

Earthing systems

What is earthing?

- The whole of the world may be considered as a vast conductor which is at reference (zero) potential.
- In the UK it is referred to this as 'earth' whilst in the USA it is called 'ground'.
- People are usually more or less in contact with earth, so if other parts which are open to touch become charged at a different voltage from earth a shock hazard exists.
- The process of earthing is to connect all these parts which could become charged to the general mass of earth, to provide a path for fault currents and to hold the parts as close as possible to earth potential. In simple theory this will prevent a potential difference between earth and earthed parts, as well as permitting the flow of fault current which will cause the operation of the protective systems.
- The standard method of tying the electrical supply system to earth is to make a direct connection between the two. This is usually carried out at the supply transformer, where the neutral conductor (often the star point of a three-phase supply) is connected to earth using an earth electrode. Figure 1 shows such a connection.

Types of earthing systems

1- TT systems

This arrangement covers installations not provided with an earth terminal by the Electricity Supply Company. Thus it is the method employed by most (usually rural) installations fed by an overhead supply. Neutral and earth (protective) conductors must be kept quite separate throughout the installation, with the final earth terminal connected to an earth electrode by means of an earthing conductor.

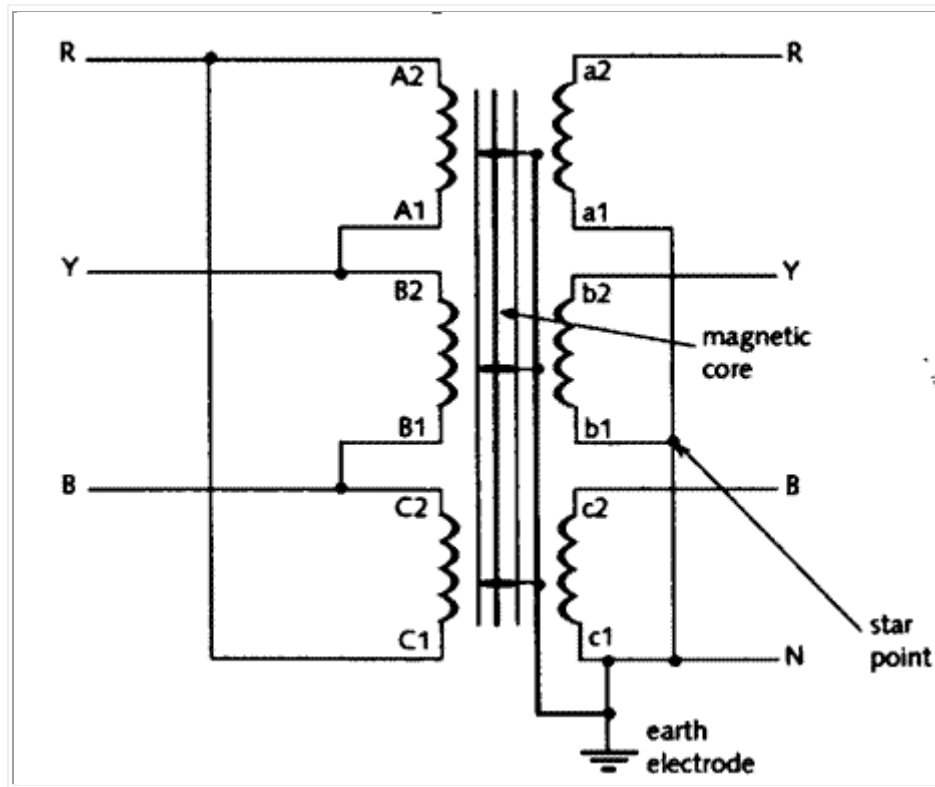


Fig .1 - Three-phase delta/star transformer showing earthing arrangements.

Effective earth connection is sometimes difficult. Because of this, socket outlet circuits must be protected by a residual current device (RCD) with an operating current of 30 mA . Fig. 2 shows the arrangement of a TT earthing system.

