



1. Introduction

The IEE's Technical Helpline receives numerous calls from contractors requesting information on the earthing and bonding requirements for hazardous locations. This article will give an overview of the hazards and problems encountered in those locations and gives information on the performance requirements of earthing and bonding to ensure that the potential for gas ignition, from low voltage electrical sources and equipment, is reduced.

2. The Regulations

BS 7671, *Requirements for Electrical Installations*, is intended to be applied to electrical installations generally but, in certain cases, they may need to be supplemented by the requirements or recommendations of other British Standards or by the requirements of the person ordering the work. Such cases would include the following:

- Electrical apparatus for explosive gas atmospheres – BS EN 60079
- Electrical apparatus for use in the presence of combustible dust – BS EN 50281

3. Definitions

Often, there is great confusion over earthing, bonding and even use of the nonsensical term, earth-bonding! BS 7671, *Requirements for Electrical Installations*, defines:

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

Bonding – the correct title is 'Equipotential bonding'.

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

There are two categories of equipotential bonding:

Main equipotential bonding

Regulation 413-02-02 of BS 7671 states: In each installation, main equipotential bonding conductors shall connect to the main earthing terminal *extraneous conductive-parts* of that installation.

Supplementary equipotential bonding

Regulation 413-02-27 of BS 7671 states: Where supplementary equipotential bonding is necessary, it shall connect together the *exposed conductive-parts* of equipment in the circuits concerned *and extraneous-conductive-parts*.

Supplementary equipotential bonding is not required on every installation, generally however, it is required in areas of increased risk; BS 7671 recognises these areas as 'Special Locations'. A hazardous location, of course, would be considered as a special location.

BS 7671 further defines:

An extraneous-conductive-part – "a conductive part liable to introduce a potential, generally earth potential and not forming part of the electrical installation"

An 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"

Defining Hazardous Locations

BS EN 60079-14: 2003, *Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)*, defines the following:

- Explosive atmosphere
- Explosive gas atmosphere
- Hazardous area

Note – The ATEX 137 Directive has adopted the concept of space instead of area; by definition, area is a two-dimensional concept, space is a three-dimensional concept.

In line with BS EN 60079-10: 2003, *Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas*, this article will consider hazardous locations where **gas ignition from low voltage electrical sources is possible** but, for the purposes of this article, the following locations will not be considered:

- a) mines susceptible to firedamp
- b) the processing and manufacture of explosives
- c) areas where a risk may arise due to the presence of ignitable dusts or fibres
- d) catastrophic failures which are beyond the concept of abnormality
- e) rooms used for medical purposes
- f) areas where the presence of flammable mist may give rise to an unpredictable risk and which require special consideration

Explosive atmosphere

Mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, mist or dust, in which after ignition, combustion spreads throughout the unconsumed mixture.

Explosive gas atmosphere

Mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour, in which after ignition, combustion spreads throughout the unconsumed mixture.

Hazardous area

Area in which an explosive gas atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of apparatus.

4. The Zonal Concept

Locations where flammable gases are, or may be, present, are defined by a Zonal concept. The definitions, shown in the table below, of the particular Zones are taken from BS EN 1127-1:1998, *Explosive atmospheres. Explosion prevention and protection. Basic concepts and Methodology*. Each site will have drawings that will indicate the extent of the Zones. The extent of the Zones is established at the design stage by the competent person who is experienced in this line of work.

5. Hazards and Problems

The prime danger in explosive atmospheres is that of explosions due to incendive sparking. Sparking can be caused by any of the following:

Fault currents and high protective-conductor currents

'Flashovers' could occur on poorly earthed circuits where expected and non-expected protective-conductor currents are present.

Static electricity

Static electricity is the retained charge on a

Zone	Definition	Example
Zone 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist, is present continuously or for long periods or frequently	Typically, the space above the liquid in a storage vessel.
Zone 1	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist, is likely to occur in normal operation occasionally	The space immediately around a storage vessel's vent-pipe openings which vent during filling.
Zone 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist, is NOT likely to occur in normal operation but, if it does occur, will persist for a short period only.	Around Zone 1, it is usual to consider the surrounding space to be Zone 2

conductor. All the energy stored on the conductor can be released in one arc or 'spark' to catastrophic effect. To retain charge on a conductor, it has to be insulated from other conductors and insulated from earth by means of a non-conductor. Sparking, due to static electricity, can be avoided by using recognised earthing and equipotential bonding techniques.

Static electricity is generated in many ways, including:

- the flow of liquids
- the mixing of powders
- the production of sprays
- the contact and separation of solids

Static electricity causes problems in many industries, such as chemical, pharmaceutical, petroleum, etc.

