical Welding System

(1) Every a.c. welding set must be **equipped with low voltage shock preventor** which shall effectively reduce the **open circuit secondary voltage not exceeding 25 V.**

(2) The low voltage shock preventors shall be of the built-in type or be housed in a weatherproof metal casing and **effectively secured or locked to prevent tampering** by welders or other unauthorised persons.

(3) It should be connected to the return terminal of the welding set through a proper return conductor.

16 Switches for Reduced Voltage Circuits

Switches controlling single-phase supplies on installations operating up to and including110 V shall be of the double-pole type with circuit protection provided in each line conductor.

17 Inspection, Testing and Maintenance

(1) TEI shall be inspected and tested in accordance with the requirements of Part 7 – **Inspection and Testing of SS CP 5 before installation is energised.**

(2) TEI shall be **inspected by a skilled person at least once a month.** Upon completion of the inspection, the skilled person shall complete and sign the checklist shown in Annex C and hand it to the operator of the electrical installation or his representative.

(3) Where any defect or unsafe condition is revealed during inspection, the skilled person shall take measures, such as rectifying the defects, or by **isolating or disconnecting the defective part** or parts from electricity supply, to render the electrical installation safe. **Appropriate measure shall be clearly indicated in the checklist.**

Low Voltage Shock Preventor (Voltage Reducing Device)

1 Introduction

The low voltage shock preventor (LVSP) is designed to use with welding equipment in order to reduce the open circuit secondary voltage to a safe level. It can be mounted externally or incorporated in the welding equipment. When welding work is not taking place, the LVSP would be activated to give an open circuit secondary voltage less than 25V. This is protecting anyone who accidentally comes into contact with the welding electrode from receiving a fatal electric shock. When welding work is taking place, the LVSP shall deactivate and give a welding voltage in the range of 60V to 90V across the secondary output terminals for continuous welding operation. Usually the welder will not touch the electrode during the welding process and hence shall not receive an electric shock.

2 Operation of a Low Voltage Shock Preventor

2.1 No Welding Action

When there is no welding, the secondary circuit of the welding equipment is open circuited. There is no current induced in the current transformer, CT as shown in the schematic diagram. Hence, no current is sent to the sensing circuit and the electromagnetic coil of the contactor, MS is de-energised. The associated contact MS-a is normally open, hence cut off supply to he primary circuit of the welding equipment. The other contact MS-b is normally closed, hence only 20V is presence in the secondary circuit of the welding equipment from the secondary winding of the small Auxiliary Transformer. The **pilot lamp is dimly lighted up**.

2.2 Start Welding

At the beginning of welding, the welding electrode touches the work-piece resulting a closed circuit in the secondary circuit of the welding equipment. The CT will send the induced current to the "Sensing Circuit" and the associated "Amplifier Circuit" will energised the electromagnetic coil of the contactor, MS. Hence the associated contact MS-a become close and contact MS-b become open. The mains supply voltage will be applied across the primary circuit of the welding equipment. The secondary winding of the small Auxiliary Transformer is isolated from the secondary circuit of the welding equipment. The **pilot lamp is brightly lighted up**. The secondary circuit of the welding equipment shall be in the range 60V to 90V.

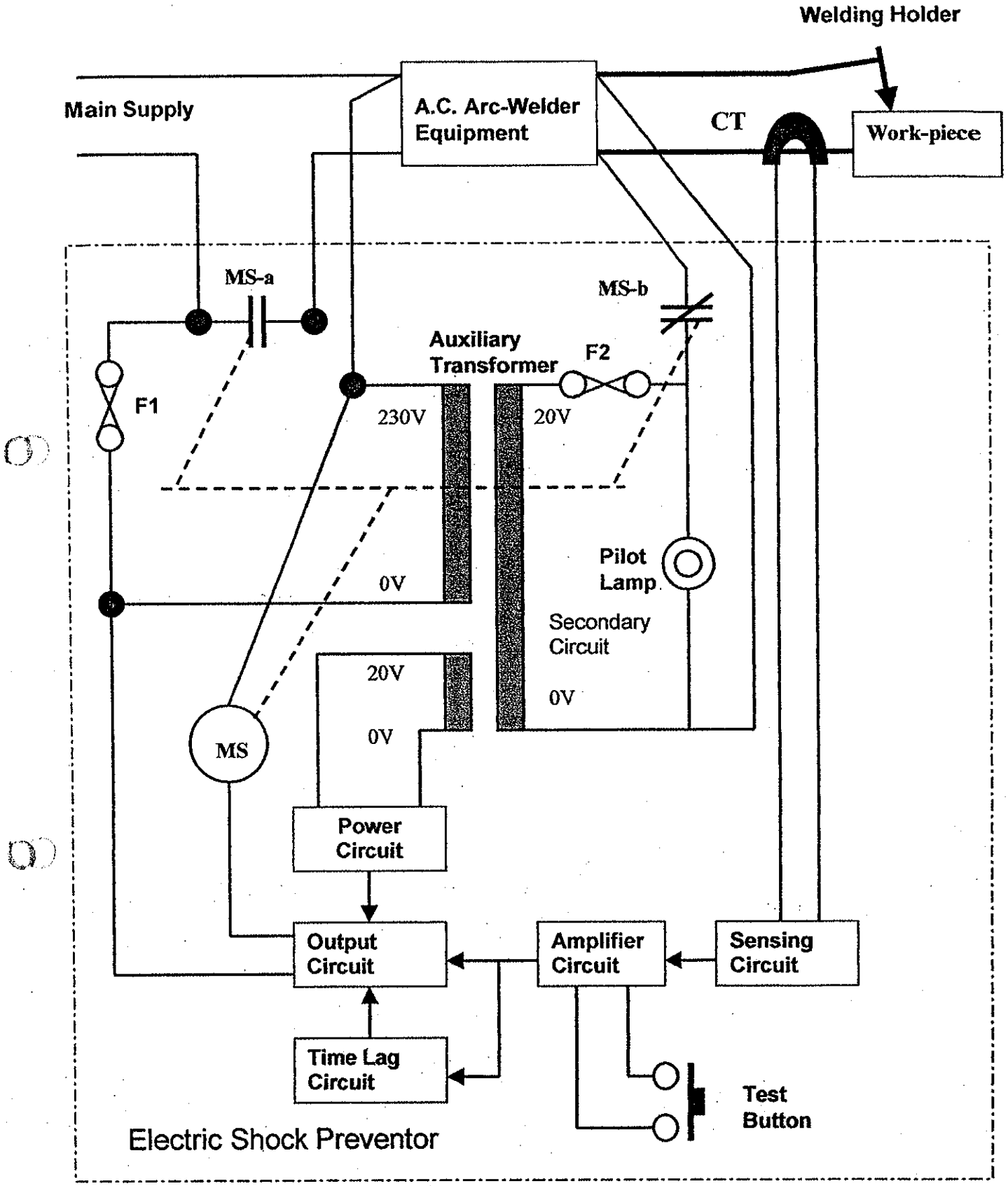
2.3 During Welding

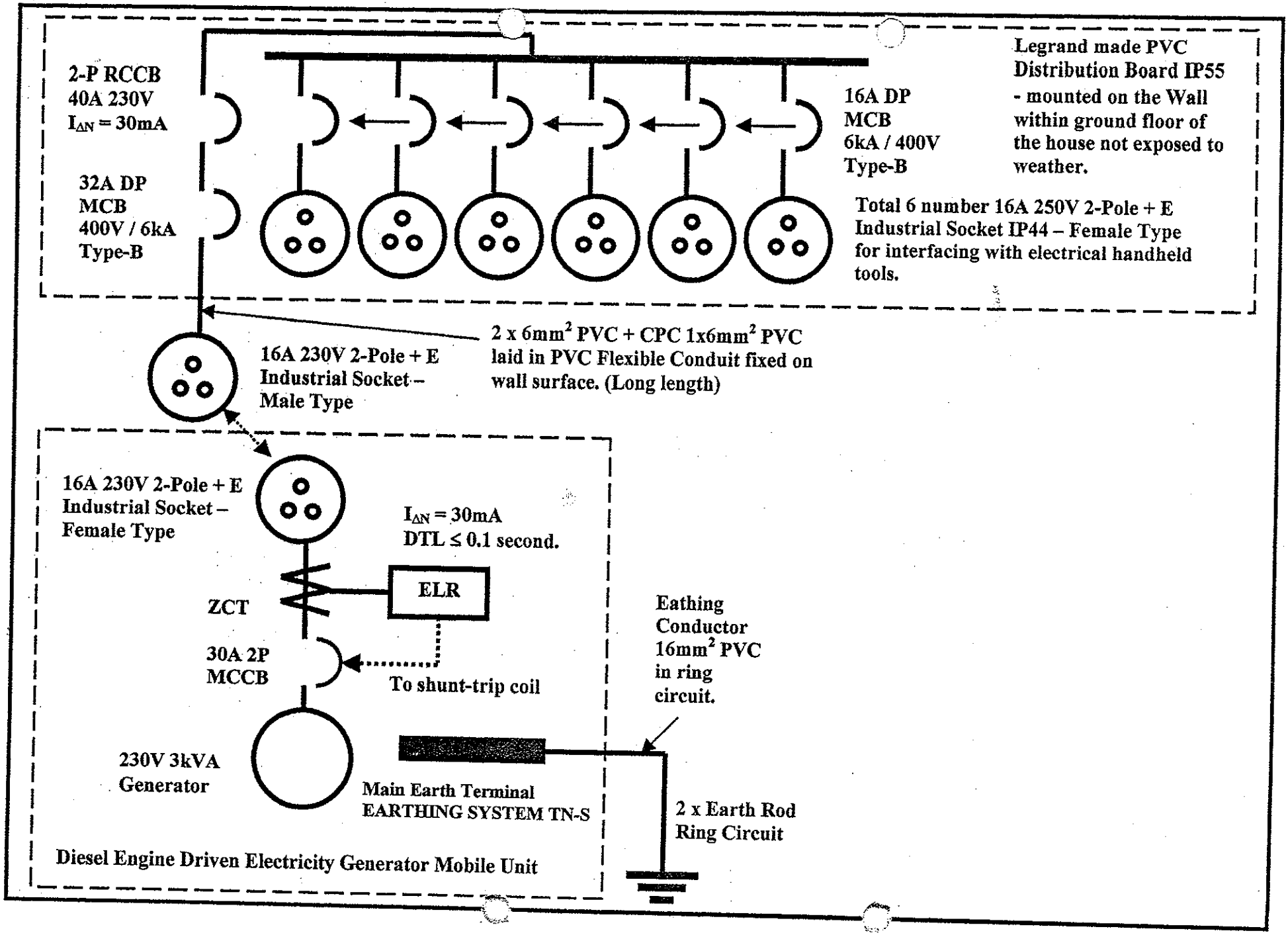
When the electrode id lifted up slightly, arcing starts to take place. During welding, a continuous signal current is being monitored by the sensing circuit to keep the electromagnetic contactor in the energised condition. The pilot lamp lights up continuously dimly and brightly depending on the voltage across the welding electrode and work-piece.