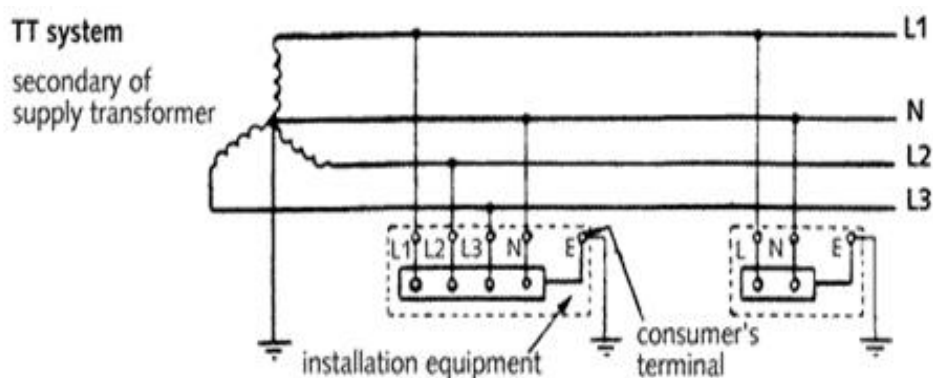


Fig.2 - TT earthing system

2 - TN-S system

This is probably the most usual earthing system in the world, with the Electricity Supply Company providing an earth terminal at the incoming mains position. This earth terminal is connected by the supply protective conductor (PE) back to the star point (neutral) of the secondary winding of the supply transformer, which is also connected at that point to an earth electrode. The earth conductor usually takes the form of the armour and sheath (if applicable) of the underground supply cable. The system is shown diagrammatically in {Fig.3}.

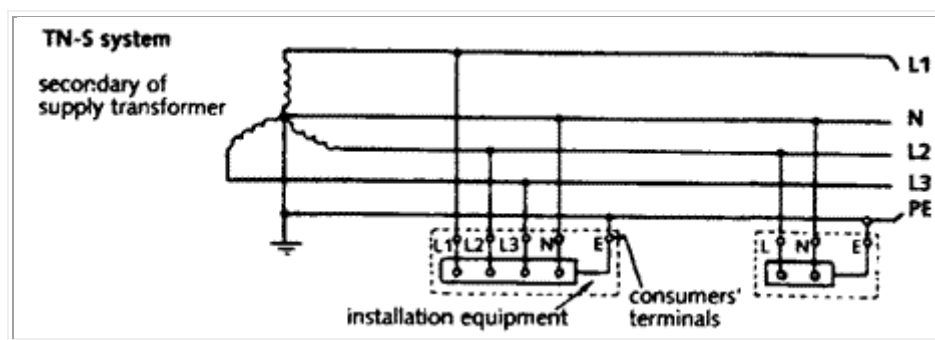


Fig.3 - TN-S earthing system

3 - TN-C-S system

In this system, the installation is TN-S, with separate neutral and protective conductors. The supply, however, uses a common conductor for both the neutral and the earth. This combined and neutral system is sometimes called the 'protective and neutral conductor' (PEN) the 'combined neutral and earth' conductor (CNE). The system, which is shown in Fig.4 is most usually protective multiple earth (PME) system.

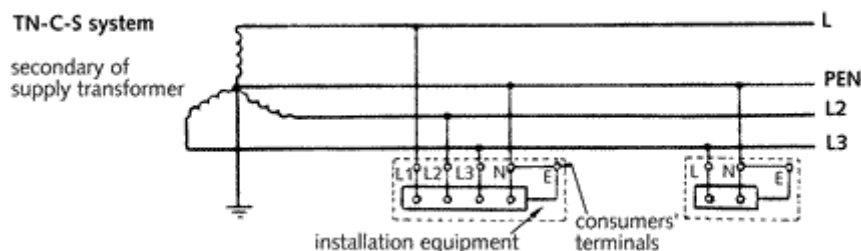


Fig.4 - TN-C-S earthing system - protective multiple earthin

4-TN-C system

This installation is unusual, because combined neutral and earth wiring is used in both the supply and within the installation itself. Where used, the installation will usually be the earthed concentric system, which can only be installed under the special conditions (mostly used in France).

