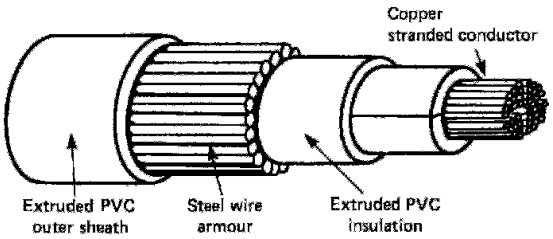
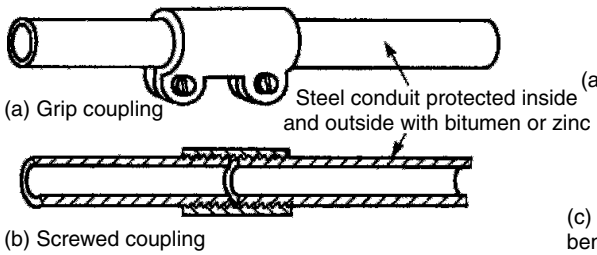
Armoured cable is used for mains and sub-mains. The cable is laid below ground level, breaking the surface where it enters sub-stations or transformers and other buildings. High voltage cable is protected below ground by precast concrete `tiles'.

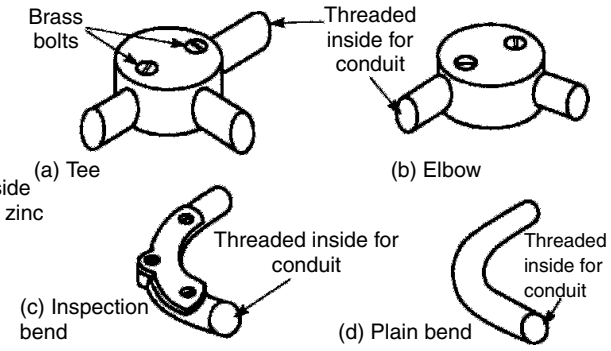


Armoured three-phase four wire cable for laying below ground level

Conduit for electrical services is produced in steel (galvanised or painted black) or plastic tube into which insulated cables are drawn. The conduit protects the cable from physical damage and heat. It also provides continuous support and if it is metal, it may be used as an earth conductor. Standard outside diameters are 20, 25, 32 and 40 mm. Steel is produced in either light or heavy gauge. Light gauge is connected by grip fittings, whilst the thicker walled heavy gauge can be screw threaded to fittings and couplings. Plastic conduit has push-fit connections.



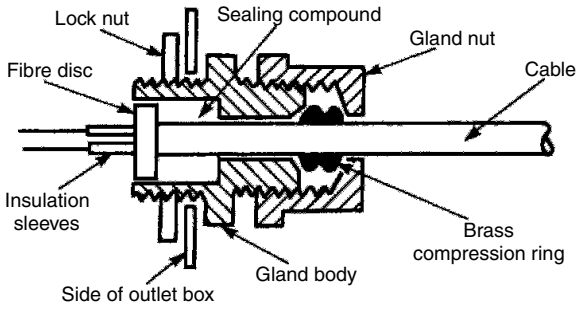
Couplings for steel conduit



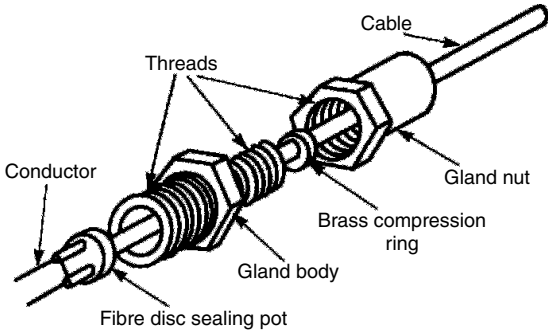
Fittings for steel conduit

Refs: BS 6346: Electric cables. PVC insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V.
BS EN 61386: Conduit systems for cable management.
BS 7846: Electric cables. 600/1000 V armoured fire resistant cables having thermosetting insulation and low emission of smoke and gases when affected by fire.

