MECH3422 Building Services Engineering I

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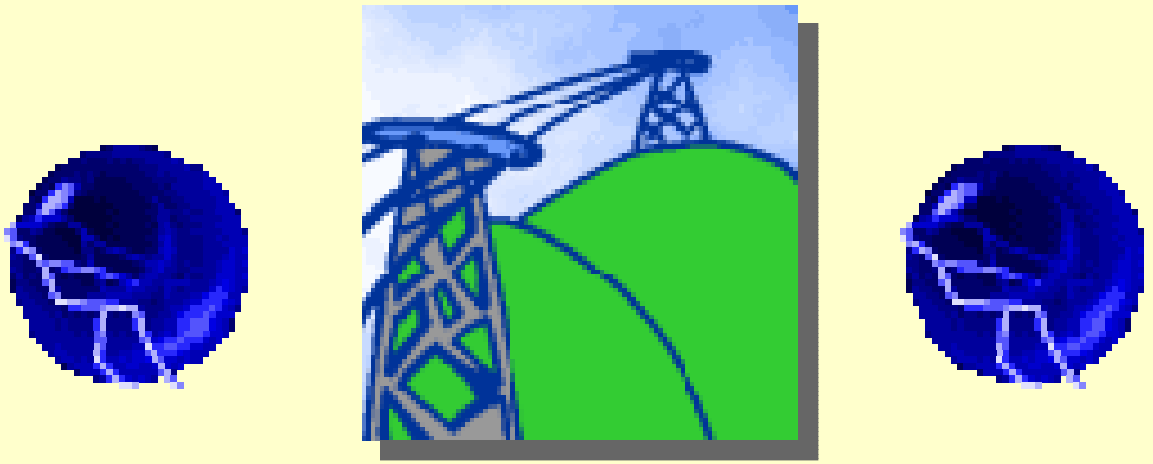

Electrical Services Systems – Regulations, Electrical Protection, Standby Power and Testing

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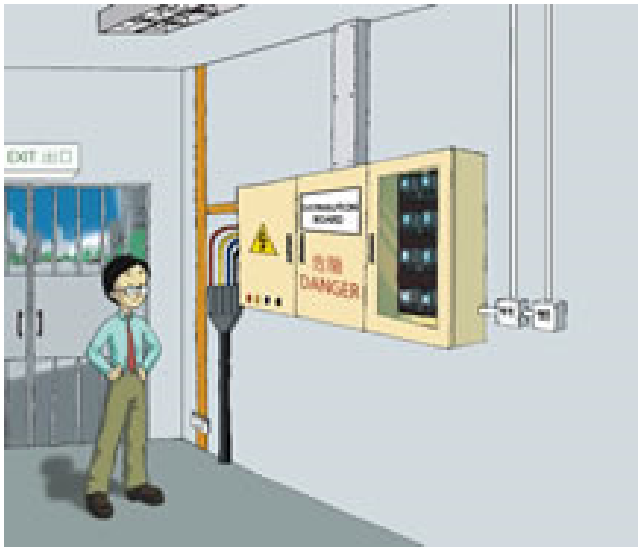


Regulations

- Typical legal system in Hong Kong (statutory)
  - Ordinance (*Laws of Hong Kong*)
  - Regulations
  - Code of Practice
- Supporting documents (non-statutory)
  - Technical Guidelines
  - Technical Notes or Technical Memoranda
  - Circular letters
  - Reference standards (usually from other countries)
  - Rules (from utilities companies)

Regulations

- Electricity Ordinance & subsidiary regulations
  - Electricity Ordinance (Cap. 406) *
    - Electricity (Exemption) Regulations
    - Electricity (Registration) Regulations
    - Electricity Supply Regulations
    - **Electricity (Wiring) Regulations**
    - Electricity Supply (Special Areas) Regulations
    - Electrical Products (Safety) Regulation
    - Electricity Supply Lines (Protection) Regulation

Most important

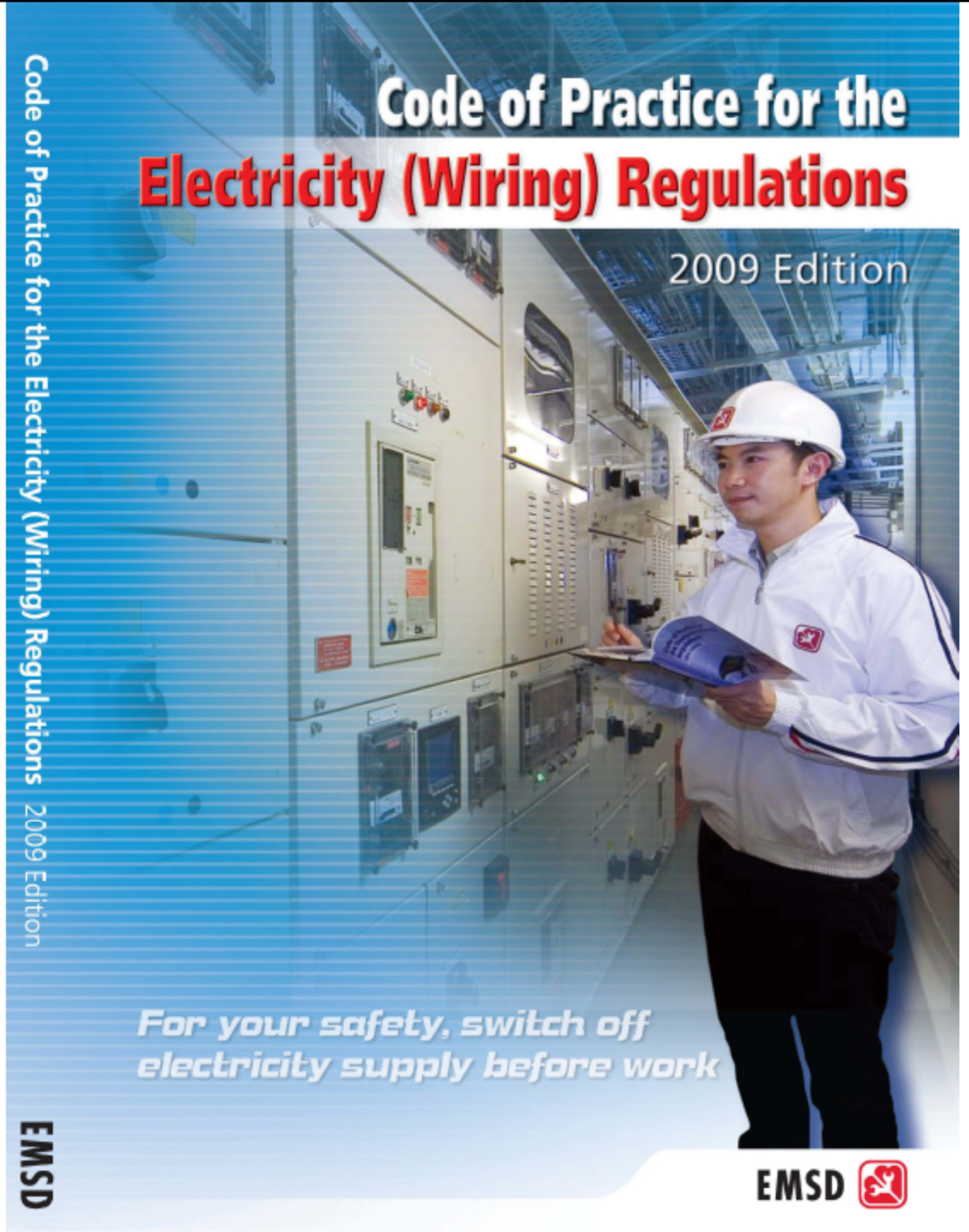
(* can be read from the website www.justice.gov.hk)

Regulations

- Relevant codes and guides to statutory regulations
  - Code of Practice for the Electricity (Wring) Regulations
  - Code of Practice for Minimum Fire Services Installations and Equipments
- Non-statutory regulations/standards
  - IEE Regulations for Electrical Installation, 15th edition and/or 16th edition *
  - Supply Rules (from power companies)
  - British Standards Specifications & Codes of Practice or other equivalent national standards and publications

(* IEE = Institution of Electrical Engineers, now IET)

This is the most important code of practice for electrical installations in Hong Kong.

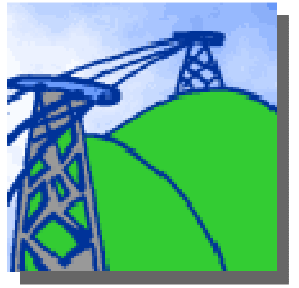


(Available from www.emsd.gov.hk)

Regulations

- Electrical Contractors and Workers
  - Registered Electrical Contractors (REC)
  - Registered Electrical Workers (REW)
    - Grade A Electrical Work (≤ 400 A)
    - Grade B Electrical Work (≤ 2500 A)
    - Grade C Electrical Work (any capacity)
    - Grade H Electrical Work (high voltage)
    - Grade R Electrical Work (special, e.g. neon sign)
      - NS: neon light; WH = water heaters; AC = air-conditioners
  - In 2006, about 8,500 REC and 68,000 REW

Regulations



- Registered Electrical Workers (REW)
  - Permitted work: code
    - 0 = any categories
    - 1 = only issue design certificate
    - 2 = only perform installation & repair works
    - 3 = only perform repair works
  - Example:
    - “B0” means REW grade B (≤ 2500 A) who can design, install and repair electrical works

Regulations

- Certification (new work, alteration or addition)
  - Completion of an installation
    - Certification on the design
    - Certification on the installation
  - Work completion certificates
    - Form WR1 – a complete installation
    - Form WR1(A) – Part of an installation (e.g. for a repair)
  - Periodic test certificates
    - Form WR2 – a complete installation
    - Form WR2(A) – Part of an installation (e.g. for a repair)

Terminology

- Electrical equipment
  - Any item for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines, transformers, protective devices, wiring materials, measuring instruments, accessories, appliances and luminaries
- Electrical installation
  - An assembly of associated electrical equipment supplied from a common origin to fulfill a specific purpose and having certain coordinated characteristics

Terminology

- Fixed appliance
  - An appliance which is fastened to a support or otherwise secured at a specific location in normal use
- Portable appliance
  - An appliance which is or can easily be moved from one place to another when in normal use and while connected to the supply
- Live part
  - A conductor or conductive part intended to be energized in normal use, including a neutral conductor

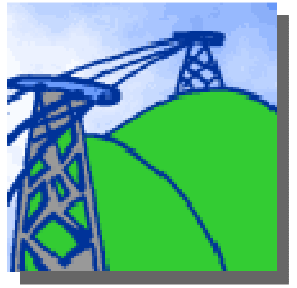
Terminology

- Skilled person
  - A person with technical knowledge or sufficient experience to enable him to avoid danger which electricity ay create
- Instructed person
  - A person adequately advised or supervised by skilled persons to enable him to avoid dangers which electricity may create.
- Low voltage (L.V.)
  - Voltage normally exceeding Extra Low Voltage but not exceeding 1000V a.c. or 1500 d.c. between conductors, or 600V a.c. or 900V d.c. between conductors and earth
- Extra low voltage (E.L.V.)
  - Voltage normally not exceeding 50V a.c. or 120 d.c., whether between conductors or to earth

