



# EARTHING: YOUR QUESTIONS ANSWERED

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**What are earthed and unearthed systems?  
What are the requirements of BS 7671?  
What are the advantages and disadvantages  
of the various types of earthing systems?**

This article, which is based on IEE Guidance notes, is intended to provide information that it is hoped will prove helpful.

BS 7671 lists five types of earthing system:  
TN-S, TN-C-S, TT, TN-C, and IT.

T = Earth (from the French word Terre)  
N = Neutral  
S = Separate  
C = Combined  
I = Isolated (The source of an IT system is either

connected to earth through a deliberately introduced earthing impedance or is isolated from Earth. All exposed-conductive-parts of an installation are connected to an earth electrode.)

When designing an electrical installation, one of the first things to determine is the type of earthing system. The distributor will be able to provide this information.

The system will either be TN-S, TN-C-S (PME) or TT for a low voltage supply given in accordance with the Electricity Safety, Quality and Continuity Regulations 2002. This is because TN-C requires an exemption from the Electricity Safety, Quality and Continuity Regulations, and an IT system is not permitted for a low voltage public supply in the UK because the source is not directly earthed. Therefore TN-C and IT systems are both very uncommon in the UK.

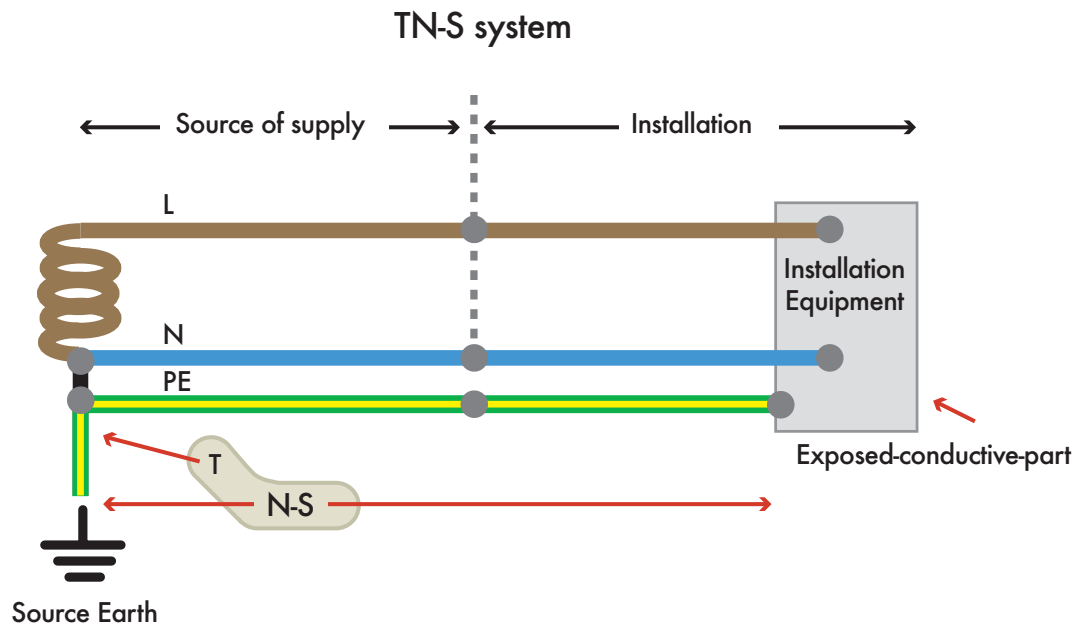


Fig 1: TN-S system

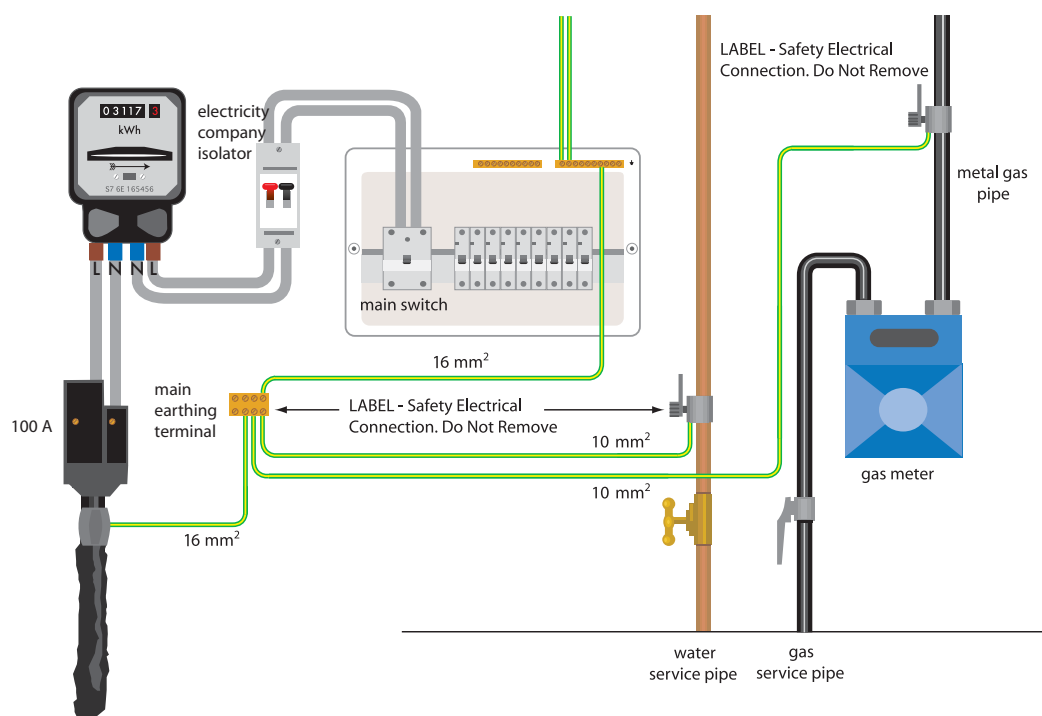


Fig 2: Cable sheath earth (TN-S system). Schematic of earthing and main equipotential bonding arrangements. Based on 25 mm<sup>2</sup> tails and selection from Table 54G.

Note: An isolator is not always installed by the electricity distributor.

## 1. Overview of earthing systems

### 1.1 TN-S system earthing

A TN-S system, shown in fig 1, has the neutral of the source of energy connected with earth at one point only, at or as near as is reasonably practicable to the source, and the consumer's earthing terminal is typically connected to the metallic sheath or armour of the distributor's service cable into the premises.