5 - IT system

The installation arrangements in the IT system are the same for those of the TT system . However, the supply earthing is totally different. The IT system can have an unearthed supply, or one which is not solidly earthed but is connected to earth through a current limiting impedance. IT system is shown in Fig.5.

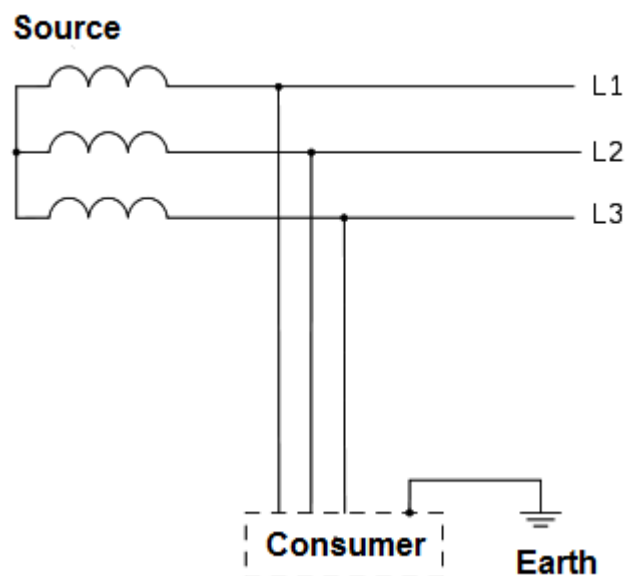


Fig.5 - IT earthing system

Principle of earthing system

- The path followed by fault current as the result of a low impedance occurring between the phase conductor and earthed metal is called the **earth fault loop**. Current is driven through the loop impedance by the supply voltage.
- The extent of the earth fault loop for a TT system is shown in {Fig .6}, and is made up of the following labelled parts.

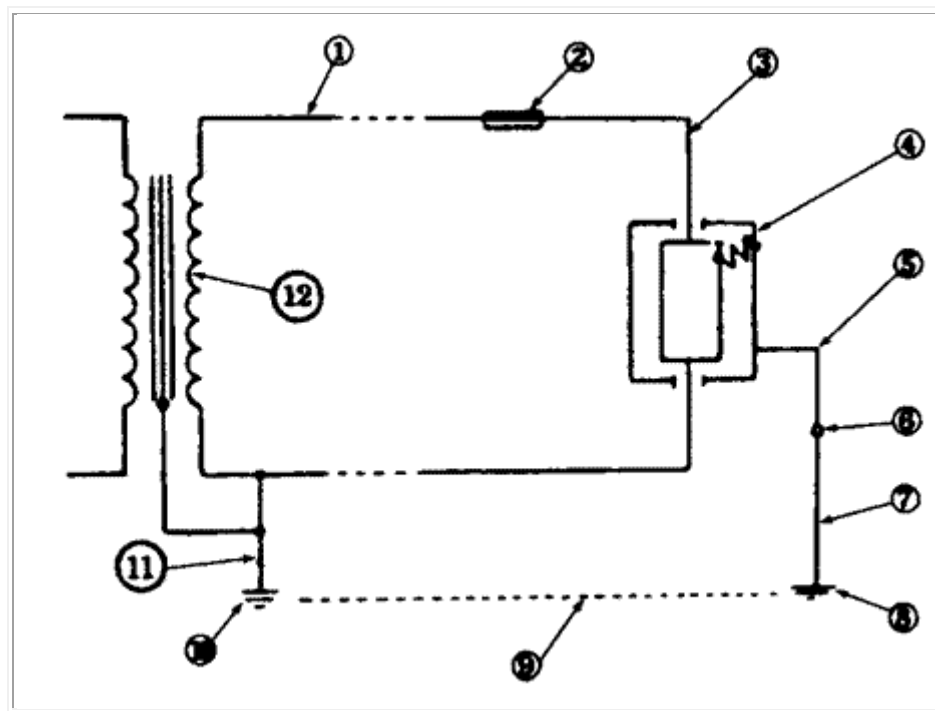


Fig.6 The earth fault loop

1. - the phase conductor from the transformer to the installation
- 2-the protective device(s) in the installation
- 3-the installation phase conductors from the intake position to the fault
4. - the fault itself (usually assumed to have zero impedance)
5. - the protective conductor system
6. - the main earthing terminal
7. - the earthing conductor
8. - the installation earth electrode