Terminology

- Earthing
  - The act of connecting the exposed conductive parts of an installation to an earth electrode
- Protective conductor
  - A conductor used for some measure of protection against electric shock and intended for connecting together any of the following parts:
    - Exposed conductive parts
    - Extraneous conductive parts
    - Main earthing terminal
    - Earth electrodes
    - The earth point of the source

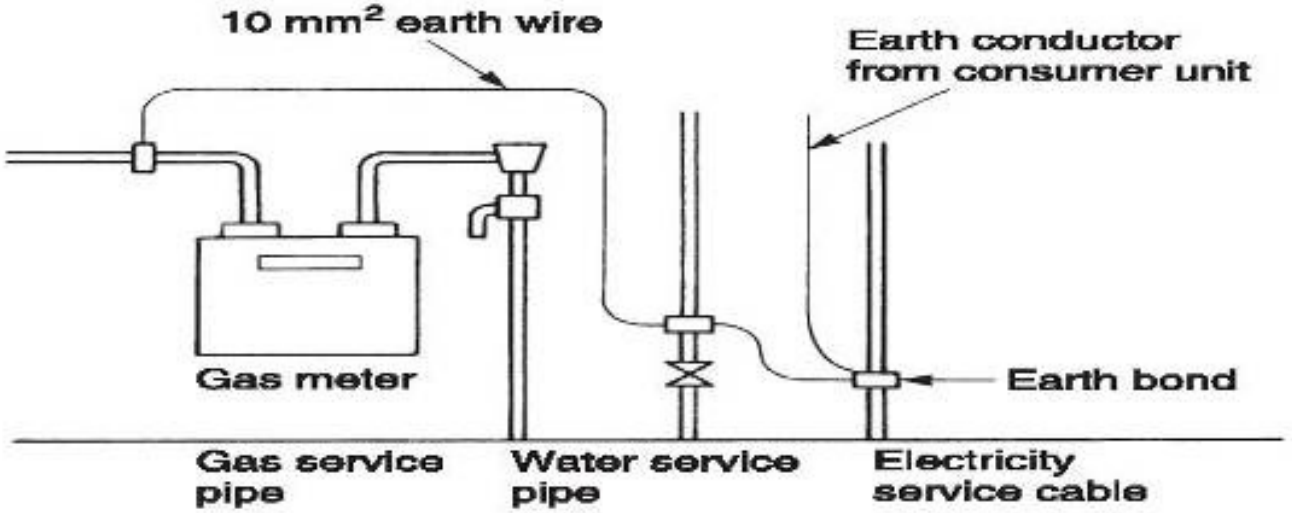
Terminology



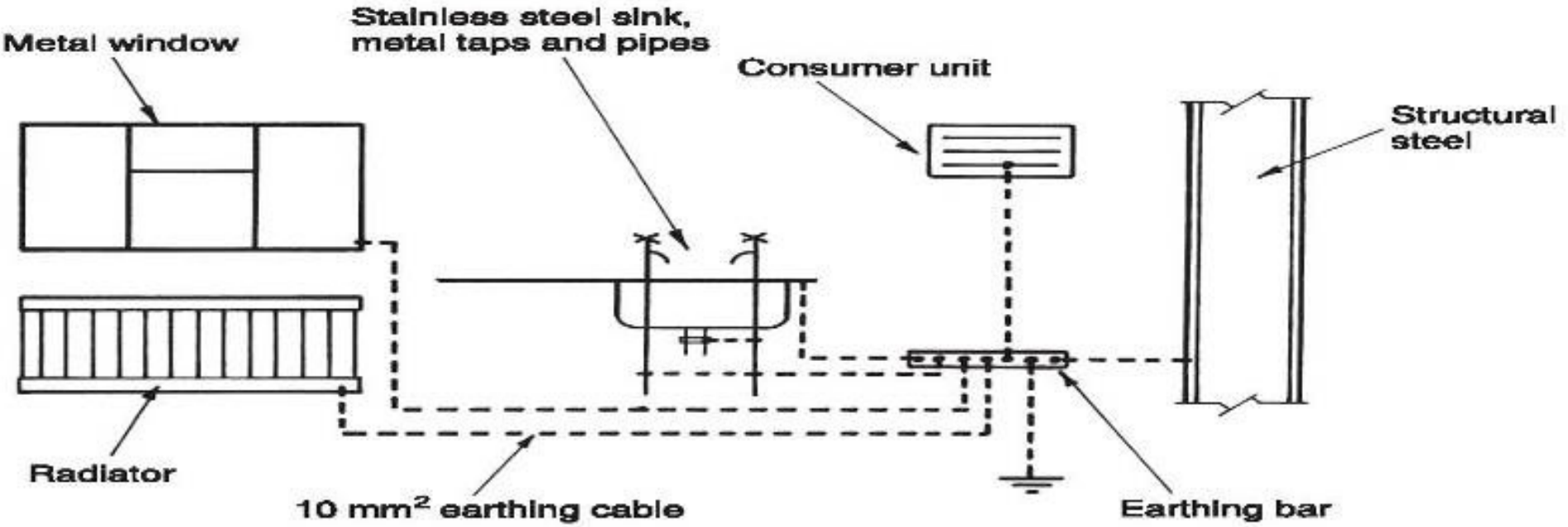
- Equipotential bonding
  - Electrical connection maintaining various exposed conductive pats and extraneous conductive parts at substantially the same potential
- Exposed conductive part
  - A conductive part of equipment which can be touched and which is not a live part but which may become live under fault conditions
- Extraneous conductive part
  - A conductive part liable to introduce a potential, generally earth potential, and not forming part of the electrical installation

Earth Bonding of Services & Extraneous Metalwork

Earthing clamp for pipes



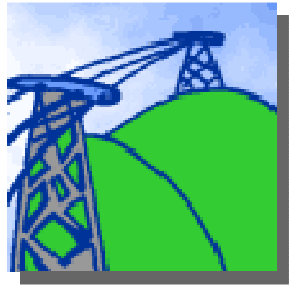
Bonding of services at intake



Supplementary bonding of extraneous metalwork

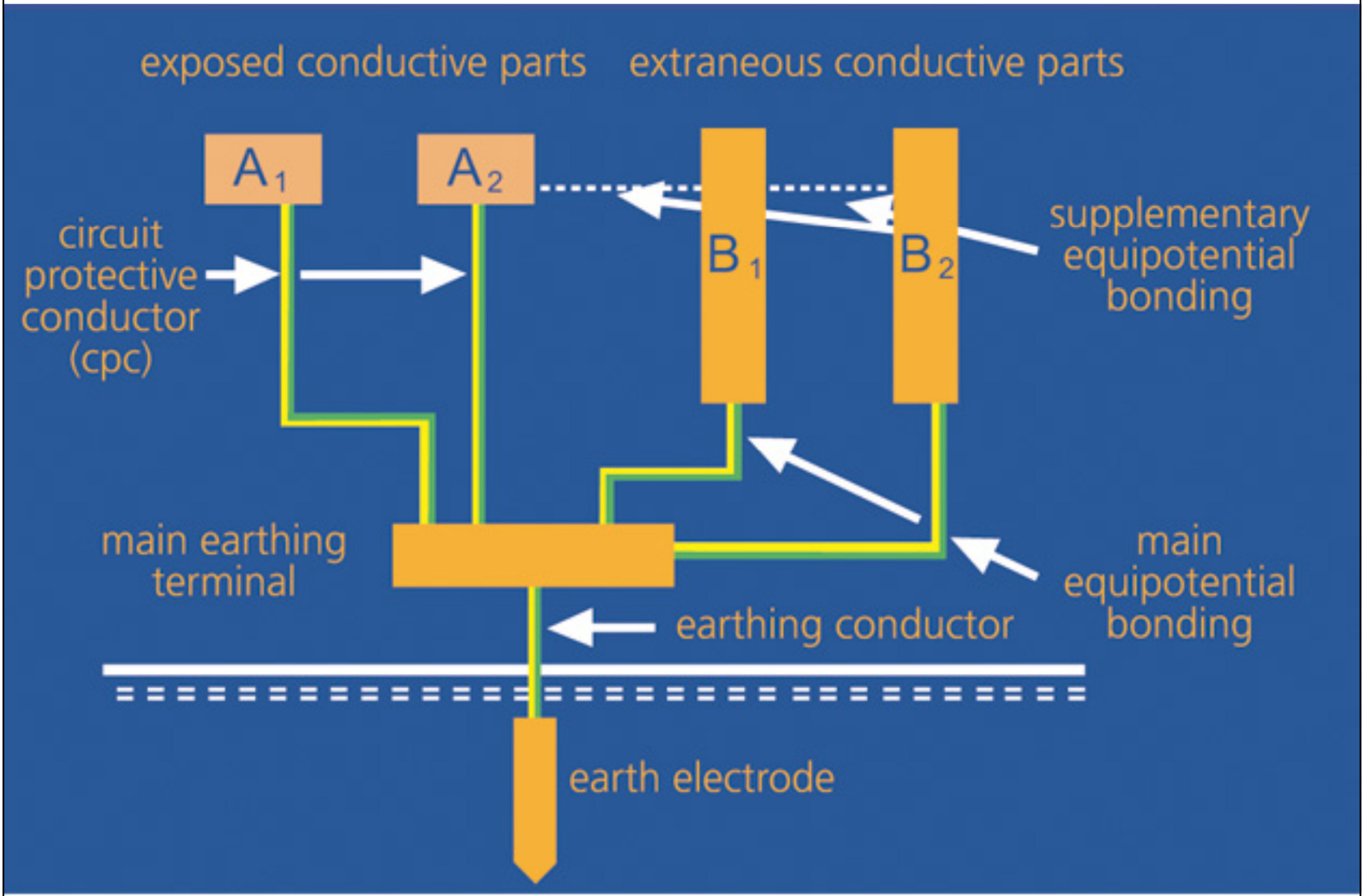
[Source: Hall, F. and and Greeno, R., 2005. *Building Services Handbook*]

Terminology



- Circuit protective conductor (CPC)
  - A protective conductor connecting exposed conductive parts of equipment to the main earthing terminal
- Earthing conductor
  - A protective conductor connecting a main eathing terminal of an installation to an earth electrode or to other means of earthing
- Direct contact
  - Contact of persons or livestock with live parts which may result in electric shock
- Indirect contact
  - Contact of persons or livestock with exposed conductive parts made live by a fault and which may result in electric shock

The system of electrical protection specified in the code



[Source: EMSD]

Electrical Protection

- Protection for safety: Scope
  - Protection from fire & burns (to property/ installation)
    - Protection against thermal effect
    - Protection against overcurrent
  - Protection against electric shock (to persons)
    - Protection against direct contract
    - Protection against indirect contract

*These are the basic concepts and principles for electrical protection as stipulated in IEE Regulations.