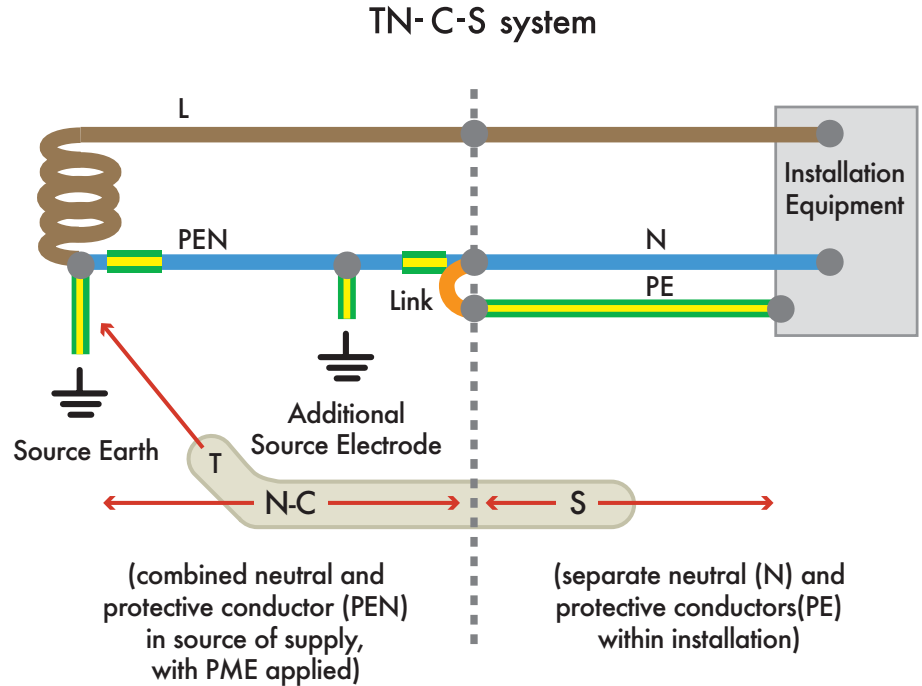


Fig 3: TN-C-S system

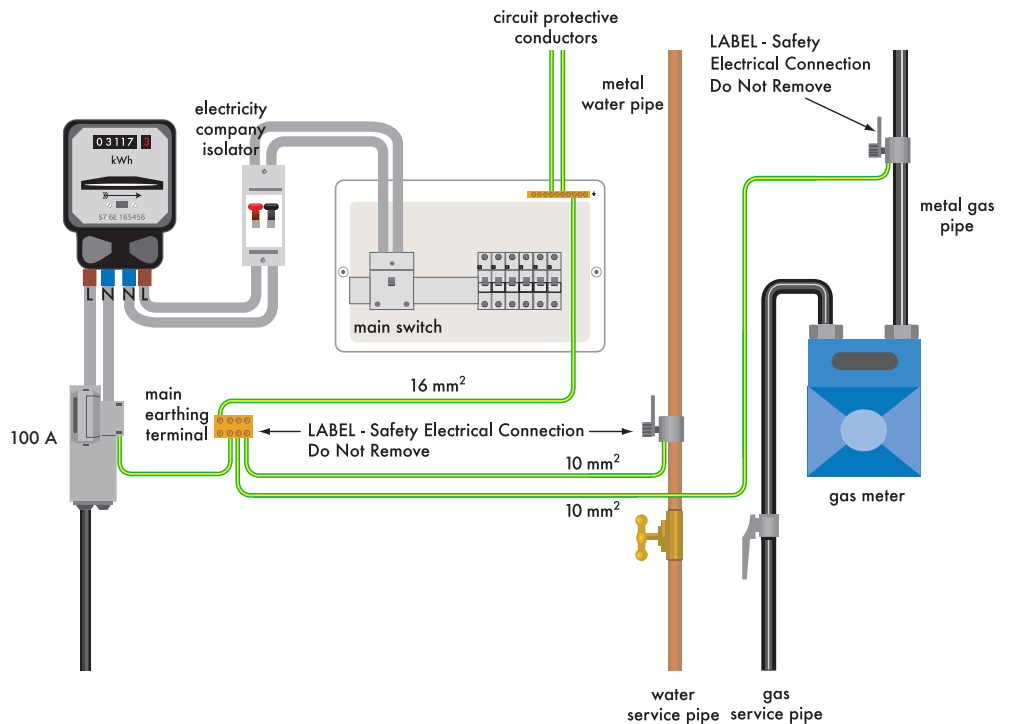


Fig 4: PME supply (TN-C-S system). Schematic of earthing and main equipotential bonding arrangements. Based on 25 mm tails and selection from Table 54G. Note: An isolator is not always installed by the electricity distributor.

**1.2 TN-C-S system earthing**

A TN-C-S system, shown in fig 3, has the supply neutral conductor of a distribution main connected with earth at source and at intervals along its run. This is usually referred to as protective multiple earthing (PME). With this arrangement the

distributor’s neutral conductor is also used to return earth fault currents arising in the consumer’s installation safely to the source. To achieve this, the distributor will provide a consumer’s earthing terminal which is linked to the incoming neutral conductor.