Mineral insulated copper covered cable (MICC) has copper conductors insulated with highly compressed magnesium oxide powder inside a copper tube. When installing the cable, it is essential that the hygroscopic insulant does not come into contact with a damp atmosphere. Cutting the cable involves special procedures which are used to seal the insulant from penetration of atmospheric dampness. The cable provides an excellent earth conductor; it is also resistant to most corrosive atmospheres and is unaffected by extremes of heat.

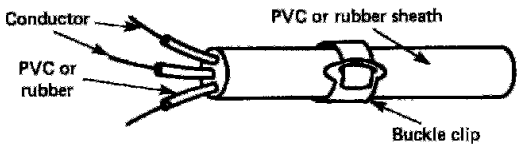


Section of termination joint for mineral insulated copper covered cable (MICC)

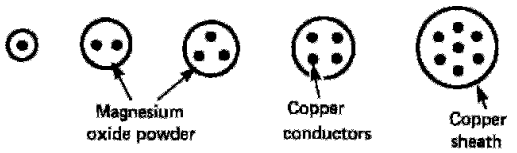


Exploded view of termination joint for mineral insulated copper covered cable

PVC and rubber insulated cables are relatively inexpensive and simple to install, requiring clipped support at regular intervals. PVC cables are in general use, but they have a temperature limitation between 0°C and 70°C. Below zero they become brittle and are easily damaged and at the higher temperature they become soft, which could encourage the conductor to migrate through the PVC. Outside of these temperatures, the cable must be protected or an appropriate rubber insulant specified. Cables usually contain one, two or three conductors. In three-core cable the live and neutral are insulated with brown and blue colour coding respectively. The earth is bare and must be protected with green and yellow sleeving where exposed at junction boxes, sockets, etc. Grey and black insulated conductors are occasionally used where an additional facility is required, e.g. two-way lighting.



PVC or rubber insulated cable



Core arrangements of mineral insulated copper covered cables

Refs: BS 6004 Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring.
BS 6007: Electric cables. Single core unsheathed heat resisting cables for voltages up to and including 450/750 V, for internal wiring.

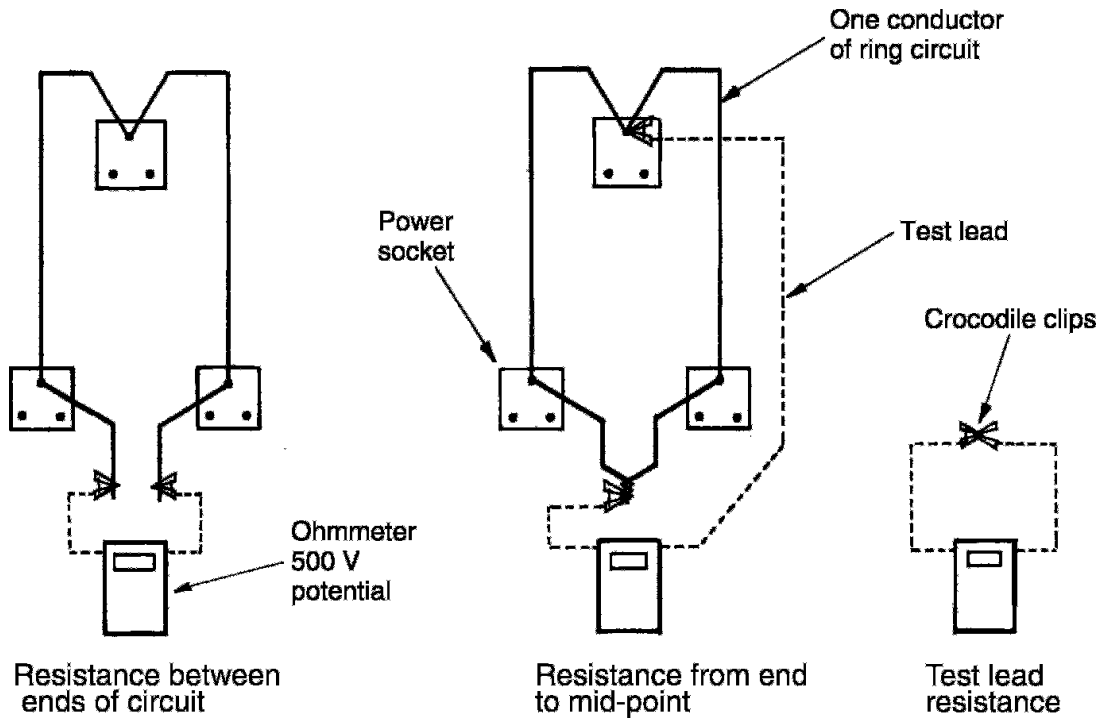
Electrical installations must be tested on completion to verify that the system will operate efficiently and safely. The tests are extensive, as defined in the Institution of Electrical Engineers Regulations. They can only be carried out by a competent person, i.e. a qualified electrician or electrical engineer. The following tests are an essential part of the proceedings:

- Continuity.
- Insulation.
- Polarity.

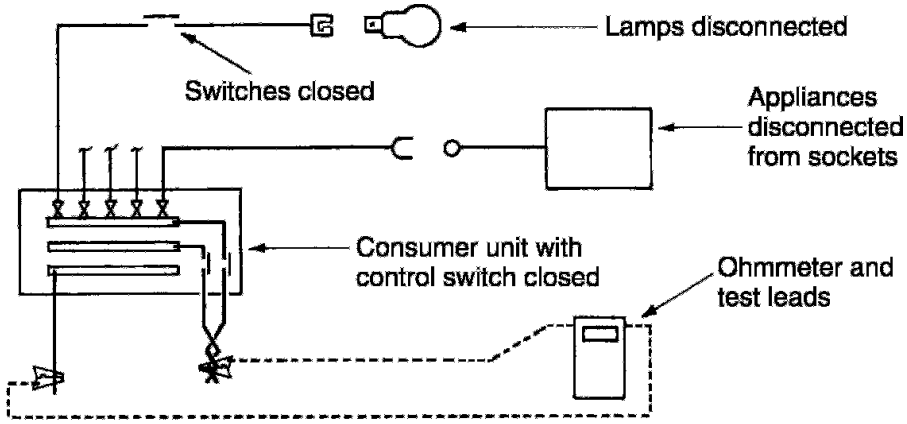
Testing is undertaken by visual inspection and the use of a multi-purpose meter (multimeter) or an instrument specifically for recording resistance, i.e. an ohmmeter.

Continuity – there are several types of continuity test for ring mains. Each is to ensure integrity of the live, neutral and earth conductors without bridging (shorting out) of connections. The following is one established test to be applied to each conductor:

- Record the resistance between the ends of the ring circuit (A).
- Record the resistance between closed ends of the circuit and a point mid-way in the circuit (B).
- Check the resistance of the test lead (C).
- Circuit integrity is indicated by: A ÷ 4 approx. = B – C.

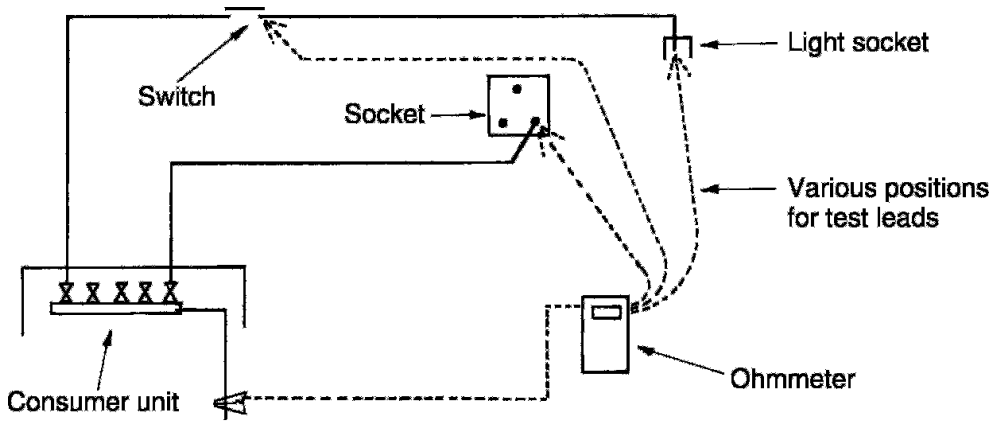


Insulation – this test is to ensure that there is a high resistance between live and neutral conductors and these conductors and earth. A low resistance will result in current leakage and energy waste which could deteriorate the insulation and be a potential fire hazard. The test to earth requires all lamps and other equipment to be disconnected, all switches and circuit breakers closed and fuses left in. Ohmmeter readings should be at least 1 MΩ.