Electrical Protection

- Protection against thermal effect
  - When fixed equipment is installed having a surface temperature sufficient to cause a risk of fire or harmful effects to adjacent materials; suitable measures such as screening by proper material or mounting so as to allow safe dissipation of heat and at a sufficient distance from adjacent material
  - Any part of fixed installation likely to attain a temperature exceeding the temperature limit specified in IEE standard should be guarded to prevent accidental contact

Accessible parts and maximum temperature

Accessible Part	**Material**	**Maximum Temp (°C)**
Hand-held means of operation	Metallic	55
	Non-metallic	65
Part intended to touch	Metallic	70
	Non-metallic	80
Part not normally to be touched	Metallic	80
	Non-metallic	90

Electrical Protection

- Protection against overcurrent: Definitions
  - Overcurrent is current exceeding the rated value for a current carrying part. It may be either an overload current or a short-circuit current
  - Overload current is an overcurrent occurring in a circuit which is electrically sound, due to loading in excess of the design current of the circuit
  - Short-circuit current is an overcurrent resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions

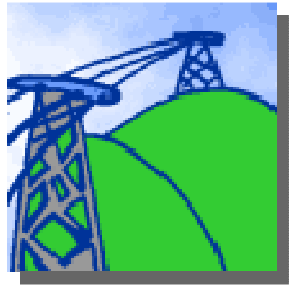
Electrical Protection

- Overcurrent protective devices
  - Every installation and circuit shall be protected against overcurrent by devices which will operate *automatically* at values of current which are suitably related to the safe current ratings of the circuit
  - The overcurrent devices shall be suitably located and constructed so as to prevent danger from overheating or arcing and to permit ready restoration of supply without danger

Electrical Protection

- Overcurrent protective devices (cont'd)
  - The means of protection against overcurrent shall be a device capable of breaking any overcurrent up to and including the prospective short circuit current at the point where the device is installed.
    - Such device may be circuit breaker incorporating overload release, or fuses, or circuit breaker in conjunction with fuses
  - The overcurrent devices shall be of adequate breaking capacity and, where appropriate, making capacity for protection against fault current

Electrical Protection

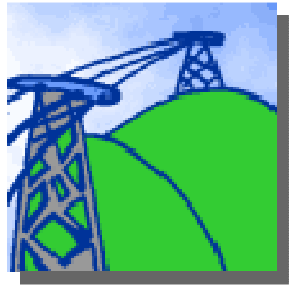


- Overload protection
  - Protective device shall be provided to break any overload current flowing in the circuit conductors before such a current could cause a temperature rise detrimental to insulation, joints, terminations, or surroundings of the conductors
  - IEE Reg. 433-02 states the condition of co-ordination between conductors and protective devices
    - I) $I_b \leq I_n \leq I_z$ and II) $I_2 \leq 1.45\ I_z$
      - I_b = Design current of the circuit
      - I_n = Nominal current rating or setting of overload protective device
      - I_z = Current carrying capacity of the circuit conductor
      - I_2 = The current ensuring effective operation of the protective device
      - "1.45" is the fusing factor of the protective device. (Fusing factor = I_2 / I_n)

Electrical Protection

- Short circuit protection
  - Protective devices shall be provided to break any short circuit current in the conductors of each circuit before such current could cause danger due to thermal and mechanical effects produced in conductors and connections
    - The breaking capacity rating shall be not less than the prospective short circuit at the point at which the device is installed

Electrical Protection

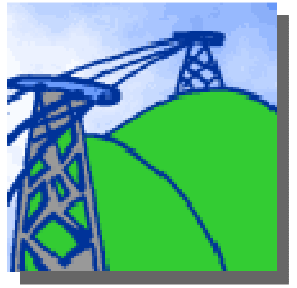


- Protection against both direct and indirect contact
  - Safety Extra Low Voltage (SELV)
    - Safely separated from other circuits that carry higher voltages
    - Live parts isolated from earth, circuit of other system or extraneous conductive parts (lack of a return path)
  - Protective extra low voltage (PELV)
    - Has a protective earth (ground) connection, such as a computer with a IEC Class I power supply
  - Functional extra low voltage (FELV)
    - Any other extra low voltage circuit that does not fulfill the requirements for an SELV or PELV circuit, such as only part of the circuit uses an ELV
    - Protection requirements for the higher voltage have to be applied to the entire circuit

Electrical Protection

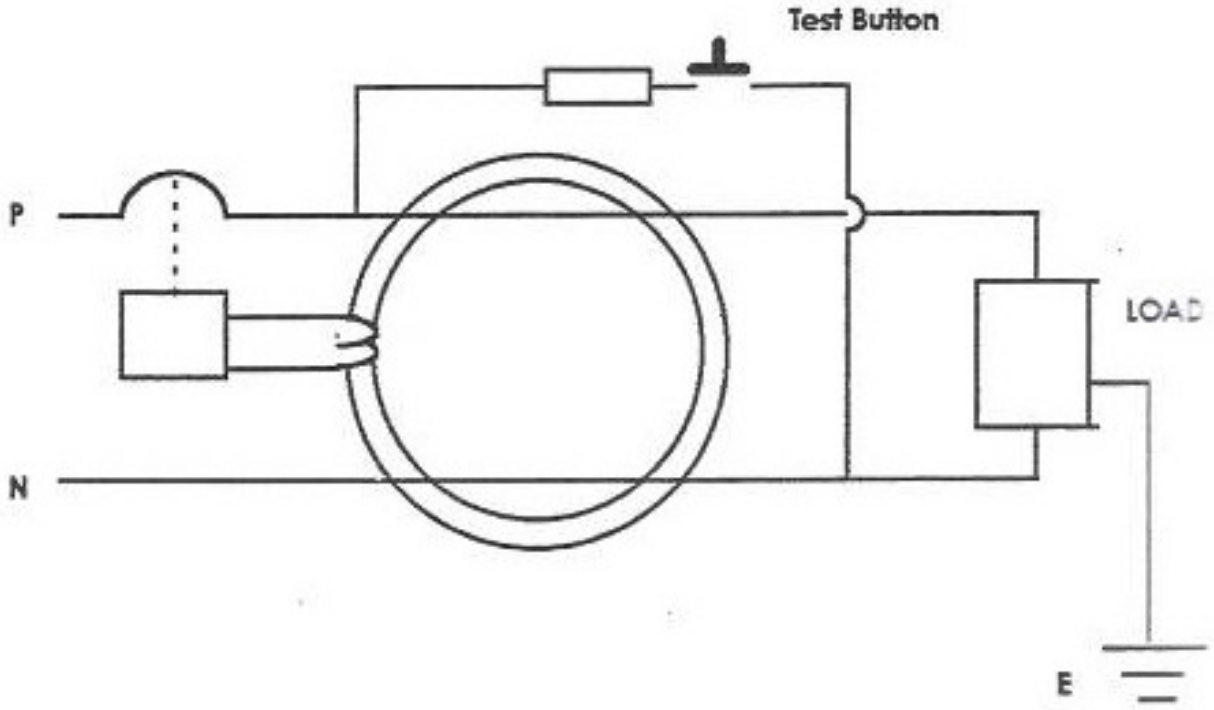
- Protection against direct contact
  - By insulation of live parts, e.g. cable
  - By barriers or enclosures, e.g. cubicle switchboard
  - By obstacles, e.g. open type switchboard
  - By placing out of reach, e.g. overhead line
- Protection against indirect contact
  - Earthed equipotential bonding and automatic disconnection of supply (using overcurrent protective device)
  - Use of Class II equipment or equivalent insulation
  - Non-conducting location
  - Earth-free local equipotential bonding
  - Electrical separation

Electrical Protection



- Provision of residual current device (RCD)
  - If the required disconnection time cannot be achieved, RCD shall be provided
  - A RCD shall not be used as the sole means of protection against direct contact
  - RCD having a rated residual operating current not exceeding 30mA shall be provided for every socket outlet circuit in a household or similar installation forming part of TT system

Residual Current Circuit Breakers (RCCB)



Q: Do you know the difference between RCCB and overcurrent protective device?

Earthing Systems

- Earthing system (or grounding system)
  - It connects parts of the electric circuit with the ground, thus defining the electric potential of the conductors relative to the Earth's conductive surface
  - Purposes:
    - To protect a structure from lightning strike (direct the lightning into the earthing rod in the ground)
    - Form part of the safety system of mains electricity
    - Common ground plane for radio antenna

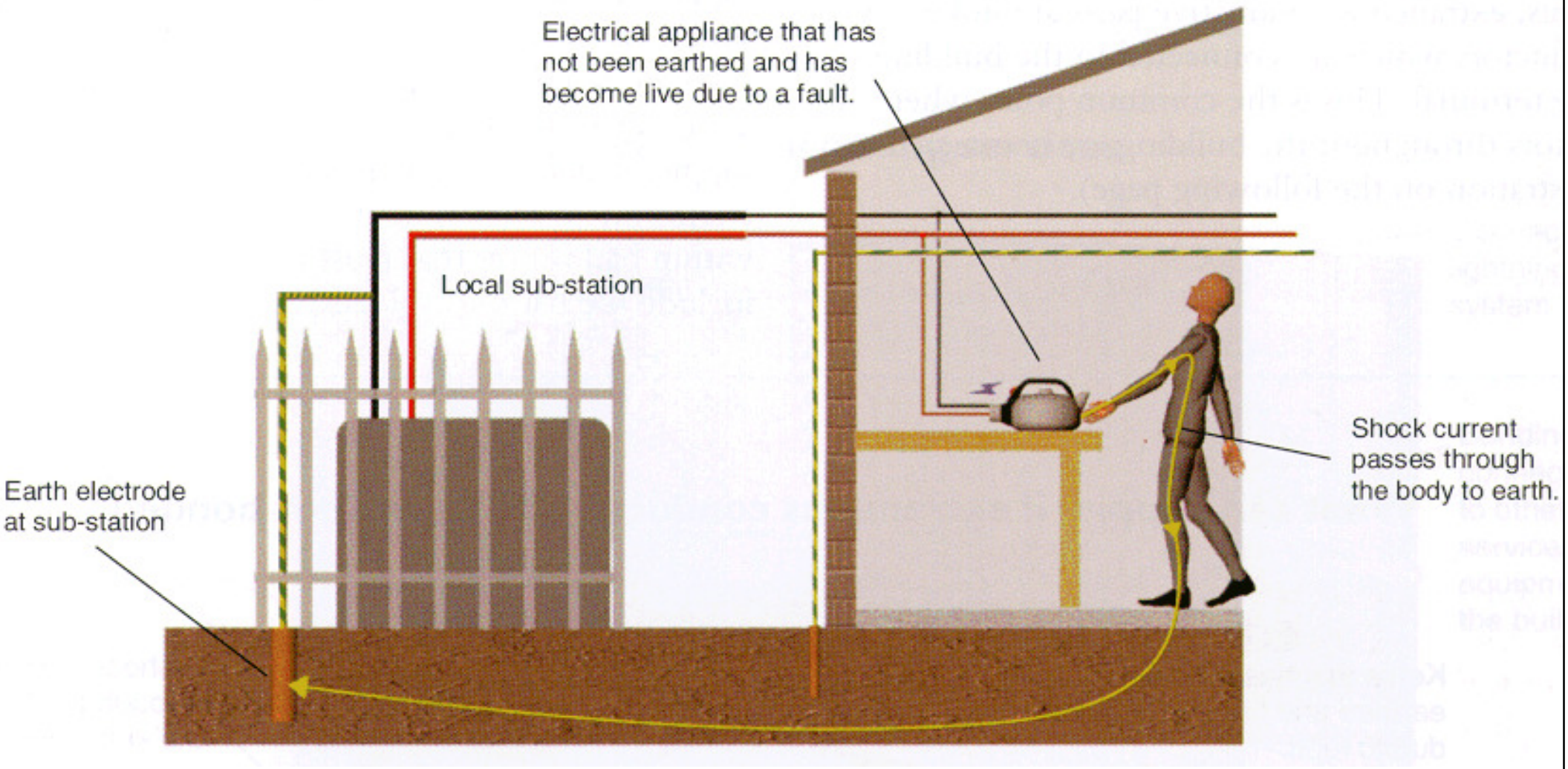
(See also: Earthing system -- Wikipedia http://en.wikipedia.org/wiki/Earthing_system)