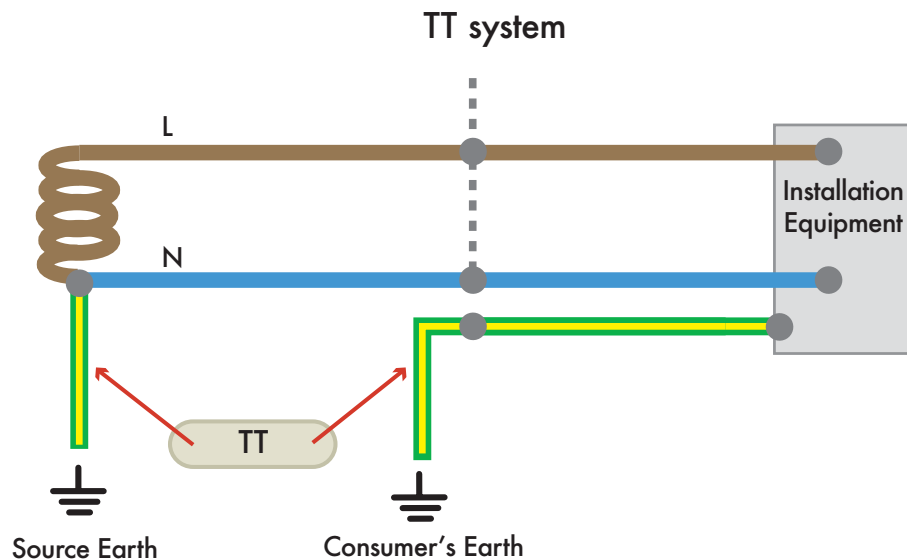


Figure 5: TT system

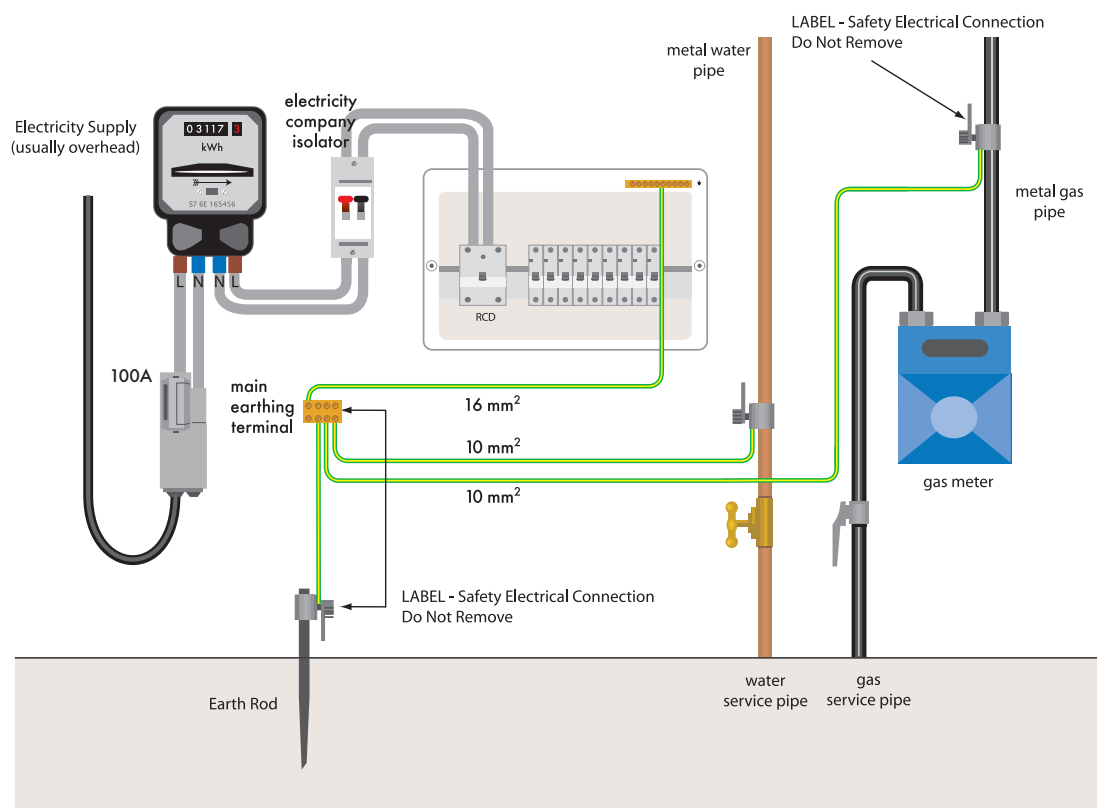


Figure 6: No earth provided (TT system). Based on 25 mm<sup>2</sup> tails and selection from Table 54G. Note: An isolator is not always installed by the electricity distributor. Manufacturers recommendations should be sought with regards to connections to earth electrodes.