Insulation test

Polarity – this is to ensure that all switches and circuit breakers are connected in the phase or live conductor. An inadvertant connection of switchgear to a neutral conductor would lead to a very dangerous situation where apparent isolation of equipment would still leave it live! The test leads connect the live bar in the disconnected consumer unit to live terminals at switches. A very low resistance reading indicates the polarity is correct and operation of the switches will give a fluctuation on the ohmmeter.



Polarity test

Ref: BS EN 61010-1: Safety requirements for electrical equipment for measurement, control and laboratory use.

Standard applications	Cable specification (mm^2 c.s.a.)
Lighting	1 or 1·5
Immersion heater	1·5 or 2·5
Sockets (ring)	2·5
Sockets (radial)	2·5 or 4 (see page 392)
Cooker	6 or 10
Shower	4, 6 or 10 (see page 286)

Some variations occur as the specification will depend on the appliance or circuit loading – see calculation below. Where non-standard circuits or special installations are necessary, the cable specification must be calculated in the following stages:

- Determine the current flowing.
- Select an appropriate cable (see table below).
- Check that the voltage drop is not greater than 4%.

Current ratings and voltage reduction for PVC insulated cables:

c.s.a. (mm^2)	Current carrying capacity (amps)		Voltage drop (mV/amp/m)
	In conduit	Clipped	
1	13·5	15·5	44
1·5	17·5	20	29
2·5	24	27	18
4	32	37	11
6	41	47	7·3
10	57	65	4·4

E.g. a 7.2 kW shower with a cable length of 10 m in conduit:

Amps = Watts ÷ Volts = 7200 ÷ 230 = 31·3
From table, select 4 mm^2 c.s.a. (32 amps)

Voltage drop = (mV × Current flowing × Cable length) ÷ 1000
= (11 × 31·3 × 10) ÷ 1000 = 3·44 volts

Maximum voltage drop = 230 × 4% = 9·2 volts.
Therefore, 4 mm^2 c.s.a. cable is satisfactory.

Note: Correction factors may need to be applied, e.g., when cables are grouped, insulated or in an unusual temperature. The IEE regulations should be consulted to determine where corrections are necessary.

Diversity in electrical installations permits specification of cables and overload protection devices with regard to a sensible assessment of the maximum likely demand on a circuit. For instance, a ring circuit is protected by a 30 amp fuse or 32 amp mcb, although every socket is rated at 13 amps. Therefore if only three sockets were used at full rating, the fuse/mcb would be overloaded. In practice this does not occur, so some diversity can be incorporated into calculations.

Guidance for diversity in domestic installations:

Circuit	Diversity factor
Lighting	66% of the total current demand.
Power sockets	100% of the largest circuit full load current + 40% of the remainder.
Cooker	10 amps + 30% full load + 5 amps if a socket outlet is provided.
Immersion heater	100%.
Shower	100% of highest rated + 100% of second highest + 25% of any remaining.
Storage radiators	100%.

E.g. a house with 7·2 kW shower, 3 kW immersion heater, three ring circuits and three lighting circuits of 800 W each:

Appliance/circuit	Current demand (amps)	Diversity allowance (amps)
Shower	$\frac{7200}{230} = 31{\cdot}3$	31·3 × 100% = 31·3
Ring circuit-1	30	30 × 100% = 30
Ring circuit-2	30	30 × 40% = 12
Ring circuit-3	30	30 × 40% = 12
Lighting	$3 \times 800 = \frac{2400}{230} = 10{\cdot}4$	10·4 × 66% = 6·9
		Total = 92·2 amps