Earthing Systems

- Earthed equipotential bonding and automatic disconnection
  - To bond all the exposed and extraneous conductive parts to earth in order to create a zone at earthed potential so that the potential difference (touch voltage) between those parts are minimized in the event of an earth fault inside the zone (touch voltage would be reduced by bonding), and then to cut the supply within the maximum safe time duration

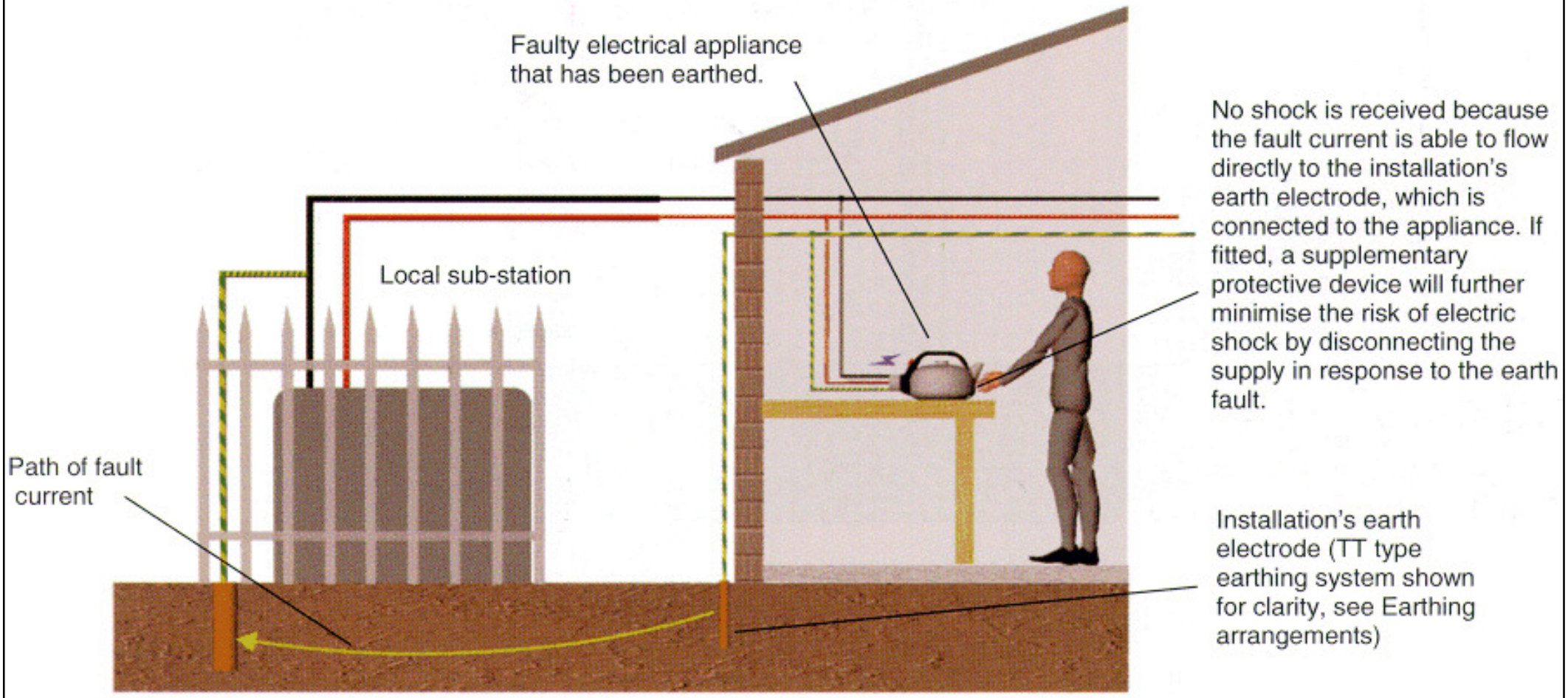
(See also: Earthing system -- Wikipedia http://en.wikipedia.org/wiki/Earthing_system)

What can happen if electrical appliances are not earthed



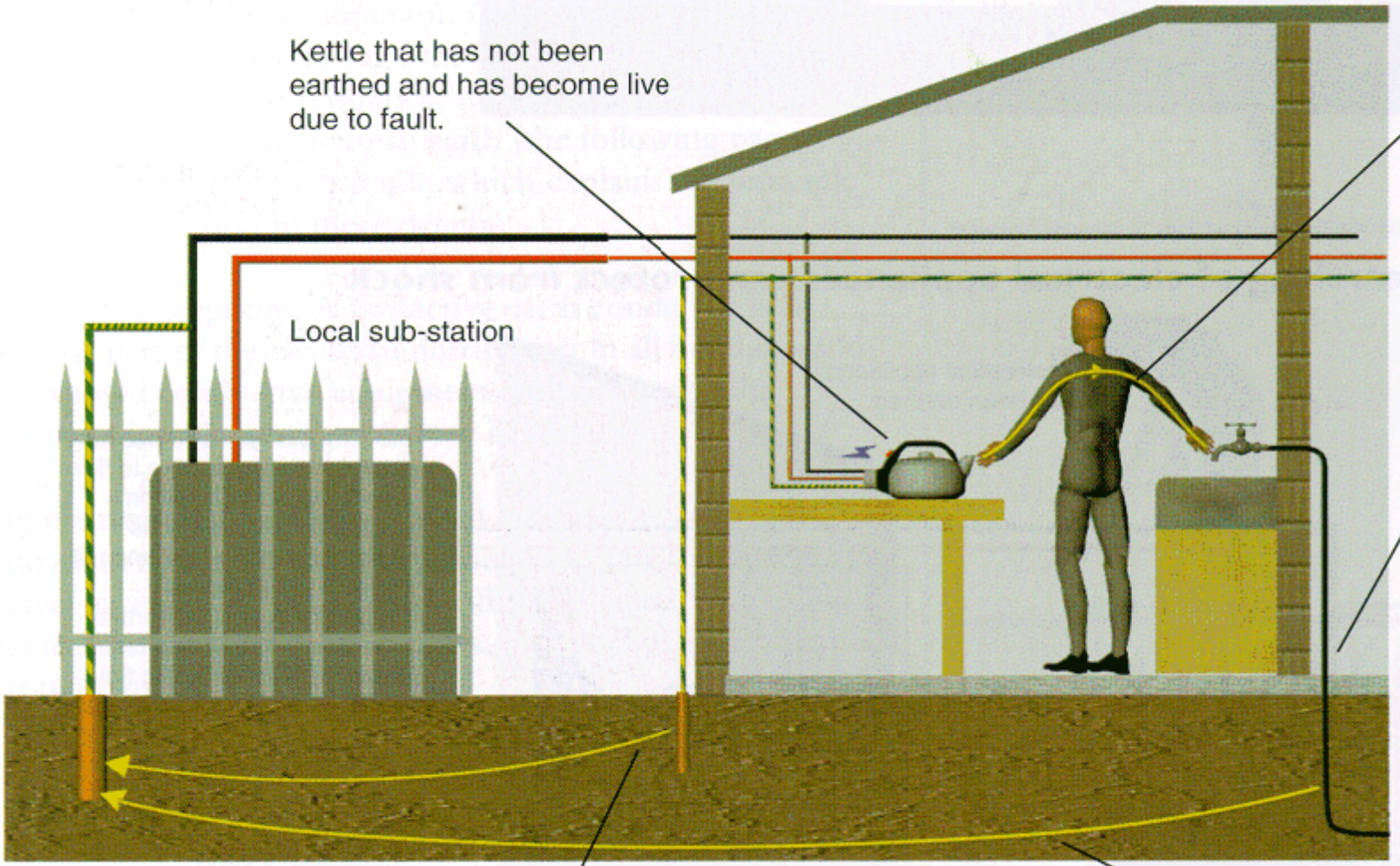
[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

How earthing of electrical appliances can protect from shock



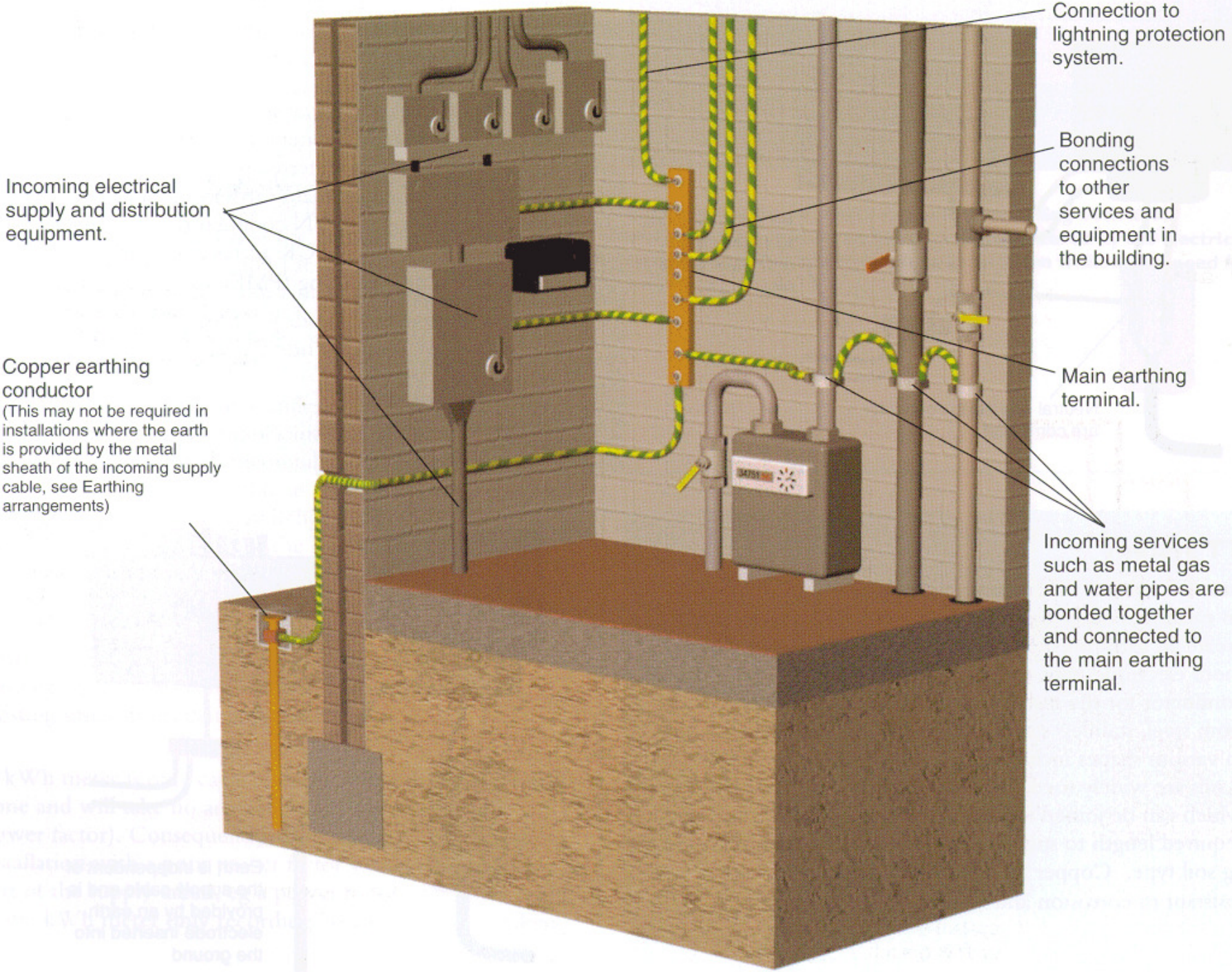
[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