9. - the general mass of earth

10. - the Supply Company's earth electrode

11. - the Supply Company's earthing conductor

12-the secondary winding of the supply transformer

- For a TN-S system (where the Electricity Supply Company provides an earth terminal), items 8 to 10 are replaced by the PE conductor, which usually takes the form of the armouring (and sheath if there is one) of the underground supply cable.
- For a TN-C-S system (protective multiple earthing) items 8 to 11 are replaced by the combined neutral and earth conductor.
- For a TN-C system (earthed concentric wiring), items 5 to 11 are replaced by the combined neutral and earth wiring of both the installation and of the supply.

It is readily apparent that the impedance of the loop will probably be a good deal higher for the TT system, where the loop includes the resistance of two earth electrodes as well as an earth path, than for the other methods where the complete loop consists of metallic conductors.

Earthing system components **(6,7 and 8)**

Earthing system has three main componens

- **Earthing conductors**
- **Earthing electrods**
- **Inspection points (earthing well)**

1- Earthing conductors

The earthing conductor is commonly called the earthing lead. It joins the installation earthing terminal to the earth electrode or to the earth terminal provided by the Electricity Supply Company. It is a vital link in the protective system, so care must be taken to see that its integrity will be preserved at all times.

2- Earth electrodes

The principle of earthing is to consider the general mass of earth as a reference (zero) potential. Thus, everything connected directly to it will be at this zero potential. The purpose of the earth electrode is to connect to the general mass of earth ,(see Fig.7).

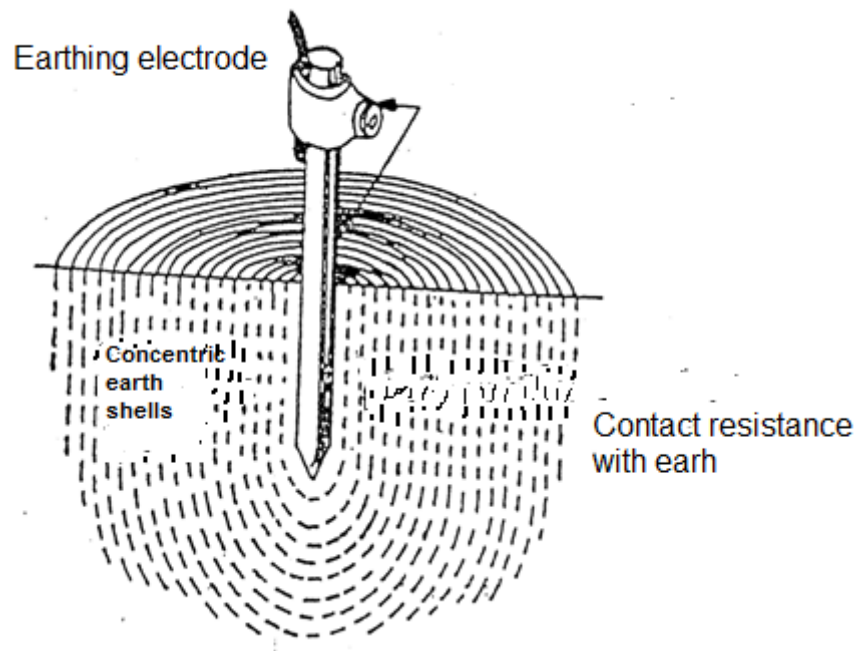


Fig.7 **Earth electrode**

Calculation of earthing resistance for one electrode driven at the earth

Equation used to calculate earthing resistance is:

$$R = \left(\frac{\rho}{2\pi l} \right) [\ln (8l/d) - 1] \dots\dots\dots (1)$$

Where

ρ = earth resistivity in ohm.m

l = length of the electrode (m)

d = diameter of the electrode in (m)

Example 1 : calculate the earthing resistance of an earthing electrode of length 3m and its diameter is 2 cm driven in an earth of 60 Ω .m resistivity.