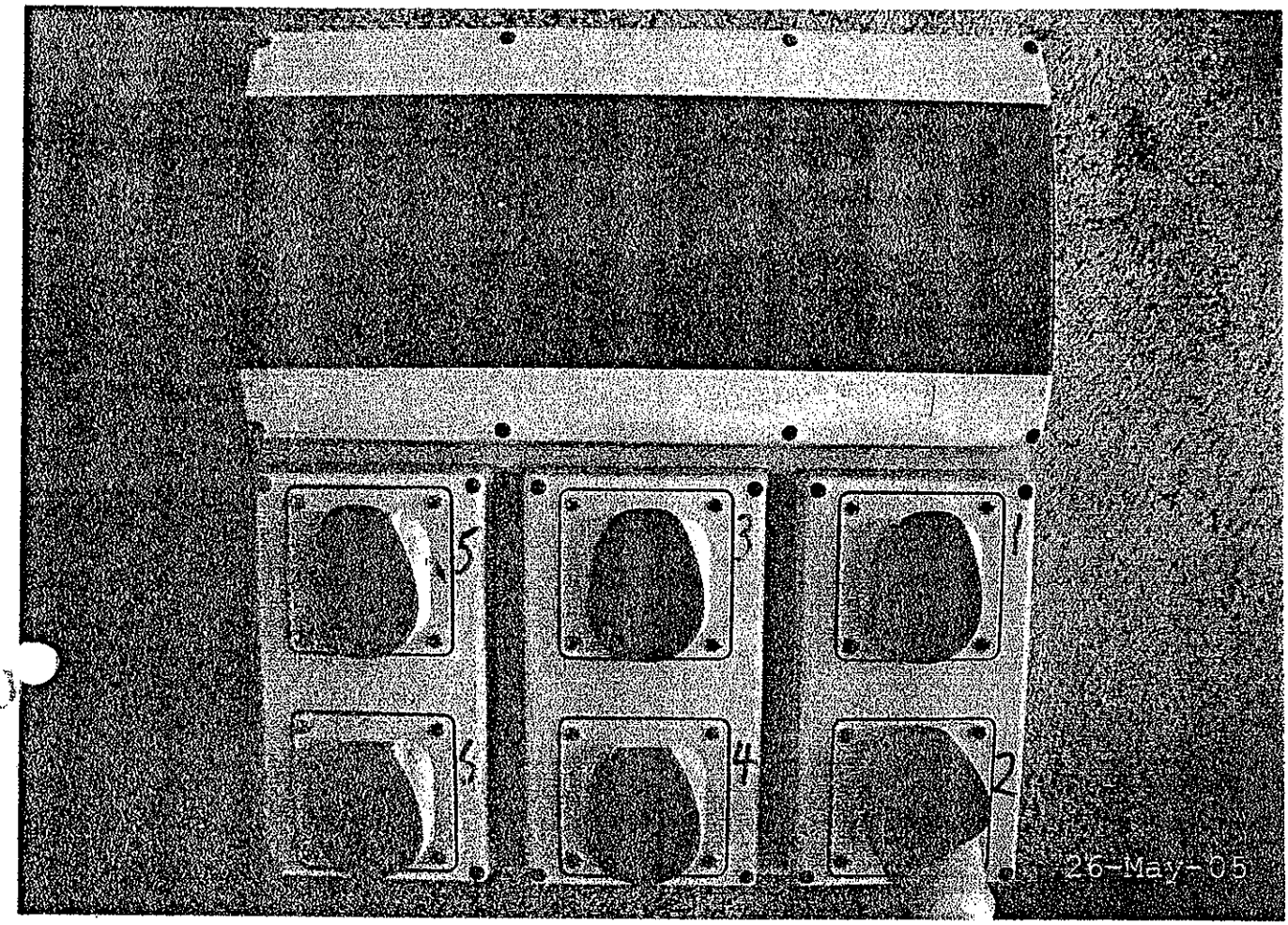
2.4 Welding Over

When welding stop, there is no current send to the "Sensing Circuit" from the current transformer, CT. However, the "Time Lag Circuit" will keep the electromagnetic contactor remain energised for about one second. Within this one-second interval, the open secondary voltage of the welding equipment (i.e. between electrode and work-piece) is in the range 60V to 90V. The pilot-lamp lights up at its brightest which indicates a danger warning.

As soon as the one-second is over, the electromagnetic contactor de-energised and and open the main contact MS-a, hence cutting off the main supply to the primary circuit of the welding equipment. The subsidiary contact MS-b closes and the secondary circuit of the welding equipment is loaded to a voltage not exceeding 25V.


Welding Holder
Main Supply
A.C. Arc-Welder Equipment
CT
Work-piece
MS-a
MS-b
Auxiliary Transformer
F2
F1
230V
20V
0V
Pilot Lamp
Secondary Circuit
20V
0V
MS
Power Circuit
Output Circuit
Amplifier Circuit
Sensing Circuit
Time Lag Circuit
Test Button
Electric Shock Preventor


2-P RCCB
40A 230V
$I_{\Delta N}$ = 30mA
32A DP
MCB
400V / 6kA
Type-B
16A DP
MCB
6kA / 400V
Type-B
Legrand made PVC
Distribution Board IP55
- mounted on the Wall
within ground floor of
the house not exposed to
weather.
Total 6 number 16A 250V 2-Pole + E
Industrial Socket IP44 – Female Type
for interfacing with electrical handheld
tools.
2 x 6mm² PVC + CPC 1x6mm² PVC
laid in PVC Flexible Conduit fixed on
wall surface. (Long length)
16A 230V 2-Pole + E
Industrial Socket –
Male Type
16A 230V 2-Pole + E
Industrial Socket –
Female Type
$I_{\Delta N}$ = 30mA
DTL ≤ 0.1 second.
ELR
ZCT
30A 2P
MCCB
To shunt-trip coil
Eathing
Conductor
16mm² PVC
in ring
circuit.
230V 3kVA
Generator
Main Earth Terminal
EARTHING SYSTEM TN-S
2 x Earth Rod
Ring Circuit
Diesel Engine Driven Electricity Generator Mobile Unit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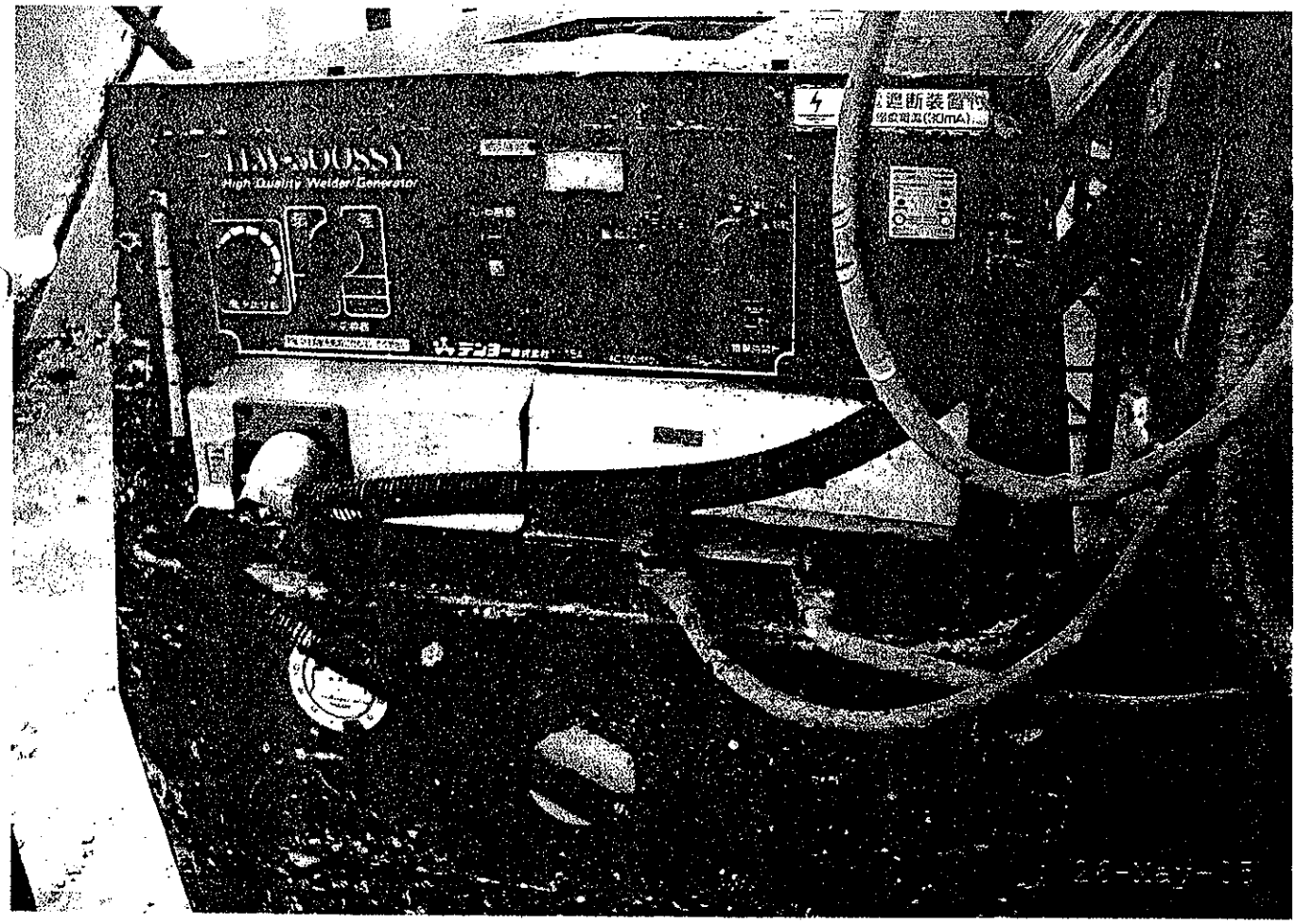

High Quality Welder/Generator

Code of Practice Temporary Electrical Installations for Festive Lighting, Trade-Fairs, Mini-Fairs and Exhibition Sites (CP88: Part 2: 2001)

1 What is Temporary Electrical Installation (TEI)?

The TEI in the CP88: Part 2 is referring to the following installation:

(1) Trade-fairs or mini-fairs;

(2) Exhibition;

(3) Amusement park;

(4) Decorative lighting in public place;

(5) Any outdoor electrical installation set up for festive, religious or commercial event accessible to the public.

2 Exceptional Electrical Installation

The following installations/part of installations are outside the scope of CP88: Part 2:

(1) Decorative lighting within domestic premises. (under SS CP5)

(2) Those parts of the TEI receive supplies at voltage higher than 1000 V.