What can happen if extraneous conductive parts are not bonded



[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

Main bonding of incoming services



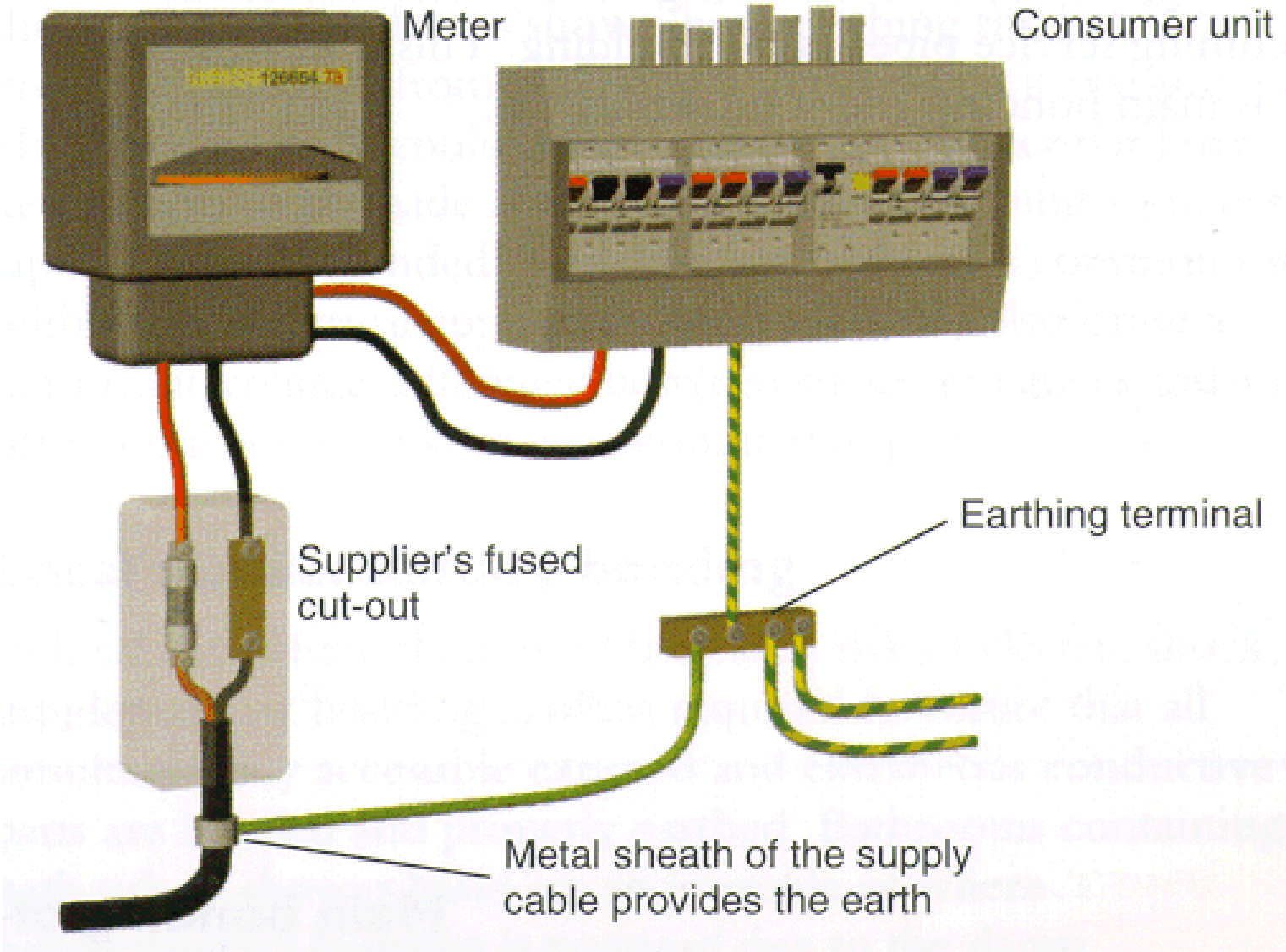
[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

Earthing Systems

- Earthing arrangements: letter coding
  - First letter – type of earthing (at the source of energy)
    - T: at least one point of the supply is directly earthed (Terra)
    - I: the supply is not directly earthed, but connected to earth through a current limiting impedance
  - Second letter – installation earthing arrangement
    - T: all exposed conductive metalwork is directly earthed
    - N: all exposed conductive metalwork is connected to an earth provided by the supply company
  - Third and fourth letters – earth conductor arrangement
    - S: earth and neutral conductors separate
    - C: earth and neutral conductors combined
    - C-S: earth and neutral conductors combined in part of system only
- Three common types of earthing systems
  - TN-S system, TN-C-S system, TT system

TN-S system

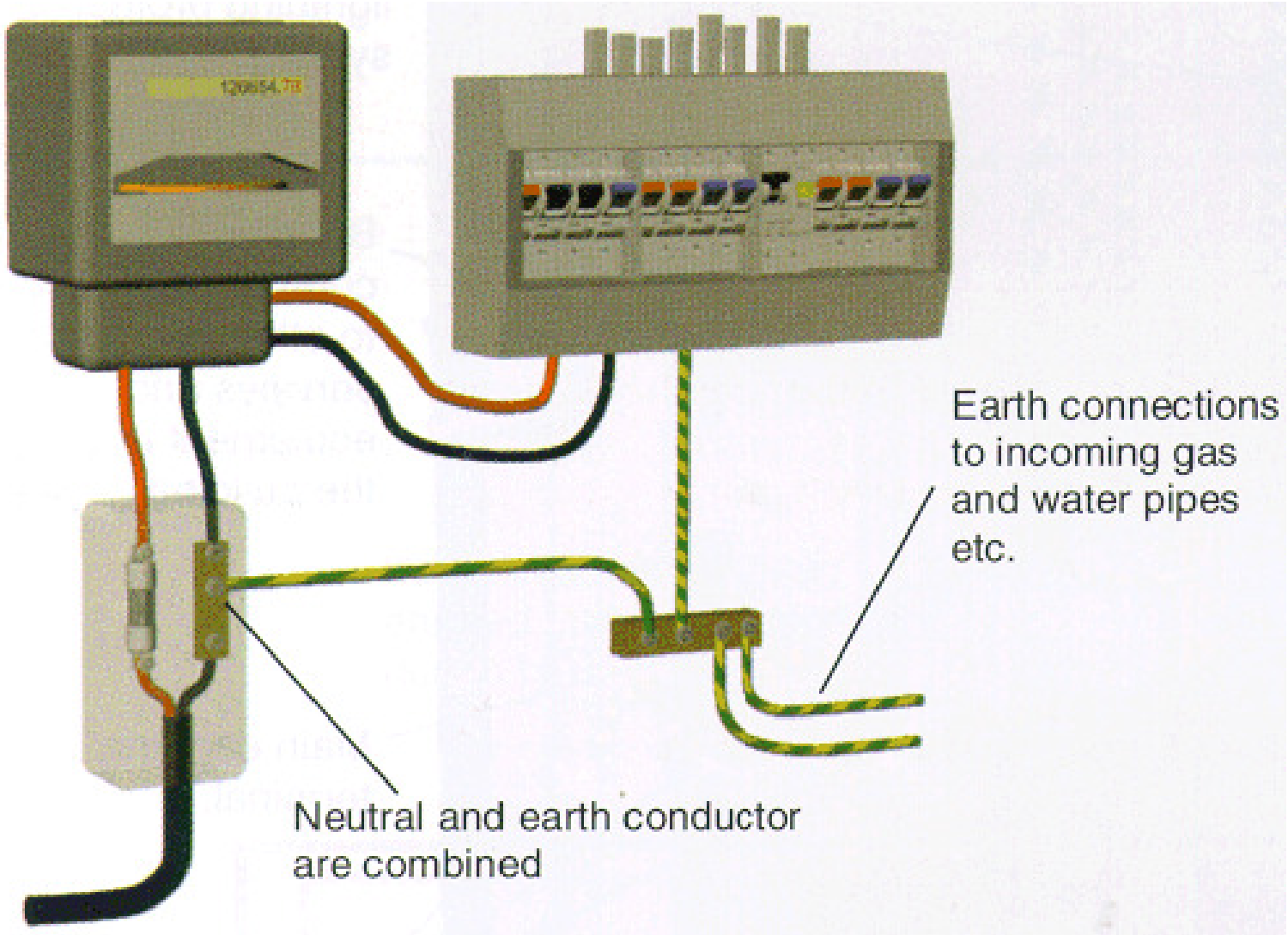
Separate neutral conductor and protective earth conductor within the supply to the building.