### 1.3 TT system earthing

A TT system, shown above, has the neutral of the source of energy connected as for TN-S, but no facility is provided by the distributor for the consumer's earthing. With TT, the consumer must provide their own connection to earth, i.e. by installing a suitable earth electrode local to the installation.

## 2. Requirements of BS 7671

### Earth electrodes

BS 7671 recognises a wide variety of types of earth electrode. Regulation 542-02-01 lists the types recognised which include earth rods, earth plates and

underground structural metal work.

The soil resistivity of the ground is probably the single most important factor in the determination of the type of earth electrode. Rods can only be as effective as the contact they make with the surrounding material. Thus, they should be driven into virgin ground, not disturbed (backfilled) ground. Where it is necessary to drive two or more rods and connect them together to achieve a satisfactory result, the separation between rods should be at least equal to their combined driven depth to obtain maximum advantage from each rod. In some locations low soil resistivity is found to be concentrated in the topsoil layer, beneath which there may be rock or other impervious strata which prevents the deep driving of rods, or a deep layer of high resistivity. Only a test or known information about the ground can reveal this kind of information. In such circumstances, the installation of copper earth tapes, or pipes or plates, would be most likely to provide a satisfactory earth electrode resistance value.

Whatever form an earth electrode takes, the possibility of soil drying and freezing, and of corrosion, must be taken into account. Preferably, testing of an earth electrode should be carried out under the least favourable conditions, i.e. after prolonged dry weather. Further information on earthing principles and practice can be found in BS 7430 : 1998 '*Code of Practice for Earthing*'.

### Earthing conductors

Earthing conductors which are defined in BS 7671 as a protective conductor connecting the main earthing terminal of an installation to an earth electrode or other means of earthing must be adequately sized particularly where buried partly in the ground, and be of suitable material and adequately protected against corrosion and mechanical damage.

The size of an earthing conductor is arrived at in basically the same way as for a circuit protective conductor, except that Table 54A of BS 7671 must be applied to any buried earthing conductor. For a TN-C-S (PME) supply, it should be no smaller than the main bonding conductors.

### Sizing of circuit protective conductors

There are several factors which may influence or determine the size required for a circuit protective conductor. A minimum cross-sectional area of 2.5 mm<sup>2</sup> copper is required for any separate circuit protective conductor, i.e. one which is not part of a cable or formed by a wiring enclosure or contained in such an enclosure.

An example would be a bare or insulated copper conductor clipped to a surface, run on a cable tray or fixed to the outside of a wiring enclosure. Such a circuit protective conductor must also be suitably protected if it is liable to suffer mechanical damage or chemical deterioration or be damaged by electrodynamic effects produced by passing earth fault current through it. If mechanical protection is not provided the minimum size is 4 mm<sup>2</sup> copper or equivalent.

BS 7671 provides two methods for sizing protective conductors including earthing conductors (see also Table 54A). The easier method is to determine the protective conductor size from Table 54G but this may produce a larger size than is strictly necessary, since it employs a simple relationship to the cross-sectional area of the phase conductor(s).

The second method involves a formula calculation. The formula is commonly referred to as the 'adiabatic equation' and is the same as that used for short-circuit current calculations (see Regulation 434-03-03). It assumes that no heat is dissipated from the protective conductor during an earth fault and therefore errs on the safe side. Even so, application of the formula will in many instances result in a protective conductor having a smaller csa than that of the live conductors of the associated circuit. This is quite acceptable.

Regulation 543-01-03 states:

The cross-sectional area, where calculated, shall be not less than the value determined by the following formula or shall be obtained by reference to BS 7454.