(3) Discharge lighting installation operating at high voltage for the purpose of decoration.

(4) Electrical equipment of machine.

3 Related Code of Practice

The general requirements of SS CP5 shall be read in conjunction with CP88: Part 2.

Because of variations in local circumstances of construction sites, the requirements of this code is given in general terms, the implementation of the code of practice shall be supplemented by the advice of a Licensed Electrical Worker.

4 Relationship with Statutory Regulation

CP88: Part 2 is to be implemented in conjunction with other statutory requirements currently in force in Republic of Singapore and should there be any conflicting requirements in the Acts and Regulation, clarification should be sought from the relevant bodies administering the Acts and Regulation.

5 Use of Established Materials, equipment and methods

- Singapore Standard (**SS**)
- International Electrotechnical Commission (**IEC**)
- Other national or international standards **not inferior** to SS or IEC.

6 Definition

(1) Booth

Unit, usually moveable, intended to accommodate equipment generally for pleasure or demonstration purposes.

(2) Cable Coupler

A cable coupler is a means of enabling the connection at will of two flexible cables. It consists of two parts:

(i) Connector – intended to be attached to the flexible cable **connected to the supply**.

(ii) Plug – intended to be attached to the flexible cable connected to the equipment or to a connector.

(3) Generating Set

A generating set is an internal combustion engine driving a rotating a.c. electrical generator together with its associated control panel, switchgear and ancillary equipment, whether integrally mounted or otherwise.

(4) Plug

A device provided with contact pins, which is intended to be attached to a flexible cable, and which can be engaged with a socket-outlet or with a connector.

(5) Readily accessible

Capable of being reached quickly, for operation, renewal, or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

(6) SELV (Separated extra-low voltage)

An extra-low voltage system, which is electrically separated from Earth and other systems in such a way that a single fault does not pose any risk of electric shock.

(7) Skilled Person

A person who is licensed as an electrical worker under the Electrical Workers Licensing Act.

(8) Socket-outlet

A device provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug. A luminaire track system is not regarded as a socket-outlet system.

(9) Site

An Area where one or more stands, decorative lighting, amusement devices or booths are erected outdoor.

(10) Stands

Area or temporary structure used for display, marketing, sales and entertainment.

(11) Supplies

All references throughout the CP88: Part 2, refer to alternating current (a.c.) supplies related to a frequency of 50 Hz unless otherwise stated. Alternating voltage and current relate to r.m.s. values unless otherwise stated.

7 Source of Supply

(i) Public electricity supply network – 50 Hz, 400V 3-phase or 230V single-phase.

(ii) Generating sets –

(a) Three-phase – 50Hz at 400V between phases and **230 between phases and earth**.
(b) Single phase – 50 Hz at 230V between phase & earth.

(iii) Reduced voltage – 110V single-phase from a **double-wound transformer** having the **centre tap of the secondary winding earthed** so that the nominal voltage to earth is only 55V.

(iv) Extra low voltage – 50V single-phase from a double-wound transformer having the **centre tap of the secondary winding earthed** so that the nominal voltage to earth is only 25V.

(v) Separated extra-low voltage (SELV)

An extra-low voltage system, which is electrically separated from Earth and other system in such a way that a single fault does not pose any risk off electric shock.

7.1 Operation Between Generating Set and the Public Electricity Supply System

(1) **No parallel operation,** unless otherwise approved by the public electricity supplier.

(2) In a service area where electricity supply is taken from a generating set, no electricity supply from the public system shall be introduced into the same service area.

7.2 Earthing System for Single Generating Set

The earthing system is TN-S system.

7.3 Earthing System for Multiple Generating Sets

(1) Share a common earthing system.

or

(2) Have separate earthing systems and the electrical installations connected to different earthing system are segregated effectively from one another or effectively bonded to prevent dangerous potential rise between conducting parts which a person can come into simultaneous contact.

7.4 Earthing System for Multiple Supplies Taken from Public Supply System

Earthing system same as paragraph 7.3

7.5 Design, Selection and Installation of Protective Conductors

In accordance with SS CP5.

8 Installation of Generating Set

8.1 General

(1) Generating set shall be suitably barricaded to prevent access by non-authorised person.

(2) Adequate clearance around generating set to facilitate operation & maintenance work.

(3) Readily accessible to the generating set.

(4) Readily accessible to any switch or control for stopping and starting the engines.

(5) Generating set **shall not be installed**

(i) in damp situation or exposed to weather **unless suitably protected**.

(ii) in hazardous area, unless the equipment and method of installation comply with "BS 5345-CP for selection, installation and maintenance of electrical apparatus for use in potentially explosive atmosphere (other than mining applications or explosive processing and manufacturing)", and the additional requirements of any relevant authority.

(6) Fuel and its container shall be stored in a safe manner.

8.2 Earthing Arrangement of Generating Set

(A) Earthing system requirement:

(1) Share a common TN-S system.

(2) Main Earthing Terminal or Bar shall be of adequate rating and connected to the earth electrode system via Earthing Conductors.

(3) The star-point of a 3-phase generator winding or the mid-point of a single-phase centre-tapped generator winding shall be solidly earthed through adequately rated conductors to the earthing system of the installation.

(B) Bonding system requirement:

The following parts of the generating set shall be bonded together to form the "generator bonding system" which shall be connected effectively to the "main earthing terminal".

(1) Engine frame.

(2) Generator frame.

(3) All metal enclosure for electrical equipment & wiring.

(4) Earthing terminals of socket-outlet.

(5) The main frame terminal (marked )

8.3 Protection Against Direct Contact of Live Parts

In accordance **SS CP5.**

8.4 Labeling of Generating Set

Information such as:

(1) Name of the manufacturer.
(2) Model number, serial number of the set.
(3) Type of fuel or fuel-oil mixture.
(4) Rated output in Watts or kilowatts at a stated power factor.
(5) Voltage & frequency.
(6) Output terminal markings (unless all outputs are socket-outlets)

(7) The frame terminal: symbol marked 

(8) The word "**NOT WEATHER PROFF**" shall be on the set if it is intended for undercover or weather protected usage.

(9) On a set intended for out door use without further protection against weather/environment, the IP classification of its electrical equipment.

(10) A **danger sign** made of **durable material** with the word "DANGER" with the specification as specified in Annex D shall be **displayed at a prominent location near the generating set.**

9 Protection for Safety

9.1 General

Switchgears shall be readily accessible and shall incorporate:

(1) Means of isolation; and

(2) Means of overcurrent and earth fault protection; and

(3) Means of earth leakage protection (except extra-low voltage installations i.e. not exceeding 50V a.c.)

9.2 Protective Device for Incoming Supply

(1) Incoming supply up to 300A – Circuit breaker with **RESIDUAL CURRENT DEVICE.**

(2) Incoming supply exceeding 300A – Circuit breaker incorporating **OVERCURRENT** and **EARTH FAULT protective device.**

9.3 Prohibited Use of Fuse for Final Circuit

FUSES SHALL NOT BE USED FOR PROTECTING FINAL CIRCUITS IN ANY PART OF THE INSTALLATION.

Note: Except for those SSO incorporated with fuse protection.

9.4 Protection Against Direct Contact

One or more of the following as indicated in SS CP5.

(1) Protection by insulation of live parts;

(2) Protection by barrier or enclosure.

9.5 Protection Against Indirect Contact for Low Voltage System

(1) By the use of Residual Current Device (RCD) and the setting will be based on the following:

(a) For TN-S system:

$$\mathbf{Z_s\, I_{\Delta N} \leq 25\ Volts}$$

(b) For TT system:

$$\mathbf{R_a\, I_{\Delta N} \leq 25\ Volts}$$

Where Z_s is the earth fault loop impedance.

$I_{\Delta N}$ is the **rated residual operating current** of the protective device in Ampere.

R_a is the sum of the resistance of the "earth electrode" and the "protective conductors" connecting it to the "exposed-conductive-part.

(2) Protection by Residual Current Device (RCD) for Final Circuit

Final circuits are to be protected by one or more RCD. The type of tripping sensitivities of residual current device to be used for the final circuit of the following rating shall be:

(a) Final circuits of rating ≤ 63A at 400V 3-phase or 230V 1-phase:

Use **R**esidual **C**urrent **C**ircuit **B**reaker (**RCCB** complying with SS97) with the tripping current, $I_{\Delta N}$ not exceeding 30 mA and a tripping time within 0.1 second.

(b) Final circuits of rating ≤ 100A at 400V 3-phase or 230V 1-phase:

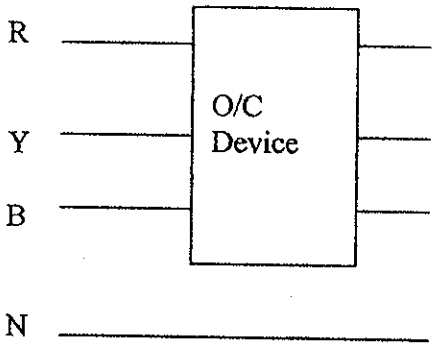
Use **RCCB** (complying with SS97) with a $I_{\Delta N} \leq 300$mA.

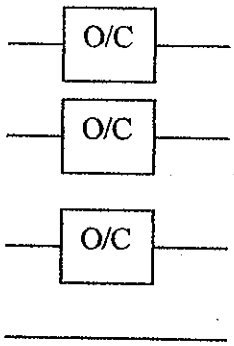
(c) Final circuits of rating > 100A at 400V 3-phase:

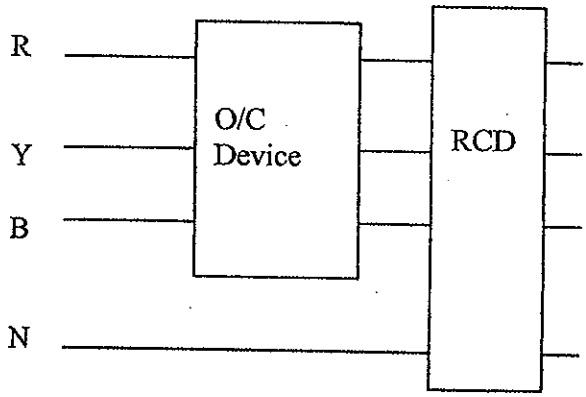
Use **RCD** with $I_{\Delta N} \leq 500$mA.

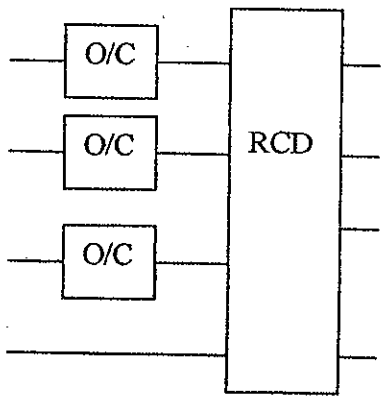
9.6 Protection Against Indirect Contact for Reduced Voltage System

(1) Automatic disconnection device installed in each phase conductor can be an **Overcurrent Device (O/C) or RCD**.