Solution:

$$R_I = \left(\rho / 2\pi l \right) [\ln (8l / d) - 1] = (60 / 2\pi \times 3) [\ln (8 \times 3 / 0.02) - 1] = 19.4 \Omega$$

This is very large value. To reduce this resistance we can put another rode (electrode) at distance D in parallel with the first rode. Hence the total earthing resistance R_{II} will be:

$$R_{II} = \left((1 + \alpha) / 2 \right) R_I$$

$$\alpha = \left(\rho / 2\pi D R_I \right) \quad (2)$$

Example 2: For example 1 above calculate the erthing resistancse when two similar electrod are put in parallel.

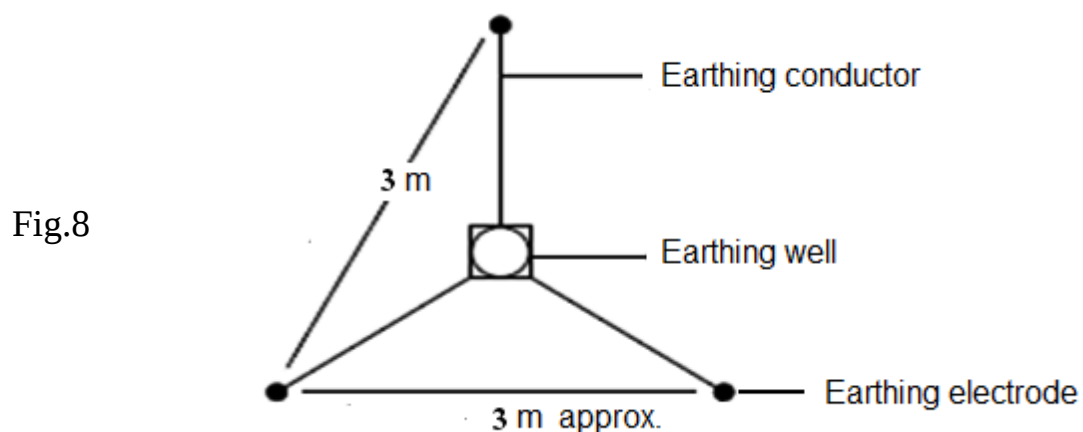
Solution:

From example 1 $R_I = 19.4 \Omega$

$$\alpha = \left(\rho / 2\pi D R_I \right) = (60 / 2 \times 3.14 \times 3 \times 19.4) = 0.16$$

$$R_{II} = \left\{ (1 + 0.16) / 2 \right\} (19.4) = 11.25 \Omega$$

For standard building, it is found that the best earthing system is to use thee rodes connected in triangular form as shown in Fig.8, in this case the earthing resistance will be reduce to $R_{III} = R_I / 3$.



For any number of rods in parallel, we can calculate the earthing resistance from the following equation and table:

$$R_{eq} = [RI / \text{No. of rods.}] \times F \quad (9-4)$$

Where F is a multiplying factor that can be taken from the following table-1. The resistivity (ρ) in $(\Omega \cdot m)$ for various types of soils are given table-2.