[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

TN-C-S system

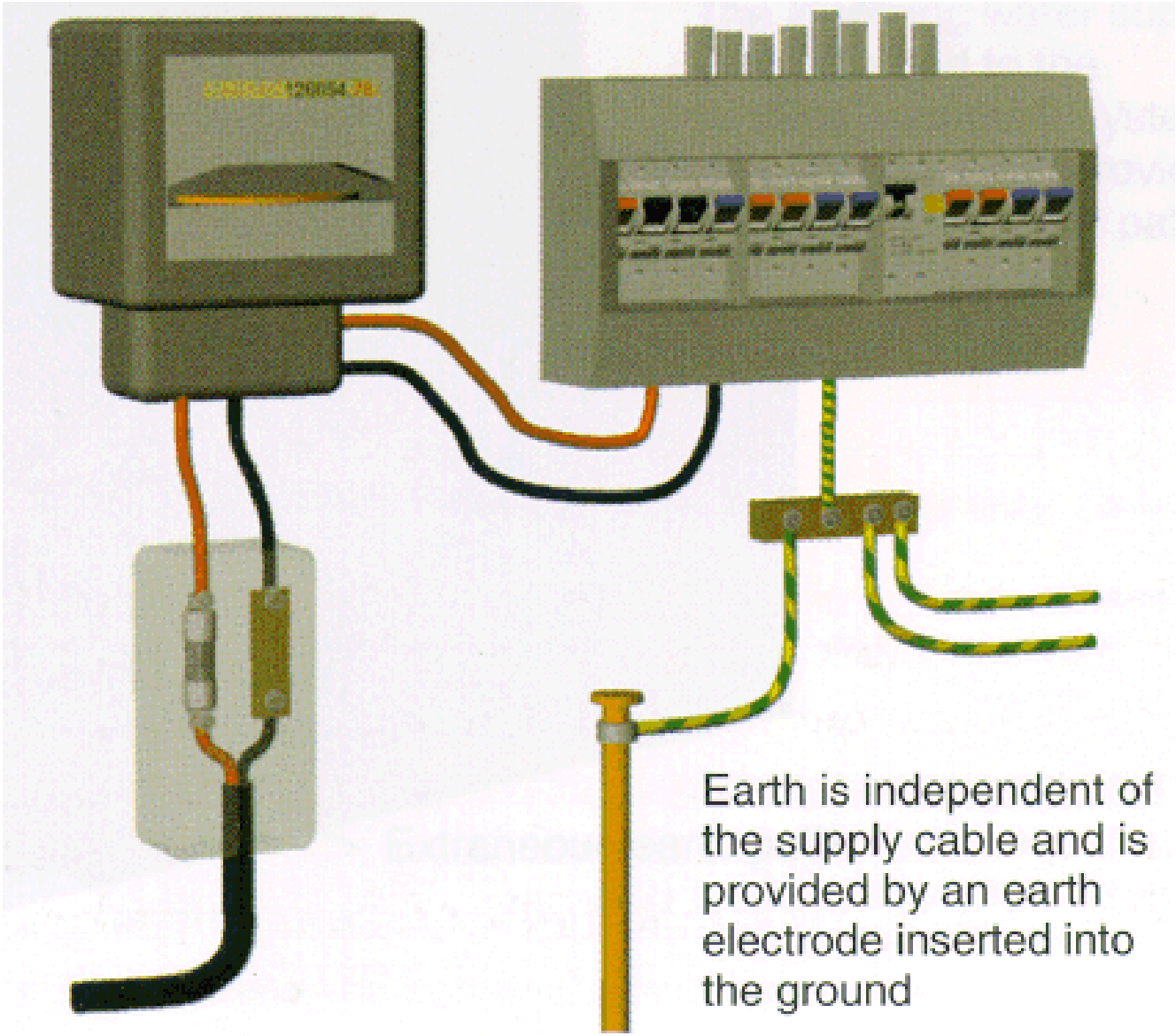
Metal sheath of incoming supply acts as both the neutral and the earthing conductor (PEN conductor). Also known as protective multiple earthing (PME)



[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

TT system

Incoming supply does not incorporate an earthing conductor; local earthing is created on site (e.g. by earth electrode rods)



[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

Backup of Normal Supply

- Need for standby power supply
  - To satisfy statutory fire services requirements
  - To maintain essential control and safety systems
- Possible ways of alternative sources to backup the normal supply during power failure:
  - 1) Duplicate mains supply (dual feed)
  - 2) Battery supply
  - 3) Uninterruptible power supply (UPS)
  - 4) Standby/emergency generating supply

Backup of Normal Supply

- 1) Duplicate mains supply
  - A consumer may require a duplicate supply for added security and the supply company may agree to install an extra mains supply cable
  - This additional cable will operate in fully in parallel with the original supply or just as standby. The additional cable may be fed from a different point of the supply network of the supply company (dual feed)

Backup of Normal Supply

- 2) Battery supply
  - A battery can be used to provide standby power
  - Even for generators, batteries usually provide the starting power, and are often used to provide power to essential loads for the initial period, while the generator is running up to speed
  - When a large amount of rechargeable batteries are used in the installation, usually a separate battery room is provided
  - Batteries are also commonly used in those stand-alone emergency lighting systems

Backup of Normal Supply

- 3) Uninterruptible power supply (UPS)
  - For applications where no interruption of supply can be tolerated even for a fraction of a second, an UPS is needed
  - Typical applications are computer systems and information systems
  - UPS has been developed rapidly so that its capacity can up to several hundred of kW
  - Many systems available but they broadly follow the same concept of an AC supply backed to a DC supply and the use of static changeover switch

Backup of Normal Supply

- 4) Standby generating plant
  - Money spent on standby generating plant can be described as a non-productive expenditure of capital. It is therefore in the consumer's interest to keep the capital expenditure to a minimum and also to minimize the amount of fuel that needs to be stored
  - The most commonly used prime mover for standby set is diesel engine. Today it is more usual for them to drive AC generator

Backup of Normal Supply

- 4) Standby generating plant (cont'd)
  - Alternative starting techniques are possible, depends on the applications, the requirements and the availability of other means of standby supplies:
    - Started automatically, following the failure of the mains supply, with the generator being run up to speed and switched in immediately
    - Started automatically, following the failure of the mains supply, with the generator being run up to speed, but standby supply is switched in system only when required

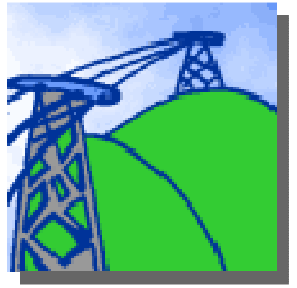
Backup of Normal Supply

- 4) Standby generating plant (cont'd)
  - Started manually, from a push button on a control panel adjacent to the generator
  - Started manually, form a remote push button, say located in the main control room of the building
  - Start manually & mechanically by using a starting handle (only for small portable sets)

Genset examples

Q: What is this for?

Standby Generator

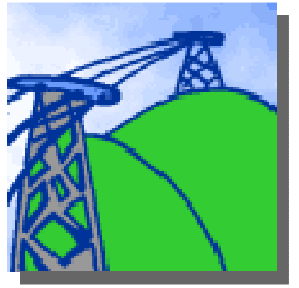


- Sizing of standby generator
  - To determinate the power rating of the “genset”, not only the total essential loading of connected electrical equipment needs to be catered for
    - Since the starting of a larger motor load may give rise to an unacceptable voltage drop, thus causing momentarily dimming of light or the connected motors may cease to run
    - Therefore, the rating of the generator shall cope with the steady state loading condition as well as the starting of these loads

Standby Generator

- Location of standby diesel generator
  - It should be located in a well ventilated room with adequate space between machines to allows for easy repair, checking and maintenance
  - It is normally supplied with the engine and alternator on a common base plate but massive concrete foundations are neither necessary nor recommended
  - As a rule the machine should be supported in anti-vibration mounting to reduce the transfer of vibration through the structure of the building

Standby Generator

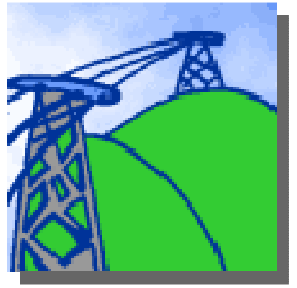


- Requirements of Fire Services Department (FSD)
  - In the CoP for Minimum Fire Service Installation and Equipment, it lists statutory requirements on standby generator, the diesel engine, fuel storage, installation of the genset, engine starting, operation of the genset, maintenance & testing, generator room, service tank room, and also on controls, safety devices & control panel/ cubicle of the genset

Testing of L.V. Systems

- First inspection, testing and certification
  - For new work, alternation or addition
    - By a Registered Electrical Worker (REW)
  - Certification on the design
  - Certification on the installation
  - Work completion certificate
    - Before it is energised

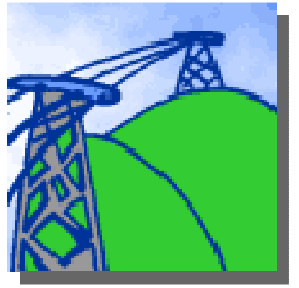
Testing of L.V. Systems



- Periodic inspection, testing and certification
  - Fixed installation requiring annual inspection
    - Place of public entertainment
    - Premises for manufacturing/storing of dangerous goods
    - High voltage installations
  - Fixed installation requiring inspection every 5 yrs.
    - Factories & industrial undertakings > 200 A
    - Any premises > 100 A
    - Hotels, hospitals, schools/universities, etc.
  - Periodic test certificate (Form WR2)

(See also: Periodic Test for Fixed Electrical Installations
http://www.emsd.gov.hk/emsd/eng/pps/electricity_feipt.shtml)

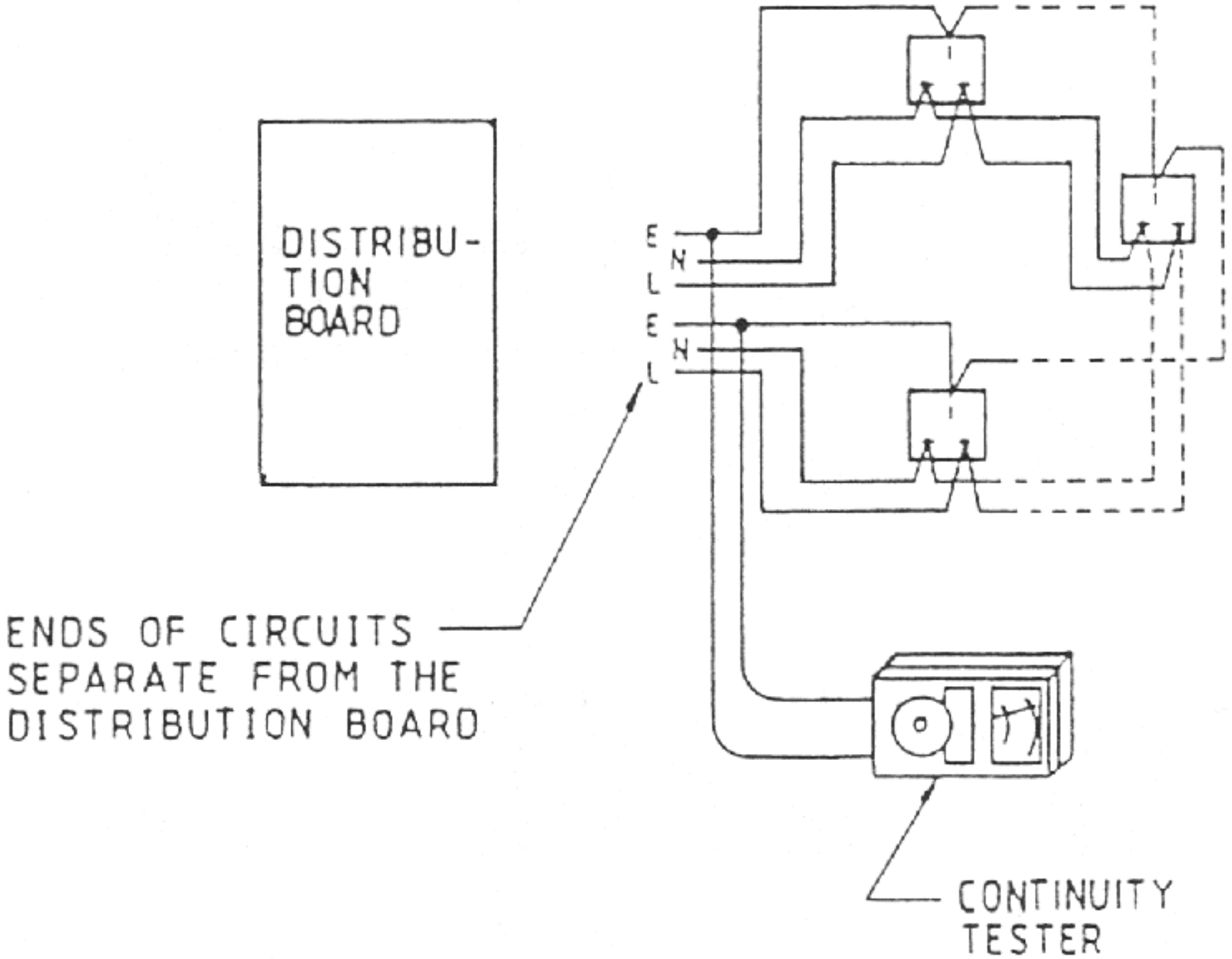
Testing of L.V. Systems



- Inspection of L.V. installations, e.g.
  - Adequacy of working space & access
  - Connection & sizes of conductors
  - Fire protection
  - Protection against electric shock
  - Isolation & switching
  - Overcurrent protective devices
  - Warning notices and labels
  - Diagrams, instructions & other info.