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

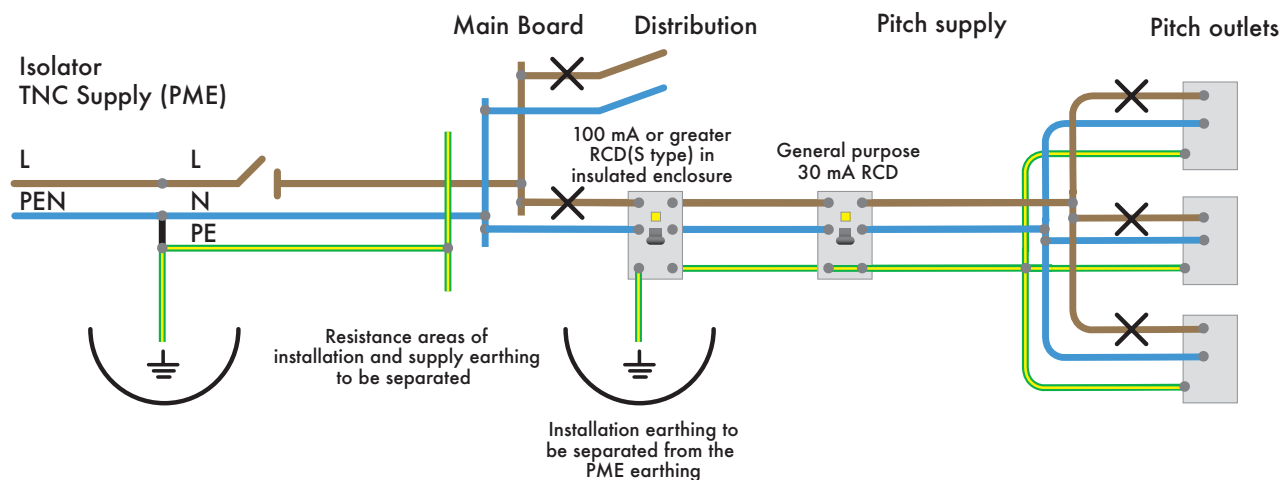
where:

**S** is the nominal cross-sectional area of the conductor in mm<sup>2</sup>.

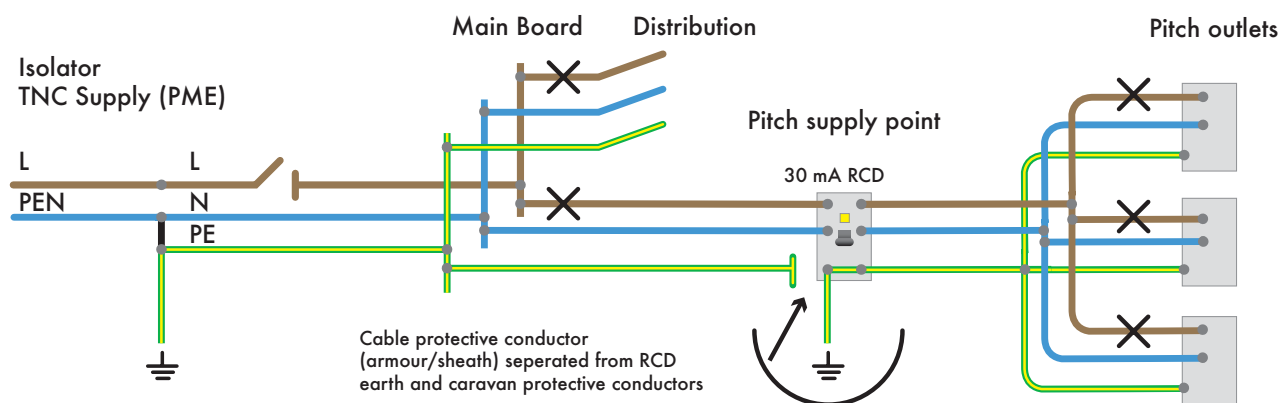
**I** is the value in amperes (rms. for a.c.) of fault current for a fault of negligible impedance, which can flow through the associated protective device, due account being taken of the current limiting effect of the circuit impedances and the limiting capability ( $I^2 t$ ) of that protective device.