Table-1

F	No.of rods
1.16	2
1.29	3
1.36	4
1.68	8
1.8	12
1.92	16
2.0	20

Table-2

المقاومية ρ ($\Omega \cdot m$)	Type of soil نوع التربة
30 – 5	مستنقعات وترب مغمورة بالماء
100 – 20	تربة طينية
500 – 50	طين – رمل
3000 – 200	رمل سليكوني
3000 – 1500	أرض صخرية

3- Inspection points (Earthing well)

For protection of the earthing rod and earthing conductors and also for maintenance and inspection purposes an earth well is constructed as shown in Fig.9. Earthing conductors, as well as protective and bonding conductors, must be protected against corrosion. Probably the most common type of corrosion is electrolytic, which is an electro-chemical effect between two different metals when a current passes between them whilst they are in contact with each other and with a weak acid. The acid is likely to be any moisture which has become contaminated with chemicals carried in the air or in the ground.

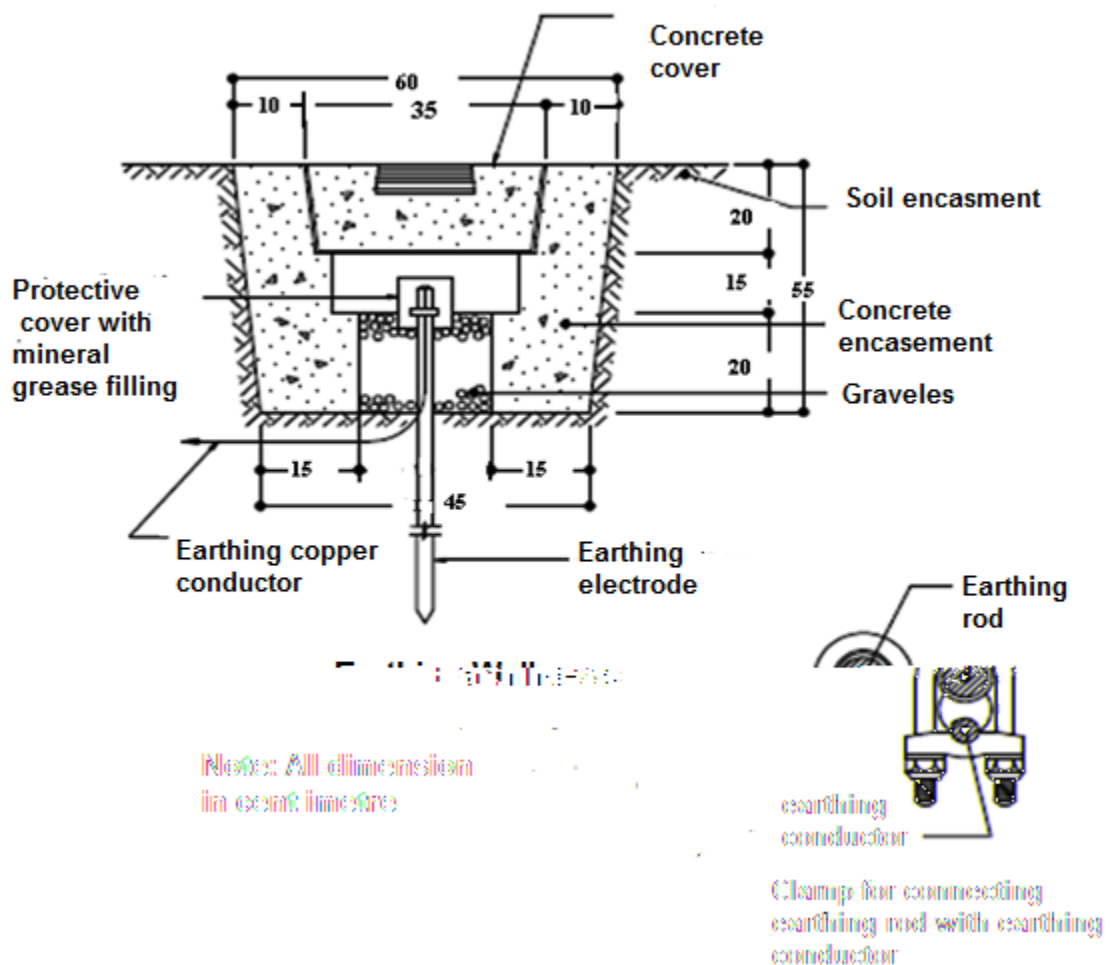


Fig.9 Earthing well

- A main earth terminal or bar must be provided for each installation to collect and connect together all protective and bonding conductors. It must be possible to disconnect the earthing conductor from this terminal for test purposes, but only by the use of a tool. This requirement is intended to prevent unauthorised or unknowing removal of protection.