Testing of L.V. Systems

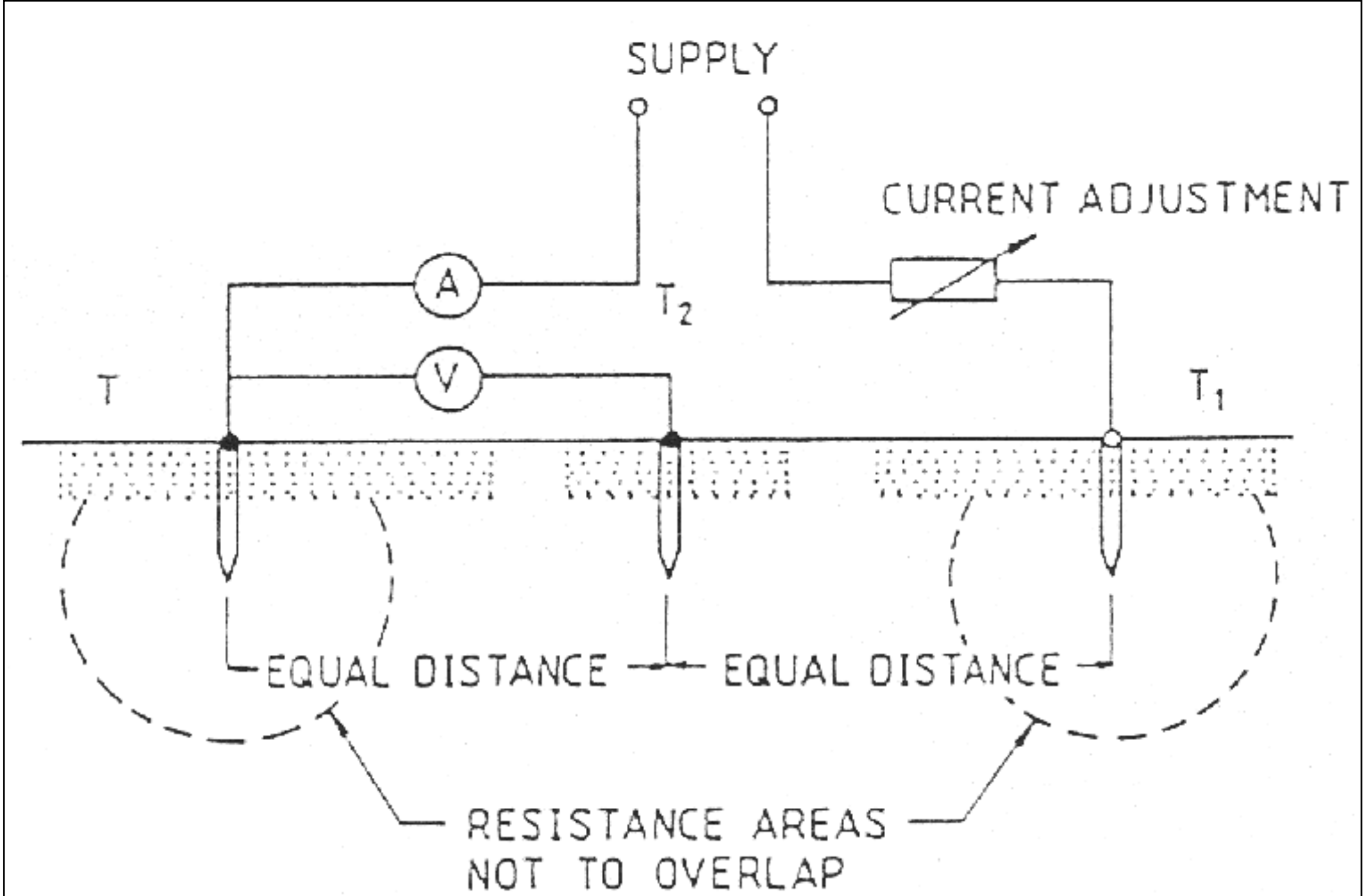
- Testing procedures (in correct sequence)
  - Continuity of ring final circuit conductors
  - Continuity of protective conductors, including main and supplementary equipotential bonding
  - Earth electrode resistance
  - Insulation resistance
  - Polarity
  - Earth fault loop impedance
  - Functions of all protective devices
  - Functions of all items of equipment