(2) All exposed-conductive-parts of the **Reduced Voltage System** shall be connected to Earth.

(3) The **earth fault loop impedance** at every point of utilisation, including socket-outlets, shall be such that the **disconnection time ≤ 5 seconds**.

(4) Where the O/C device is a **circuit breaker** which is use for automatic disconnection of supply under earth fault condition.

Table 1 – Maximum earth fault loop impedance (Z_s) for a disconnection time 5 second and U_0 of 55 volts (single-phase)					
MCB Type to SS 359 & BS EN 60898	1	B	2	C & 3	D
Rating amperes (I_n)	$U_0 / 4\ I_n$	$U_0 / 5\ I_n$	$U_0 / 7\ I_n$	$U_0 / 10\ I_n$	$U_0 / 20\ I_n$
6	2.29	1.83	1.31	0.92	0.46
10	1.38	1.10	0.79	0.55	0.28
16	0.86	0.69	0.49	0.34	0.17
20	0.69	0.55	0.39	0.28	0.14
25	0.55	0.44	0.31	0.22	0.11
32	0.43	0.34	0.25	0.17	0.09
40	0.34	0.28	0.20	0.14	0.07
50	0.28	0.22	0.16	0.11	0.06
63	0.22	0.18	0.13	0.09	0.04
80	0.17	0.14	0.10	0.07	0.03
100	0.14	0.11	0.08	0.06	0.03

(5) Protection Against Lightning

Refer to CP 33 if it is necessary.

10 Selection and Erection of Equipment

10.1 General

(1) **All metallic tent structure** within a fair or exhibition site shall be **bonded effectively to the earthing** of the electrical installation.

(2) Where **decorative lighting** is installed, all associated metallic-supported structures shall also be **bonded to the same earthing system.**

(3) Every item of **equipment** shall be selected and erected so as to comply with the general requirements stipulated in the **SS CP5 and the following clauses.**

10.2 Wiring System

(A) Installation of cables:

(1) Use flexible cable where appropriate.

(2) All cables shall meet the requirements of **IEC 60332-1**.

(3) Cables should meet the requirements of IEC 60332-3 for enhanced performance if needed.

(4) Cables should meet the minimum recommended performance in IEC 61034-2 if low smoke cables is needed.

(5) Cable shall have a **minimum voltage designation of 450/750 V**; except that, within amusement devices, cables and cords having a minimum voltage designation of 300/750 V may be used.

(6) Risk of mechanical damage – use armoured or cables protected against mechanical damage.

(7) The armour of an armoured cable cannot be used as the sole protective conductor.

(8) For buried cable:

(i) Use armoured cable or cables is provided with mechanical protection.

(ii) The routes of the cables shall be marked at suitable intervals.

(9) Cables shall not run across public roads or walkways unless:

(a) Adequate protection of the cables is provided against damage; and

(b) Such installation will not cause any obstruction or pose any danger to the public.

(10) Cables installation for fixed wiring within the area covered by tents shall not caused obstruction to the public.

(11) Non-metallic sheathed PVC insulated cables used for fixed wiring within the area covered by tents outdoor shall be installed in conduit or trunking. Except for rubber-insulated cables, such as neoprene, ethylene propylene rubber, etc.

(B) Electrical Connection:

(1) Joints shall not be made in cables and cords.

(2) Where joint is required as a connection to a circuit, joints are made:

(a) Cable couplers to **IEC 60309-2**.

(b) Connection unit to **SS 241** or equivalent IEC standard and installed in an enclosure with a degree of protection suitable for the environments but **not less than IP 4X** shall be used.

(c) All cable coupler and connection units shall be **supported above floor or ground level** in such a manner that the risk of **mechanical damage is prevented**.

(d) Where strain may be transmitted to terminals, **cable anchorage** shall be used.

10.3 Devices for Isolation and Switching

(1) A means of **isolation or switching** shall be provided and readily accessible at every switchboard or distribution board for the purpose of **disconnecting all phases, poles and the neutral.**

(2) **Every electrical installation of a booth, stand or amusement device** shall have its own means of **isolation** and **overcurrent protection** and readily accessible.

10.4 Switchgear and Controlgear

10.4.1 Enclosure for Low-Voltage Assembly

(1) The enclosure of each assembly shall be:

- **robustly constructed**
- adequate strength
- rigidity

(2) The enclosure for door installation shall have:

(a) at least **IP44** complying with SS IEC 60529; and

(b) a roof so designed to **prevent stagnation of water** on its surface.

(c) A roof shall **extend at least 76 mm** beyond the main body of the enclosure.

(3) The enclosure shall be so placed, installed and safeguarded:

- to **prevent damage by external influences** that may affect the design and safe operation of the equipment; and

- shall be provided with **adequate and safe means of access** and working space for operation and maintenance purposes.

10.4.2 Switchboard and Distribution Board

(1) Provide means for isolation and switching of the incoming supply. **Isolating switches and circuit breakers** used for this purpose shall be suitable for **securing in the OFF position**.

(2) Every switchboard and distribution board shall be erected to **satisfy the requirement of "Protection for Safety" as stipulated in paragraph 9**.

11 Other Equipment

11.1 General Requirement for Equipment installed outdoor including Tents

(1) All **luminaires, socket-outlets, distribution boards**, or **accessories** such as junction boxes, ceiling roses etc. shall be installed and **suitable for the environmental conditions**.

(2) All equipment or accessories if likely to be exposed to the weather or water splashing shall have a degree of protection of:

(i) **minimum IP44** to SS IEC 60529,
or
(ii) contained in weatherproof enclosure.

11.2 Luminairs and Fans

(1) All luminaires, fans and decorative chains shall be securely attached to the structure or support intended to carry them. The supply cable shall not carry the weight unless it has been selected and erected for this purpose.

(2) Luminaires and decorative chains mounted less than 2.5 m (within arm's reach) above floor level or otherwise accessible to accidental contact shall be

(i) firmly fixed and so sited or guarded as to prevent risk of injury to persons or ignition of materials

(ii) a tool is required for the removal of the barrier or an enclosure before access to the light source.

11.3 Lampholders

Insulation-piercing lampholders shall not be used.

11.4 Lamps in Shooting Galleries and Other Sideshows where Projectiles are Used

All lamps shall be suitably protected against accidental damage.

11.5 Lighting Chain

Complying with the requirement of SS 263.

11.6 Floodlights

(1) All floodlight's shall be mounted so that the luminaire is inaccessible to the public.

(2) Use flexible cable with adequate mechanical protection.

11.7 Fire Risk of Luminaires and Floodlights

Luminaires and floodlights shall be so fixed and protected that focusing or concentration of heat is not likely to cause ignition of any material.

11.8 Electrical Discharge Lamp Installations

Every installation of luminous tube, sign or lamps on a booth, stand or amusement device with an operating voltage higher than 230/400 V a.c. shall comply with the requirements of BS 559 (Specification for design, construction and installation of sign) and the following requirements:

(1) Location

The sign or lamp shall be installed out of arm's reach (more than 2.5m above floor) or shall be adequately protected to reduce the risk of injury to persons.

(2) Installation

The fascia or material behind luminous tube, signs or lamps shall be non-ignitable materials.

Control gear with output voltage higher than 230/400 V a.c. shall be mounted on non-ignitable material.

(3) Emergency Switching Devices

A separate circuit shall be used to supply such signs or lamps, which shall be controlled by a emergency switch. The emergency switch shall be easily visible, accessible and marked in accordance with SS CP5.

11.9 Safety Isolating Transformers and Electronic Converters

Multiple connection safety isolating transformers shall comply with IEC 61558-2-6 or provide an equivalent degree of safety.

A manually reset protective device shall protect the secondary circuit of each transformer or electronic converter (IEC 60204-1).

Safety isolating transformer shall be mounted out of arm's reach of the public and shall have adequate ventilation. Access by skilled or instructed persons for testing and maintenance of protective device shall be provided.

Electronic converters shall conform to IEC 61046.

Enclosures containing rectifiers and transformers shall be adequately ventilated and all vents not obstructed when in use.

11.10 Overground or Control Box

Overground or control boxes shall preferably be made of **high impact PVC** or **insulation material** which serve as supplementary insulation to **reduce the risk of electric shock**.

Overground/control box shall be suitable for the environmental condition.

11.11 Socket-outlets, Plugs and Couplers

(1) Provide **adequate number** of socket-outlets for use, and shall be **firmly installed**.

(2) If exposed to weather condition, they shall comply with **IEC 60309-2** or contained in **weatherproof enclosure**.

(3) **Not more than one flexible cable or cord** shall be connected to a plug unless the plug is specifically designed for multiple connections.

(4) Multiple-way plug-in type adapters shall not be used.

12 Decorative Lighting

(1) Operation Voltage

(i) Use low voltage of SELV.

(ii) However, where decorative lighting installation is accessible to or within reach of the public or accessible to accidental contact, it shall be operated at SELV not exceeding 25 V a.c. r.m.s. or 60 V ripple-free d.c.

(iii) Every decorative lighting circuit operated low voltage shall be protected a RCCB of 30mA sensitivity.

12.1 Protection by SELV not Exceeding 25V a.c. r.m.s. or Ripple-Free 60 V d.c.

12.2 Source of Supply

(a) Safety isolating transformer complying with IEC 60742.

Or

(b) Motor-generator with windings providing electrical separation equivalent to that of the safety isolating transformer of (a) above.

12.3 Protection Requirement for SELV Exceeding 25 V a.c. r.m.s. or 60 Ripple-Free V d.c.

Provide protection against Direct Contact by:

(a) a barrier or an enclosure affording at least the degree of protection IP 2X or IP XXB;

or

(b) insulation capable of withstanding a test voltage of 500 V d.c. for 60 seconds.

12.4 Arrangement of Circuit for SELV

(1) A live parts of SELV system shall

(a) be electrically separated from that of any other higher voltage system. Except for cables the electrical separation shall be not less than that between the input and output of a safety islating transformer.

(b) not be connected to Earth or to a live part or a protective conductor forming part of another system.

(2) Segregation of Circuit Conductor of SELV System from Those of Any Other System:

(a) SELV circuit conductors shall be insulated in accordance with the requirements of the clauses for the higest voltage present;

(b) SELV cables shall be non-metallic sheathed cables complying with Chapter 52 of SS CP5. (Selection & Erection of Wiring System)

(c) Conductors of systems at voltages higher than SELV shall be separated from those at SELV by an earthed metallic screen or an earthed metallic sheath;

(d) Where circuits at different voltages are contained in a multicore cable or other grouping of conductors, the conductors of SELV circuits shall be insulated, individually or collectively, for the highest voltage present in the cable or grouping.