- Where the final connection to the earth electrode or earthing terminal is made there must be a clear and permanent label **Safety Electrical Connection - Do not remove** (see {Fig.10}).

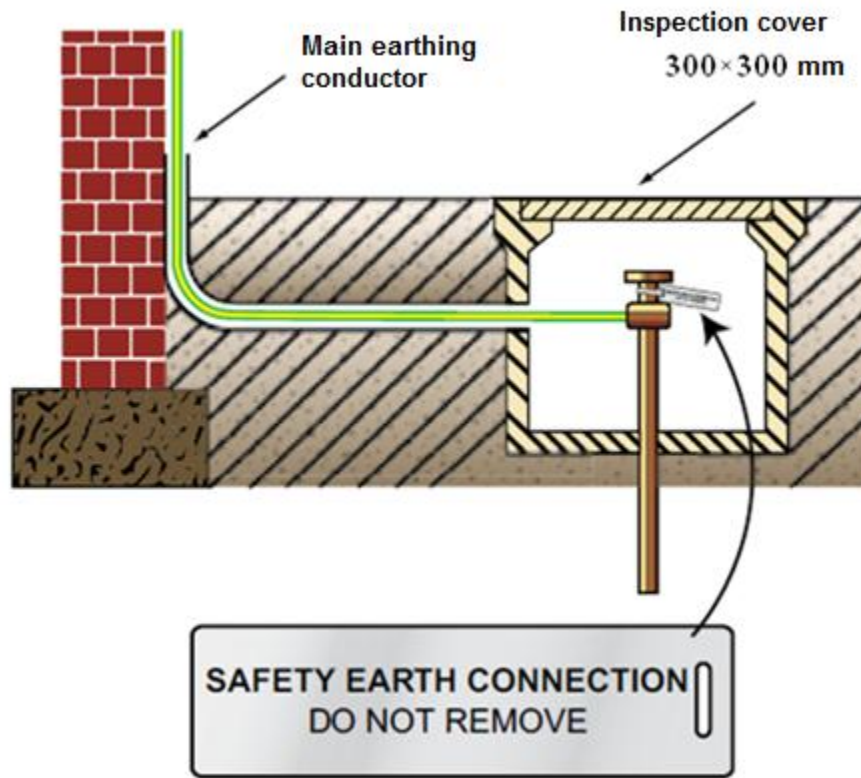


Fig.10

- With the increasing use of underground supplies and of protective multiple earthing (PME) it is becoming more common for the consumer to be provided with an earth terminal rather than having to make contact with earth using an earth electrode.

What is protective multiple earthing?

- If a continuous metallic earth conductor exists from the star point of the supply transformer to the earthing terminal of the installation, it will run throughout in parallel with the installation neutral, which will be at the same potential. It therefore seems logical that one of these conductors should be removed, with that remaining acting as a combined protective and neutral conductor (PEN). When this is done, we have a TN-C-S installation .***The combined earth and neutral system will apply only to the supply, and not to the installation.***
- PME can be installed by the Electricity Supply Company **only** after the supply system and the installations it feeds must have complied with certain requirements.
- The great virtue of the PME system is that neutral is bonded to earth so that a phase to earth fault is automatically a phase to neutral fault. The earth-fault loop impedance will then be low, resulting in a high value of fault current which will operate the protective device quickly. It must be stressed that the neutral and earth conductors are kept quite separate within the installation: the main earthing terminal is bonded to the incoming combined earth and neutral conductor by the Electricity Supply Company. The difficulty of ensuring that bonding requirements are met on construction sites means that PME supplies must not be used. Electricity Supply Regulations forbid the use of PME supplies to feed caravans and caravan sites.