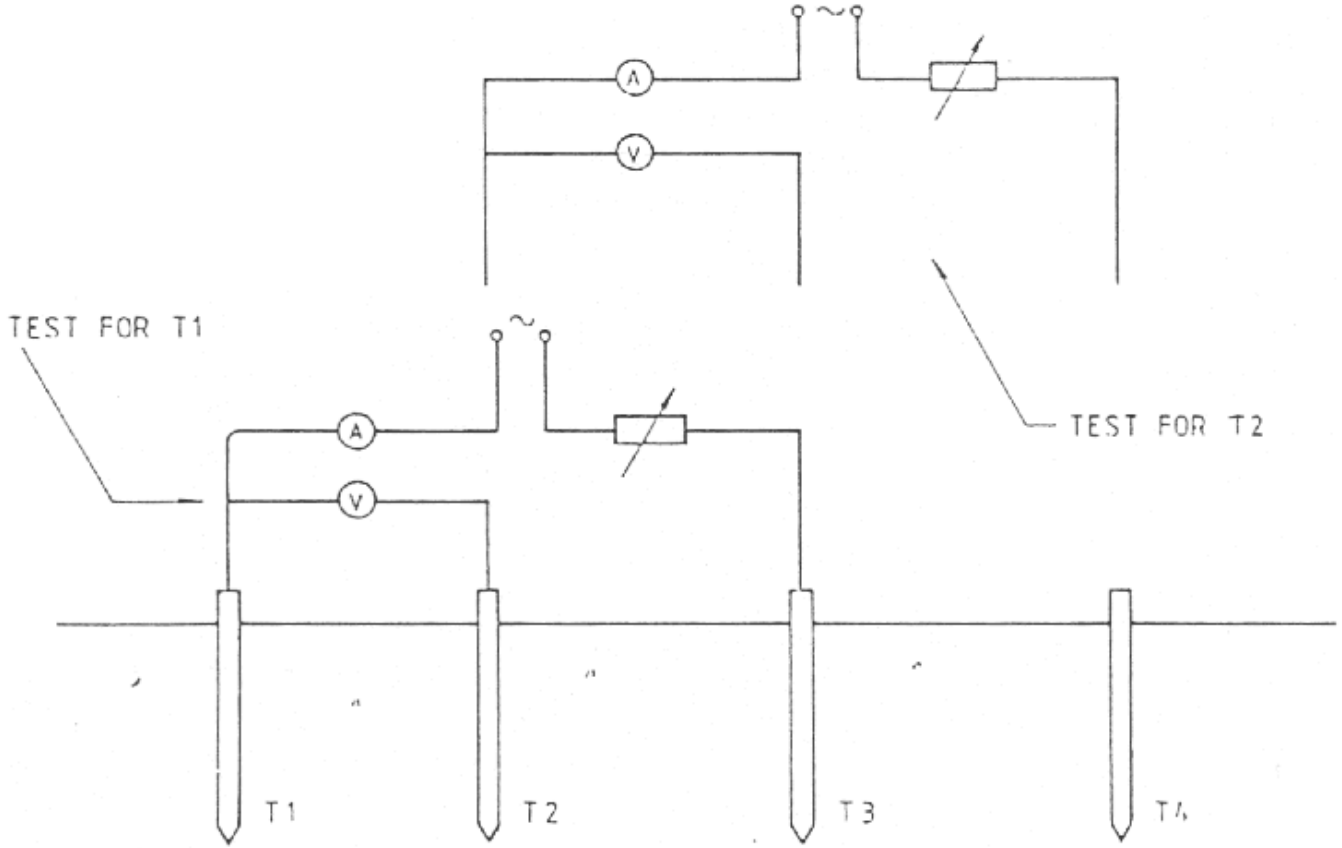
Continuity test of final circuit

Continuity Testers

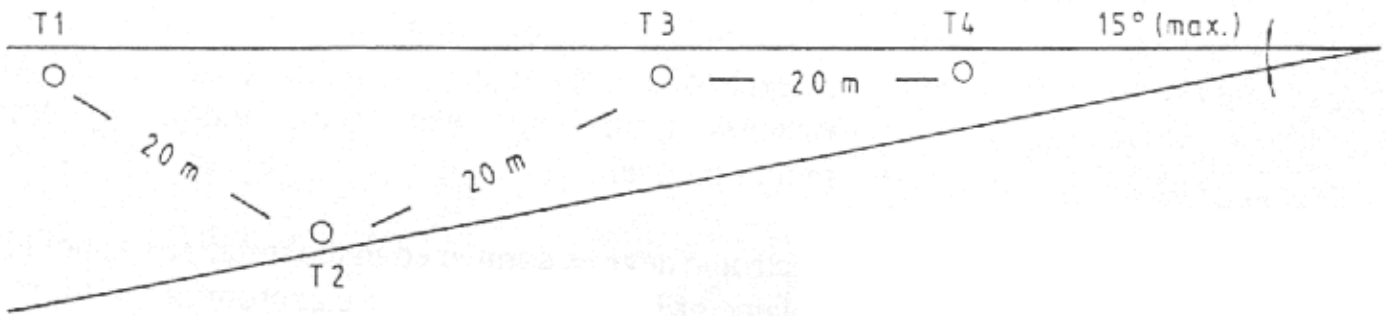
Digital Multimeter



Earth electrode resistance test

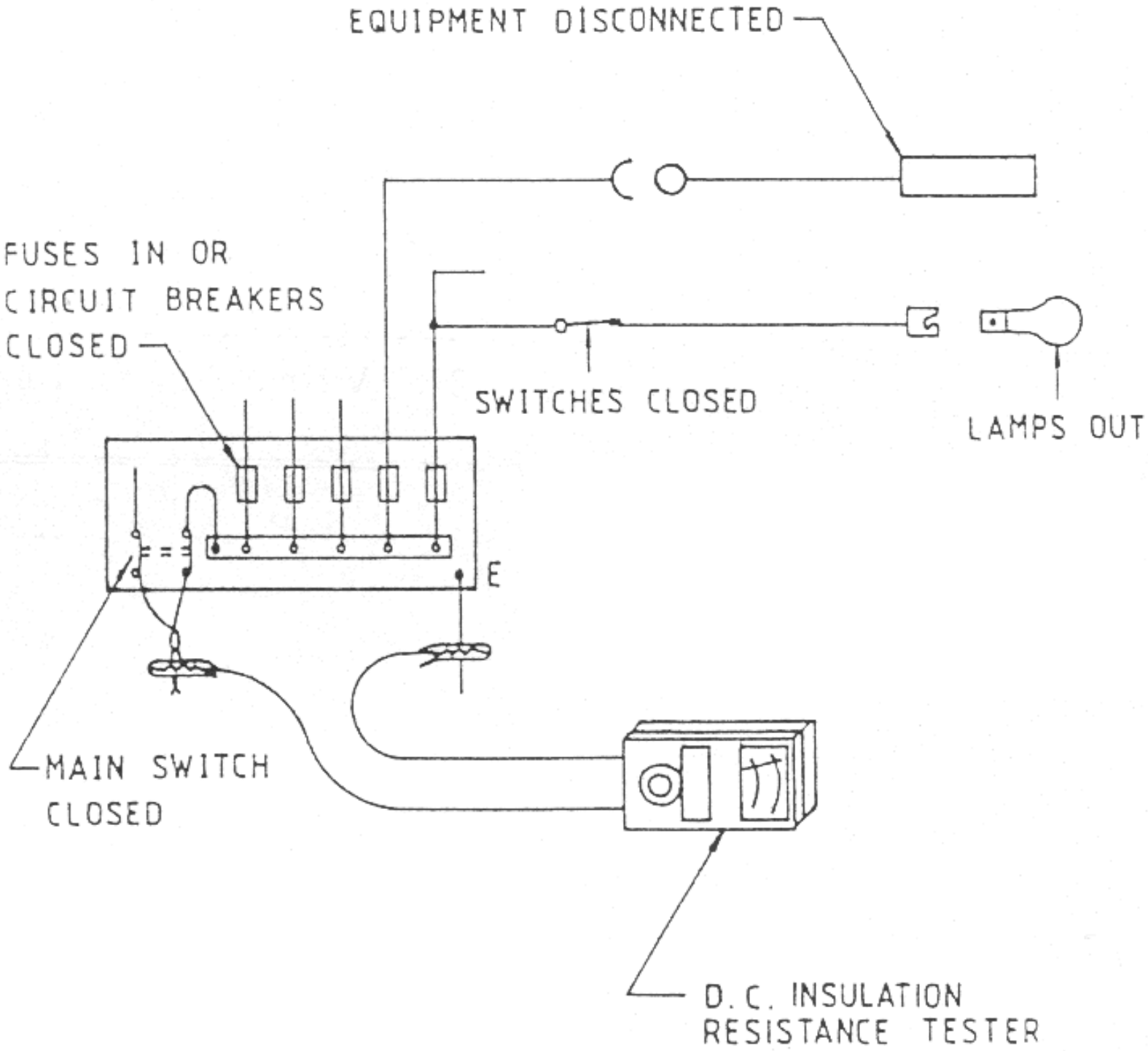


ELEVATION



PLAN

Test of earth electrode resistance having four or more electrodes



Insulation resistance to earth test

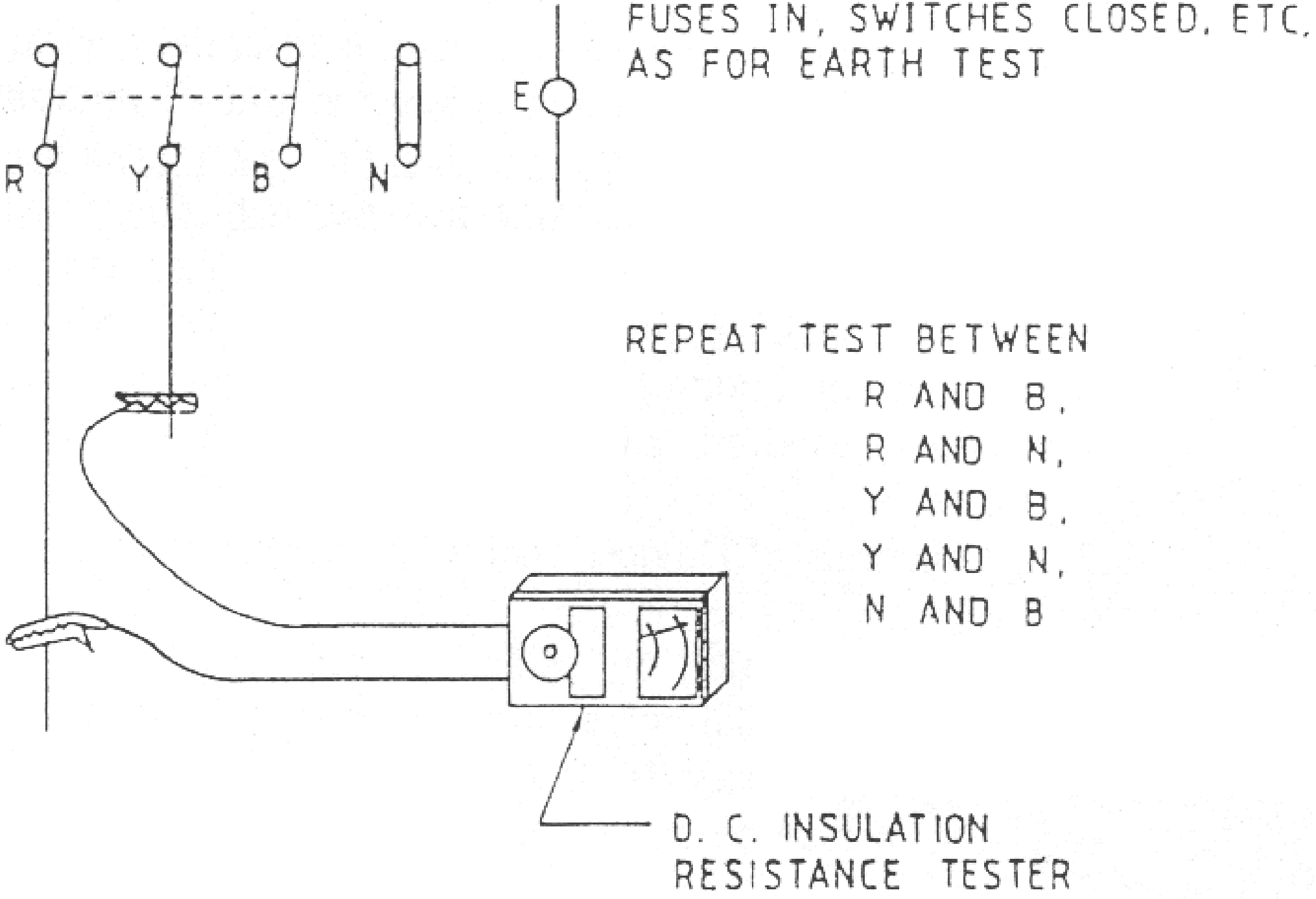
Minimum values of insulation resistance

Circuit nominal voltage (Volts)	Test voltage d.c. (Volts)	Minimum insulation resistance (megaohms)
Extra-low voltage *	250	0.25
Up to 500 V	500	0.5
Above 500 V	1,000	1.0

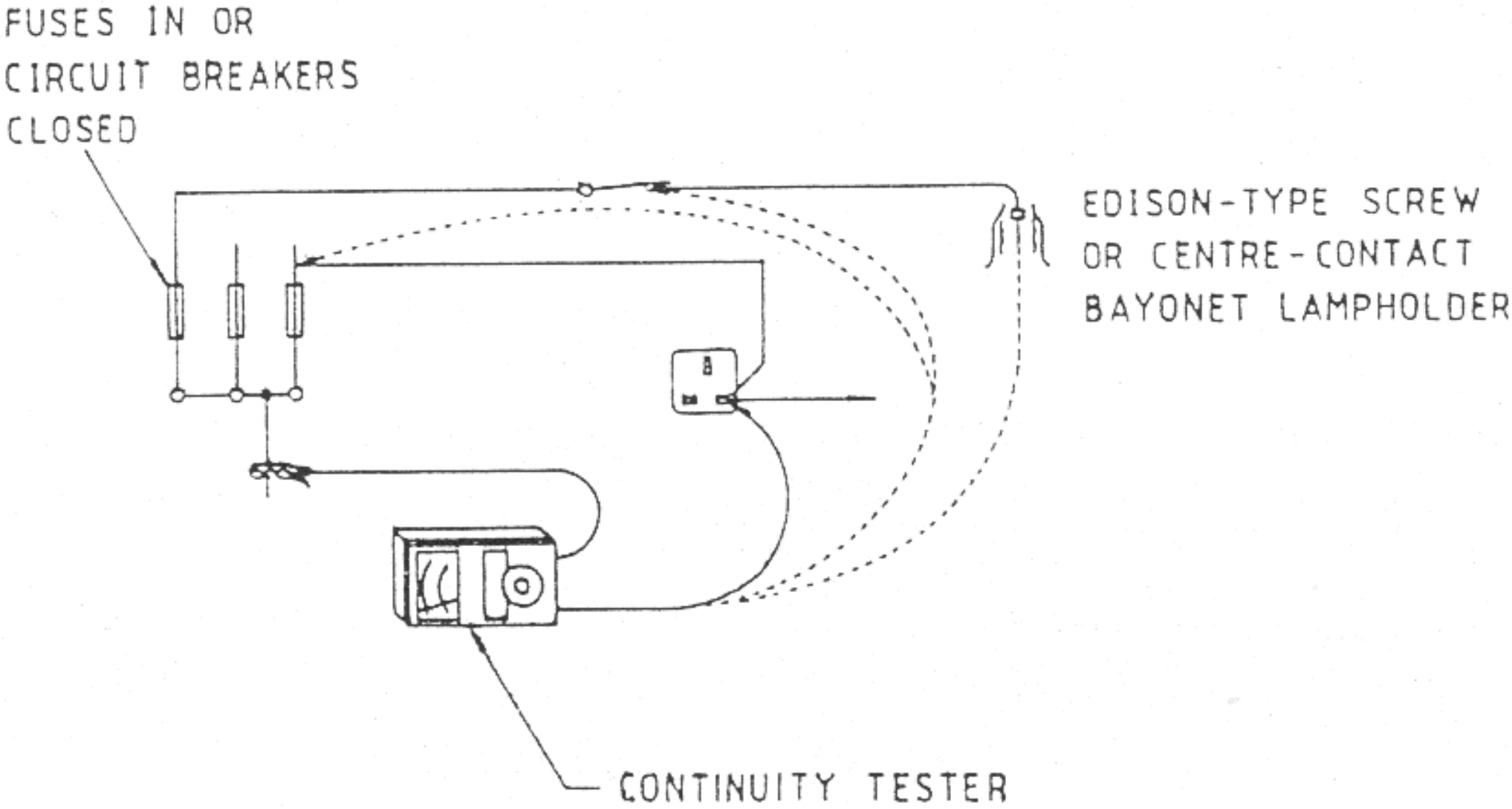
* When the circuit is supplied from a safety isolating transformer or safety extra-low voltage (SELV).

Insulation Tester (MegOhmMeter)

Earth Bonding
Resistance Meter



Insulation resistance test between phases



Polarity test

Testing of L.V. Systems

- Earth fault loop impedance
  - Measured by a phase-earth loop tester
- Functions of all protective devices
  - Checked by residual current device tester (built-in)
  - Checked by hand operation (MCB, MCCB, ACB)
- Additional checks for hazardous environment
  - Such as dangerous goods (DG) stores & industrial process