(3) Exposed-Conductive-Part of SELV System

No exposed-conductive-part of SELV system shall be connected to any of the following:

(a) earth;

(b) an exposed-conductive-part of another system;

(c) a protective conductor of the system;

(d) an extraneous-conductive-part, except where electrical equipment is inherently required to be connected to an extraneous-conductive-part, measure shall be taken so that the parts cannot attain a voltage exceeding 25 V a.c.

(4) If an exposed-conductive-part of the SELV system is liable to come into contact, either fortuitously or intentionally, with an exposed-conductive-part of any other system, the system shall not be deemed to be SELV.

12.5 Socket-Outlet in SELV System

(1) A socket-outlet in a SELV system shall require the use of a plug that is **not dimensionally compatible** with those used for any other voltage system in use in the same premises.

(2) A socket-outlet **shall not have a protective conductor contact.**

12.6 Luminaire Support Coupler for SELV System

A luminaire supporting coupler **shall not have a protective conductor contact**.

12.7 Inspection, Testing and Maintenance

(1) Strict maintenance and periodic inspection of the TEI and its wiring distribution shall be carried out by **a skilled person (Licensed electrical worker)**.

(2) Upon completion of the inspection, the skilled person shall **complete and sign the checklist shown in Annex B** and hand it over to the operator of the electrical installation or his representative.

(3) Where any defect or unsafe condition is revealed during the inspection, the skilled person shall take measures, such as by rectifying the defects, or **isolating** or **disconnecting** the defective part(s) from electricity supply, so as to render the electrical installation safe.

(4) Appropriate measures taken against the defect or unsafe condition shall be clearly indicated in the checklist.

LEW REFRESHER COURSE

Common non-compliance in Electrical installations

1. INTRODUCTION

In NEM, EMA has re-categorized the common non-compliances into three groups

Category 1 -- Serious
Category 2 -- Minor and
Category 3 – Operational

EMA is monitoring the common non-compliances in category 1 & 2 only. A proper penalty will be given to these two categories. For category 3, no penalty is imposed by EMA. However, SP Services or SP PowerGrid may not allow the supply to be turned-on.

No electricity supply shall be taken from a supply line until every electrical installation connected to such supply line has been inspected and certified fit by a licensed electrical worker; and where the installation is exempted from licensing, it shall be checked by the Market Support Services Licensee.

If the inspection failed, LEW is to check the installation thoroughly, rectify all defects and apply for another appointment. A fee per account is chargeable for each subsequent inspection.

2. NON-COMPLIANCES OF SS CP 5:1998 AND OTHER RELEVANT REGULATIONS

The non-compliances are grouped into three separate categories depending upon the severity of the defect

2.1 CATEGORY 1

Non-compliances that pose immediate safety hazards or are of a serious nature

1001	No protection against direct contact for live conductors.
1002	Wrong polarity / phase sequence.
1003	Using single-pole circuit breaker for neutral conductor
1004	Using unacceptable or deceptive method for earthing system / earthing system not provided.
1005	No provision of residual current circuit breaker (RCCB) of 30 mA sensitivity for domestic SSO / lighting circuits.
1006	No provision of residual current circuit breaker (RCCB) of 30 mA sensitivity for market / food stall, etc.
1007	No provision of residual current circuit breaker (RCCB) of 30 mA sensitivity for socket-outlet assembly used at construction site.
1008	No provision of residual current circuit breaker (RCCB) of 30 mA sensitivity for general-purpose SSO circuit outdoor.
1009	Neutral of generating set not effectively connected to Earth.

2.2 CATEGORY 2

Non-compliances that may pose safety hazards

2.2.1 General

2101 Insulation resistance value less than 0.5 MΩ for low voltage circuit.

2102 No documentation on tests carried out / incomplete test reports.

2103 Single-line drawing not provided / updated / endorsed by LEW.

2104 No provision of safety related equipment or signs such as rubber mat / fire extinguisher / danger sign / CPR chart at main intake switchboard.

2105 Improper installation of reduced voltage or SELV system.

2106 Improper installation that pose electrical safety hazards to the public. (to specify)

2107 Improper installation of generating sets.

2.2.2 Switchboard / DB / Control of Circuits

2201 Switchboard or distribution board not readily accessible.

2202 Circuit breaker before / after meter not of appropriate type.

2203 Circuit breaker of insufficient short circuit capacity.

2204 Improper interconnection of sources of supply.

2205 Failure to provide DP isolator / circuit breaker at meterboard or incoming of DB.

2206 Fittings or final circuits in defined area supplied from different sources of supply.

2207 Non-weatherproof distribution board located below water or drainage pipe joint or valve.

2208 Circuit breaker overrated for protection of a circuit.

2209 Additional point(s) sharing air-con or water heater final circuit.

2.2.3 Earthing

2301 Earthing system inadequately / improperly installed.
2302 Improper or no earth electrode inspection chamber.
2303 Earth fault loop impedance is high for TN-S system or the product of $R_a I_a$ exceeds 50 volts for TT system.
2304 Circuit protective conductor (CPC) not provided or sharing of CPC in final circuits.
2305 Earthing conductor / CPC / bonding conductor undersized.
2306 Using green & yellow colour combination wire as live conductor / wrong colour coding for protective conductor.
2307 Main equipotential bonding not provided for main water pipe, gas pipe or exposed metallic part of building structure.
2308 Exposed conductive parts not bonded to Earth.

2.2.4 Equipment / SSO

2401 Circuit breaker / isolator / RCCB / switch / ceiling rose / connection unit underrated.
2402 Switch or SSO in enclosed space susceptible to risk of fire or explosion.
2403 No provision of residual current circuit breaker (RCCB) for SSO in non-domestic electrical installation.
2404 Non weatherproof electrical device(s) exposed to weather or water splashing.
2405 Non weatherproof electrical equipment installed under tents in outdoor conditions.
2406 SSO installed at less than 150 mm above working surface or floor level.
2407 SSO installed on floor without mechanical protection or protection against ingress of water.
2408 Switch controlling SSO for general purpose not readily accessible.
2409 Using electrical accessory/fitting not complying standards stipulated in the code of practice CP 5 or CP 88.
2410 Socket-outlets (SSO) / switches installed inside bathroom.

2.2.5 Cable / Wiring

2501 Mains / sub-mains / busbar / final circuit undersized.

2502 Cables laid underground without armour or metallic sheath; non-sheathed cable installed in underground pipe.

2503 Cable installed not suitable for the environment or weather conditions.

2504 Single PVC-insulated cable installed without conduit or trunking.

2505 Wiring above false ceiling not properly installed or installed without mechanical protection.

2506 Cable in same conduit / trunking / ducting with other services.

2507 More than one final circuit in one circuit breaker way.

2508 Cable armour improperly bonded or not bonded to Earth.

2509 No provision of PVC or rubber grommet / bushing at metallic sharp edges to prevent damage of cable insulation.

2510 Electrical connections / joints not mechanically and / or electrically sound.

2511 Wiring encroached into other premises / another electrical installation.

2.3 CATEGORY 3

Non-technical issue

3001	Licensed electrical worker absent.
3002	Gate/door locked.
3003	Work incomplete.
3004	No incoming electricity supply.
3005	Meter board/meter compartment at gatepost not complying with requirements.
3006	Incorrect address.
3007	Premises not fully accessible for inspection of electrical wiring installation.
3008	Wrong type of application.
3009	No Statement of turn-on.

2.4 ABBREVIATIONS

CPC	Circuit Protective Conductor
mA	Milliampere
M-ohm	1,000,000 ohm
RCCB	Residual Current Circuit Breaker
DP	Double Poles
SSO	Switched Socket Outlet
PVC	Polyvinyl Chloride

3. DETAILED DESCRIPTIONS OF COMMON NON-COMPLIANCES ON SITE

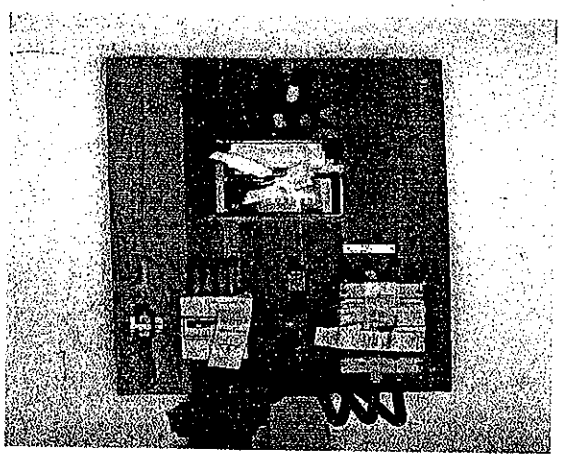
3.1 Low Insulation Resistance

Minimum value of insulation resistance

Circuit nominal voltage(V)	Test Voltage d.c.(V)	Minimum insulation Resistance (Mohm)
SELV and PELV	250	0.25
Up to including 500V with the exception of the above systems	500	0.5
Above 500	1000	1.0

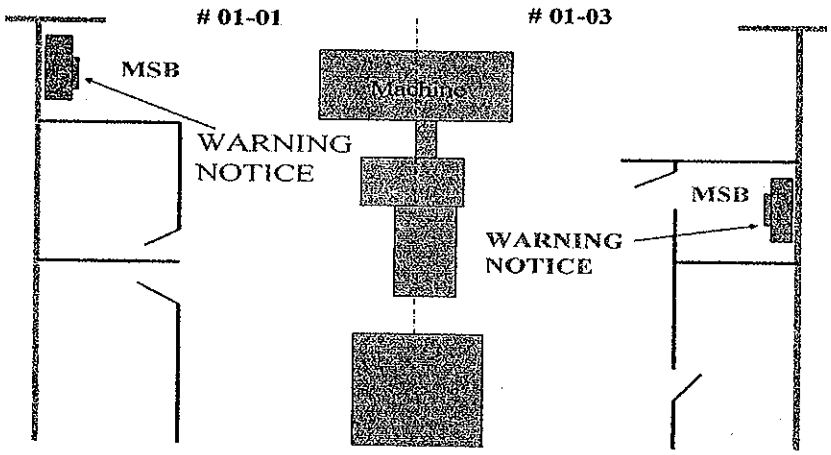
3.2 Identification of Protective Conductor without Using the Colour Combination of Green and Yellow or Using Single Colour Green

e.g. In a final Circuit, a black colour neutral cable is used as a circuit protective conductor. It is acceptable to use sleeve at both end of the cable; the sleeve shall have the combination colours of green and yellow.