Account shall be taken of the effect, on the resistance of circuit conductors, of their temperature rise as a result of overcurrent - see Regulation 413-02-05.

**t** is the operating time of the disconnecting device in



**Figure 7: Typical site distribution for a PME supply, separation from PME earth at main distribution board**



**Figure 8: Typical site distribution for a PME supply, separation from PME earth at pitch supply point**

seconds corresponding to the fault current  $I$  amperes.

$k$  is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

### 3.0 Type of earthing systems, advantages and disadvantages

#### 3.1 Protective multiple earthing (PME).

Such a supply system is described in BS 7671 as TN-C-S. The advantage of this system is that it provides an effective and reliable method of providing customers with an earth connection. For example the maximum  $Z_e$  specified by a distributor is  $0.35 \Omega$  for TN-C-S

supplies compared to  $0.8 \Omega$  for TN-S supplies.

However, under certain supply system fault conditions (PEN conductor of the supply becoming open circuit external to the installation) a potential can develop between the conductive parts connected to the PME earth terminal and the general mass of earth. However, since there are multiple earthing points on the supply network and bonding is provided within the building complying with BS 7671, the risk is considered to be small.

#### Special Locations

The Electricity Association publications provides guidance on PME systems. Whilst PME systems provide an effective and reliable earth connection

precautions need to be taken when dealing with special locations. For example Regulation 9(4) of the Electricity Safety, Quality and Continuity Regulations does not allow the combined neutral and protective conductor to be connected electrically to any metalwork in a caravan or boat. This prevents PME terminals being used for caravans or boat mooring supplies, although they may be used for fixed premises on the sites, such as the site owner's living premises and any bars or shops, etc.

Petrol filling stations are another area where precautions need to be taken. The reference publication is "Guidance for the design, construction, modification and maintenance of petrol filling stations", published by the Association for Petroleum and Explosives Administration (APEA) and the Institute of Petroleum, which recommends a TT supply for hazardous areas.

A separate earth electrode and RCD or other alternative arrangement is required to ensure the segregation of petrol filling area earthing and that of the PME earth of the distribution network. A PME earth may be used for permanent buildings such as shops and restaurants.

Also, mines and quarries are another area. A supply taken to an underground shaft, or for use in the production side of a quarry, must have an earthing system which is segregated from any system bonded to the PME terminal.

Finally, because of the practical difficulties in bonding all accessible extraneous-conductive-parts electricity distribution companies might not provide a PME earth to agricultural and horticultural installations and construction sites.

### 3.2 TT system

With TT, the consumer must provide their own connection to earth, i.e. by installing a suitable earth electrode local to the installation. The circumstances in which a distributor will not provide a means of earthing for the consumer are usually where the distributor cannot guarantee the earth connection back to the source, e.g. a low voltage overhead supply, where there is the likelihood of the earth wire either becoming somehow disconnected or even stolen.

A distributor also might not provide means of earthing for certain outdoor installations, e.g. a construction site temporary installation, leaving it to the consumer to make suitable and safe arrangements for which they are fully responsible. The electricity distributor is required to make available his supply neutral or protective conductor for connection to the consumer's earth terminal, unless inappropriate for



reasons of safety (Reg 24 of ESQCR). Construction site, farm or swimming pool installations might be inappropriate unless additional precautions are taken, such as an additional earth electrode.

### 3.3 TN-S system

A TN-S system has the neutral of the source of energy connected with earth at one point only, at or as near as is reasonably practicable to the source and the consumer's earthing terminal is typically connected to the metallic sheath or armour of the distributor's service cable into the premises or to a separate protective conductor of, for instance, an overhead supply.

Large consumers may have one or more HV/LV transformers dedicated to their installation and installed adjacent to or within their premises. In such situations the usual form of system earthing is TN-S.

More information on earthing and bonding is available in IEE Guidance Note 5. Also more information on special locations is available in IEE Guidance Note 7. ■