3.3 Warning Notices Not Provided at the Main Linked Switches / Linked Circuit-Breaker for Installation Taking More than One Source of Supply

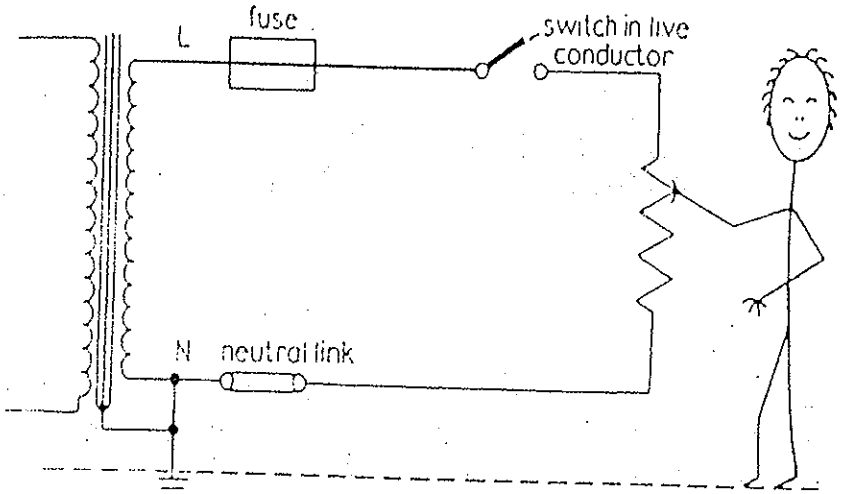
e.g. An installation has two separate main switchboards located at two different locations without the warning notices to warn any person the need to operate all the incoming circuit-breakers to achieve isolation of the installation.

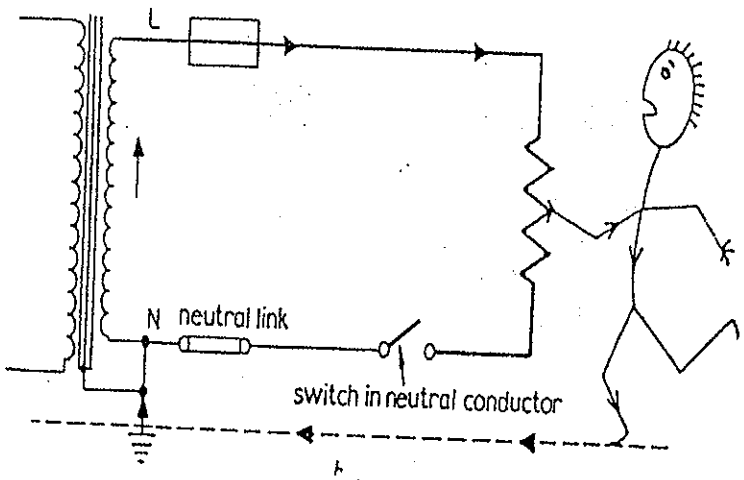


3.4 Wrong Polarity

e.g. Wrong polarity at the junction box which is used for the final connection to storage water-heater or instantaneous water-heater. The phase conductor is connected to the earth-terminal of the junction box.

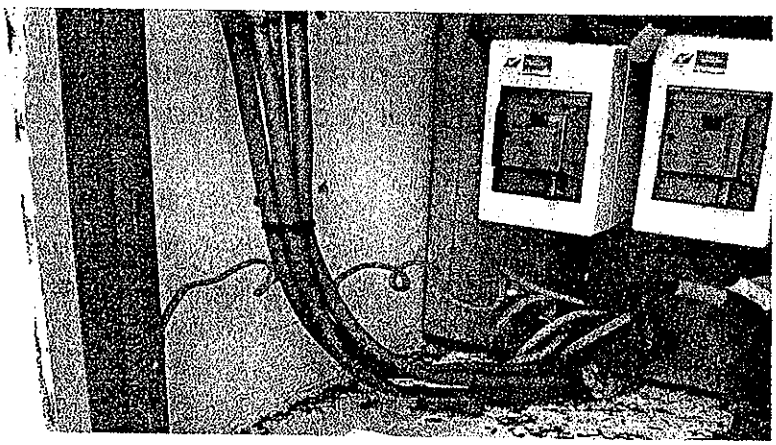
e.g. Wrong polarity at the socket-outlet such as transposition of the phase and neutral conductors or the phase conductor is connected to the earth-terminal.





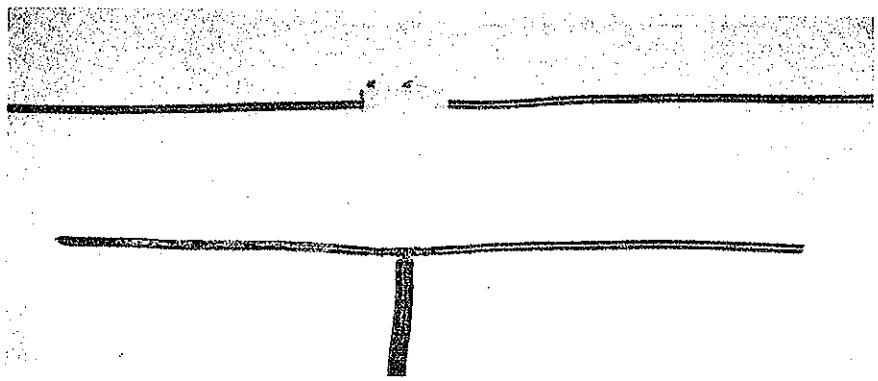
3.5 Exposed Conductive Parts Not Connected to Earth Effectively

These include the metallic enclosures of Class 1 current-using equipment, metallic cable sheaths, cable trays, trunkings and metallic conduits etc.



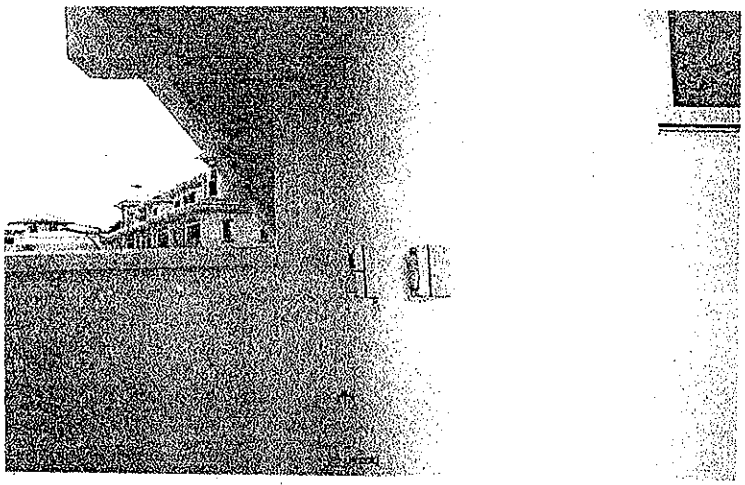
3.6 Electrical Connection / Joint Not Properly

e.g. PVC-cable is jointed to another PVC-cable by twisting the conductor together and covered the joint with PVC-tape.

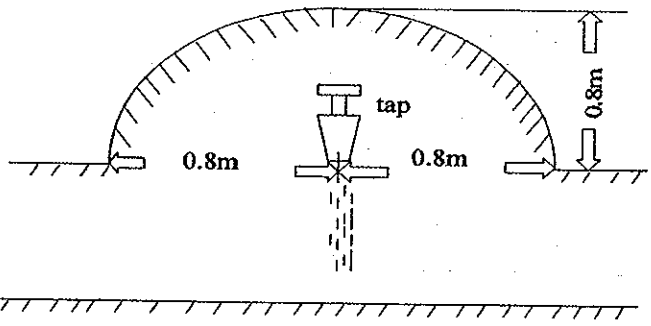


3.7 Non Weatherproof Electrical Device Exposed to Weather or Water Splashing

e.g. Wall mounted junction box or lighting fitting mounted on the wall above the bath tub.
A person standing in the wet bath-tub can touch the exposed metallic part of the light fitting or junction-box. Also, water could be sprayed on these devices when using the shower.



Acceptable distance between switch/socket outlet from water tap.

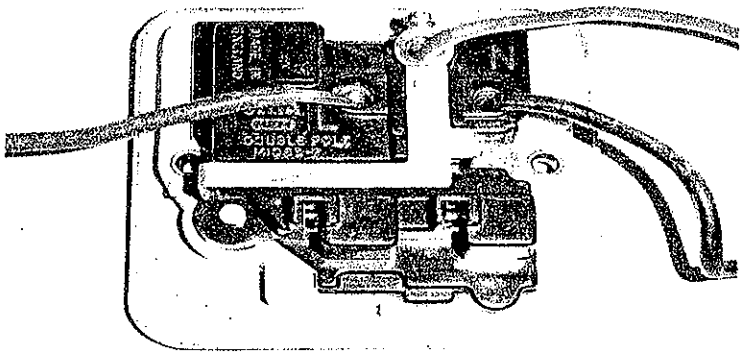


Note:

1. Switch/SSO shall be installed above the water tap source and outside the 0.8m zone to prevent water splashing.
2. Switch/SSO installed above the water tap source but less than 0.8m away from it shall be provided with a splash-proof cover to protect against water splashing.
3. Switch/SSO installed below any water tap source must be of weather-proof type.

3.8 Exposed Live Parts

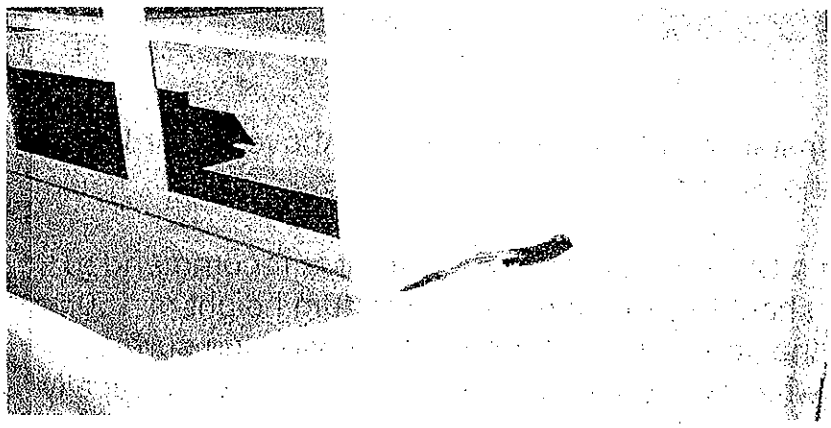
e.g. In high voltage discharge lighting installation, the joint of the high voltage conductor is exposed and not covered with suitable insulation. Furthermore, this joint can be touched by the person standing on the floor.



3.9 Accessory Not Provided for the Lighting Point

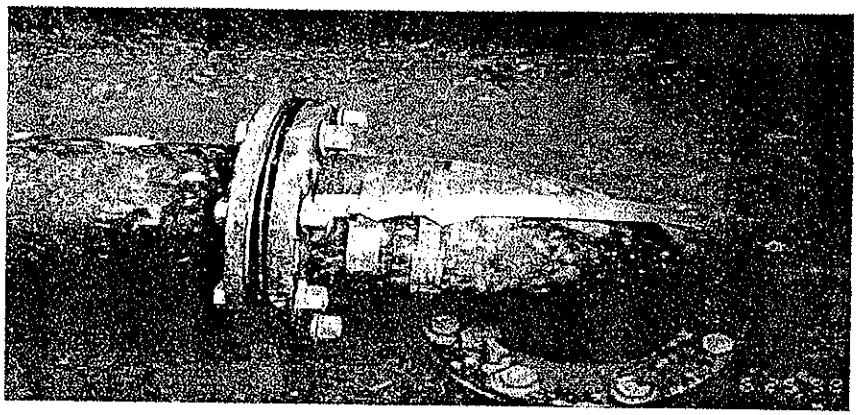
e.g. Using PVC insulated connector instead of the following accessories for the final connection of light fitting.

a) A ceiling rose to SS 23
b) A luminaire supporting coupler to BS 6972 or BS 7001.
c) A batten lampholder to SS 125 or SS 126.
d) A luminaire designed to be connected directly to the circuit wiring
e) A suitable socket outlet.
f) A connection unit to SS 241 or BS 1363 Part 4.



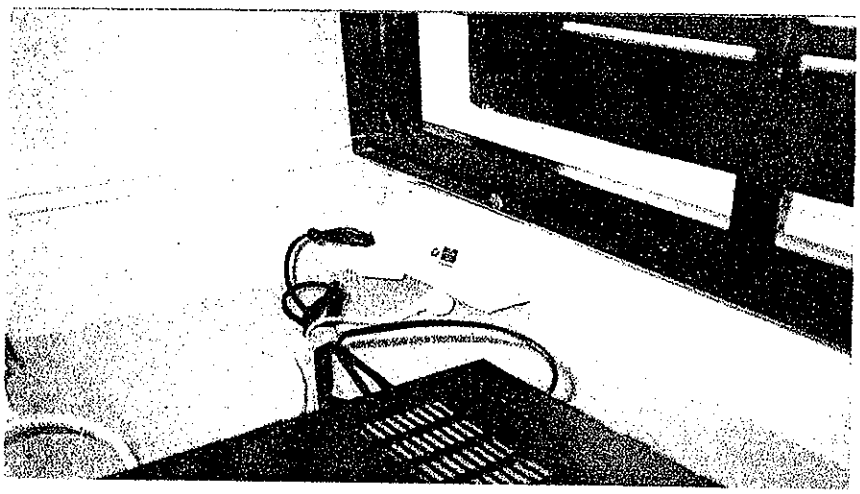
3.10 Main / Supplementary Equipotential Bonding Not Provided

Main equipotential bonding not provided for main water pipe, gas pipe or exposed metallic part of building structure.



3.11 SSO Installed at Less Than 150mm Above Floor Level or Working Surface

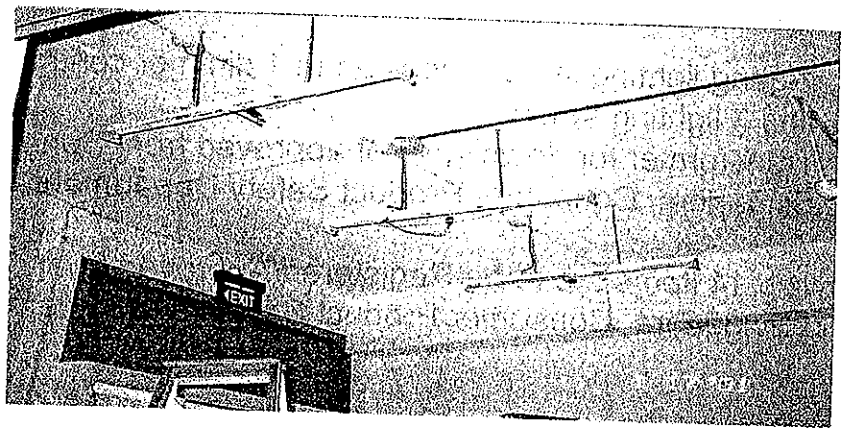
When a SSO is mounted on a wall, it is recommended that it should be mounted at a minimum height of 150mm from the floor level or 150mm above working surface. Also, when two SSO are installed side by side vertically, a distance of 150mm must be provided between the two SSO.

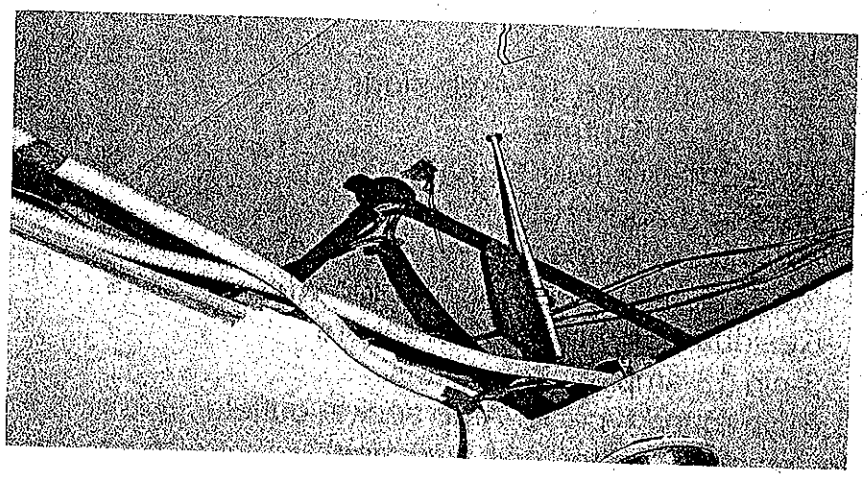


3.12 Wiring Above False Ceiling Not Properly Installed or Installed Without Mechanical Protection

e.g. Cable is laid on the false ceiling or,

e.g. Cable is laid in the conduit and hung in the air between two walls across the room.





3.13 Circuit Breaker Overrated - Does Not Afford Protection

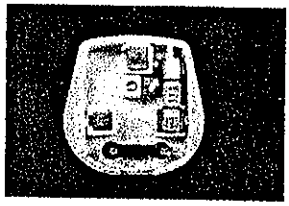
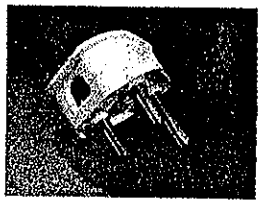
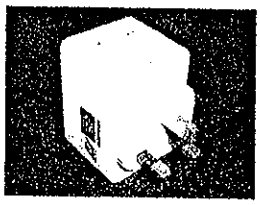
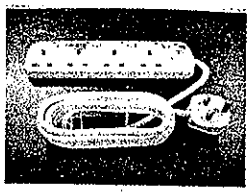
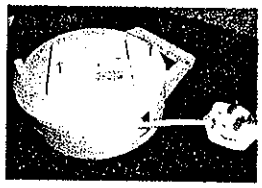
e.g. A lighting circuit is protected by a 15A MCB but the light holder is rated at 2A.

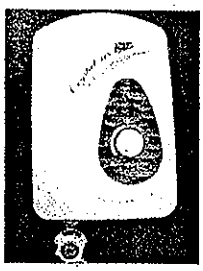
3.14 Accessory Used without the Registration/Approval from Spring Singapore, Consumer Product Safety Department

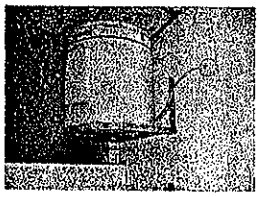
- 4-gang lighting switch modified to 1 dimmer control and 3 lighting switch.
- Transformer for downlight not approved from Spring Singapore, Consumer Product Safety Department.

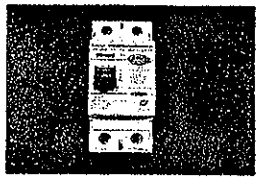
Following 14 items are to be Registered/Approved from Spring Singapore, Consumer Product Safety Department before use.

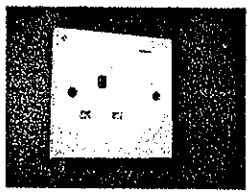
1) 3-pin rectangular type 13-Amp plugs
2) Fuses (less than or equal to 13-Amp) for use in plugs
3) 3-pin round type 15-Amp plugs
4) Multi-way adaptors
5) 3-pin portable socket-outlets
6) Portable cable reels
7) Instantaneous electric water heaters
8) Mains pressure electric storage water heaters
9) Residual current circuit breakers
10) 3-pin 13-amp socket outlets
11) 3-pin round type 15-Amp socket outlets
12) Domestic electric wall switches
13) Ballasts for tubular fluorescent lamps
14) Isolating transformers for downlight fittings

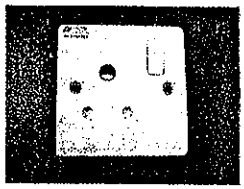







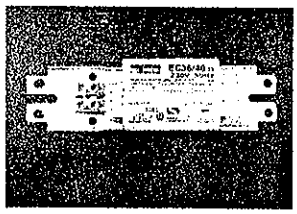


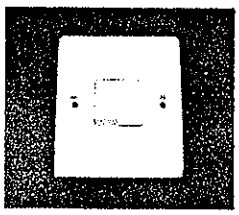


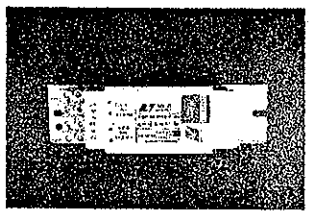




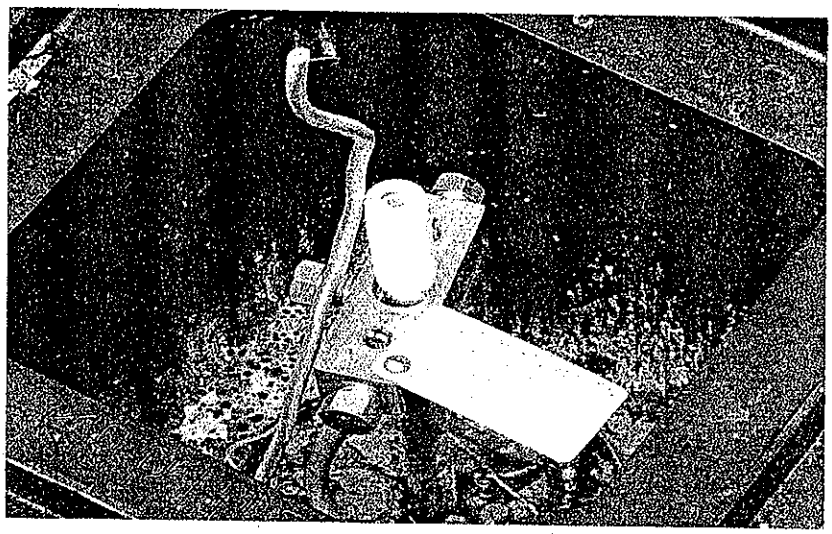




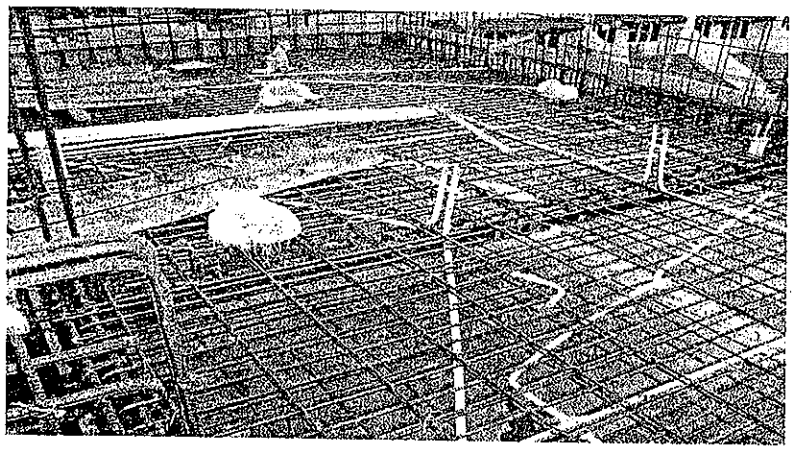




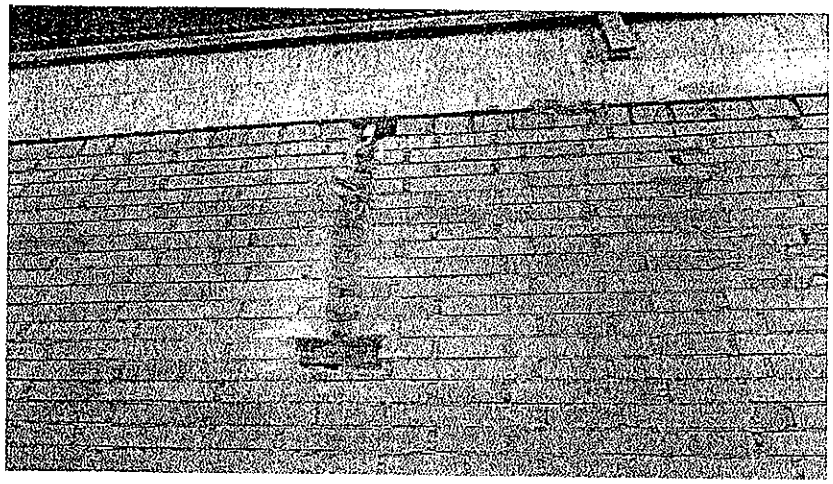
3.15 CPC, earthing conductor or bonding conductor undersized.



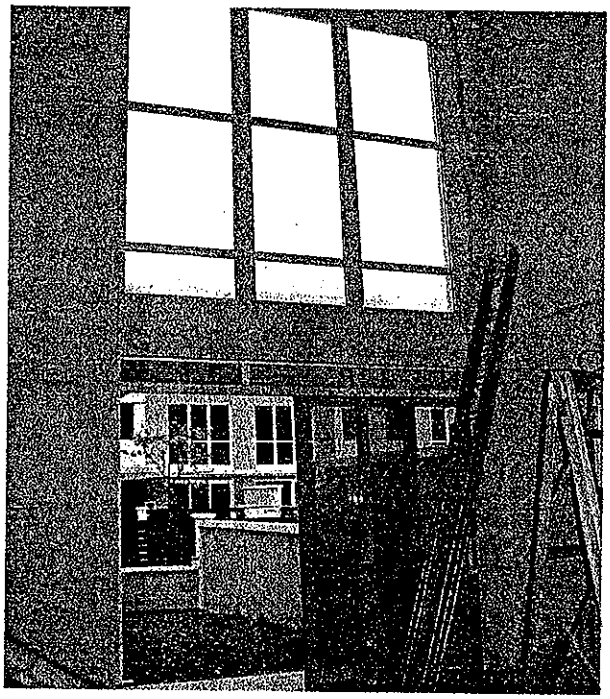
3.16 Cable laid underground without armour or metallic sheath; non-sheathed cable installed in underground pipe.



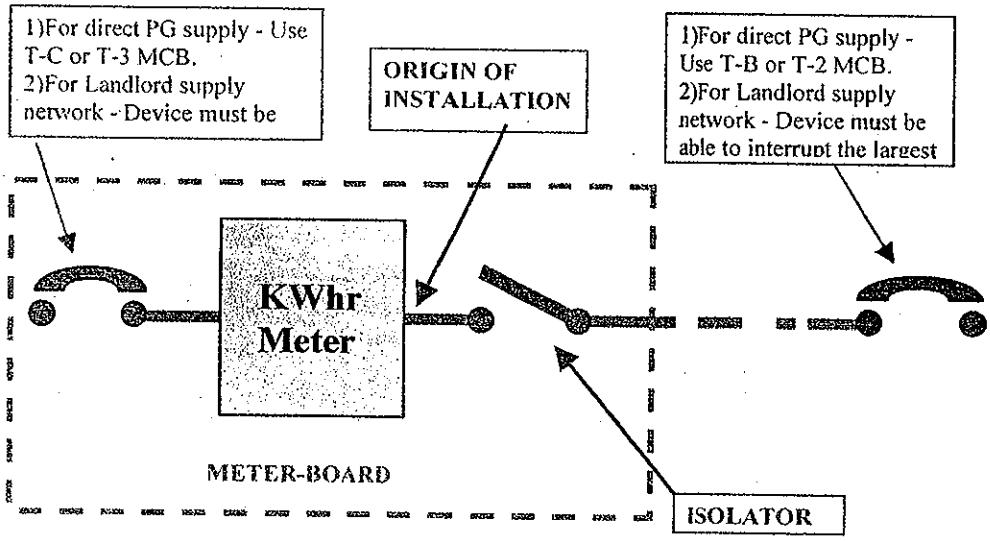
3.17 Single PVC insulated cable installed without conduit or trunking.



3.18 SSO for general purpose installed above 1.8m.



3.19 Wrong sequence of control at meter board

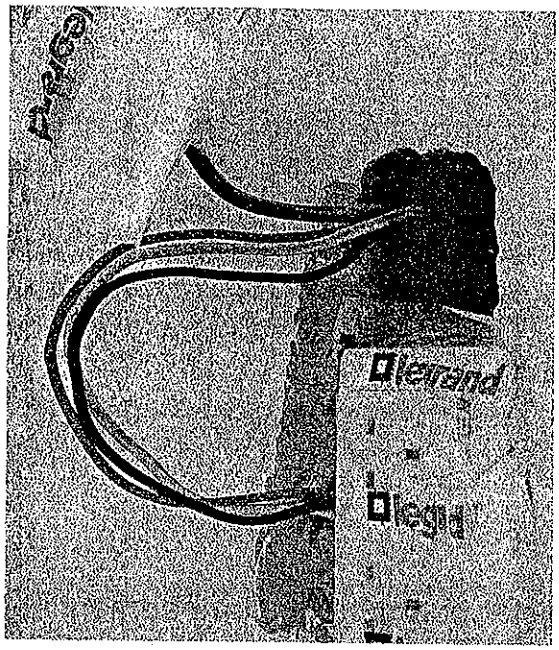


3.20 Meter board/meter compartment at gatepost not complying with requirements.(SPPowerGrid Requirement)

Please refer to SPPowerGrid's "Application for Electricity Supply" handbook for detailed requirements

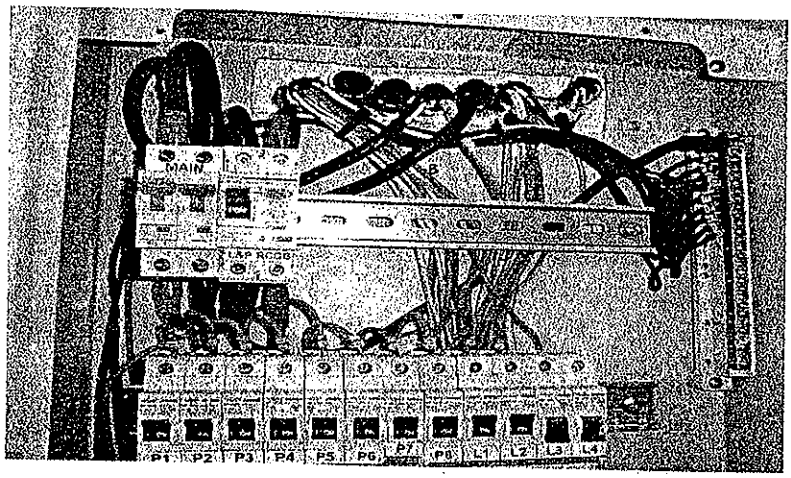
3.21 Cable in same conduit/trunking/duct with other services

- Sharing of power cables with telephone and SCV cables in the same conduit.

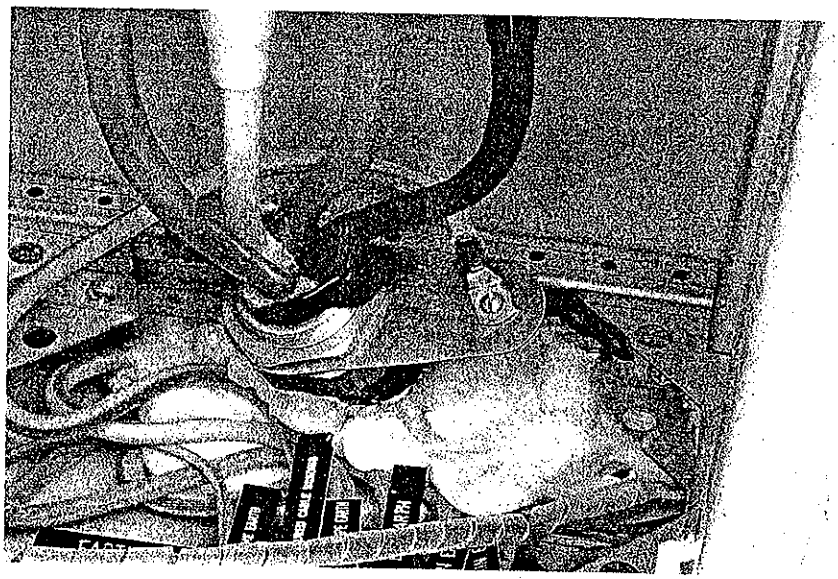


3.22 Wiring encroaching into other premises/electrical installation

3.23 No provision of PVC or rubber grommet/bushing at metallic sharp edges to prevent damage of cable insulation



3.24 Cable armour improperly bonded or not bonded to earth



3.25 Improper Installations