Static electricity-discharges from a person can be minimized by providing an adequately-conducting path between the person and earth through their footwear and the floor. BS 7193 gives requirements for two types of rubber footwear. Specifications for conducting-flooring materials and for such floors after laying are given in BS 2050 and BS 3187.

The phenomena that is Static Electricity is covered in great depth in two parts of BS 5958: 1991, Code of practice for *Control of undesirable static electricity: Part 1: General considerations*, and *Part 2: Recommendations for particular industrial situations*.

Lightning protection system

Regulation 413-02-02 of BS 7671 requires that in each installation, main equipotential bonding conductors shall connect to the main earthing terminal extraneous-conductive-parts of that installation, including the lightning protection system. However, the designer of the installation, who is a competent person, may decide that, due to particular risks, main equipotential bonding of the lightning protection system should be avoided. For further information, consult: BS 6651, Code of practice for protection of structures against lightning and BS 7430, Code of practice on earthing.

The electrical supply

The following electrical systems are **NOT** suitable for use in hazardous locations:

- TN-C
- TN-C-S (PME)

In TN-C and TN-C-S (PME) supplies, the neutral conductor is also the earthing conductor, therefore, there could be a potential difference between the main earthing terminal of the installation and the general

mass of earth. Incendive sparking could then occur between the earth of the electrical installation and any extraneous metalwork which is in contact with the general mass of earth.

Electrical equipment

Electrical apparatus for use in hazardous locations must be suited for the gas group, the temperature classification and that particular protection concept.

6. Performance requirements of earthing & bonding conductors in hazardous locations

In this section, we'll look at the sizing of conductors and desired values of resistance.

Sizing of earthing conductors

In accordance with Regulation 543-01-03 of BS 7671, two methods may be used to size earthing conductors or circuit protective conductors (CPCs); the first is the adiabatic equation, the second is Table 54G.

Sizing of equipotential bonding conductors

In accordance with Regulation 547-02-01 of BS 7671 and excluding PME as previously stated, a main equipotential bonding conductor shall have a CSA not less than half the CSA required for the earthing conductor of the installation and not less than 6 mm². The cross-sectional area need not exceed 25 mm² if the bonding conductor is of copper or a CSA affording equivalent conductance in other metals.

Further, Regulation group 547-03 of BS 7671, requires that supplementary equipotential bonding conductors are sized according to both their particular application and whether they are mechanically protected. NOTE – Table 10B of the IEE publication, *The On-Site Guide*, is a handy reference guide for sizing such conductors.

Further, *Guidance Note 3, Inspection and Testing*, published by the IEE, advises that supplementary equipotential bonding conductors should have a resistance of 0.05Ω, or less.

Eliminating static electricity

BS 5958-1: 1991, *Code of practice for Control of undesirable static electricity – Part 1: General considerations*, states that to retain a significant electrostatic charge, a resistance to earth in excess of 1MΩ is required. Generally, resistance between metals in good contact rarely exceeds a few ohms. A value less than 100Ω is readily attainable and is unlikely to deteriorate with time to a level above 1MΩ unless serious corrosion is present.

Equipotential bonding connections

BS EN 60079-0:2004, *Electrical apparatus for explosive gas atmospheres – Part 0: General requirements*, requires that equipotential bonding connections should only be made through designed connection points and not rely on fortuitous contact. All connections should be secure against self-loosening. This requires the use of materials that are designed for that particular application and fit for purpose.

It is worth noting that equipotential bonding conductors would not be required where insulation ensures that circulating currents cannot flow. However, provision shall be made for adequate earthing of isolated exposed-conductive-parts. The insulation of such parts shall be capable of withstanding a test of 100 V r.m.s for 1 min.

Potential equalisation

BS EN 60079-14:2003, *Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)*, states that potential equalization is required for installations in hazardous areas. In effect, this means that all exposed and extraneous conductive parts are connected to the equipotential bonding system. Like other installations in non-hazardous locations, the bonding system may include protective conductors, metal conduits, metal cable sheaths, steel wire armouring and metallic parts of structures. Exposed conductive parts need not be separately connected to the equipotential bonding system if they are firmly secured to and are in metallic contact with structural parts or piping which are connected to the equipotential bonding system.

Intrinsic safety

One type of protective system used in hazardous locations is Intrinsic safety. There are two categories of intrinsic safety, namely, Category ia; may be used in hazardous area Zones 0, 1 & 2, and category ib; may be used in hazardous area Zones 1 & 2. By definition, an intrinsic safety system will limit the energy available in the hazardous location to a level such that ignition of the flammable atmosphere could not occur. Limitation of energy is achieved by using one of two types of barrier; a Shunt Diode Barrier or Galvanically Isolated Barriers. The intrinsic safety earth is a direct connection between the earth terminal of the shunt diode and the main earthing terminal of the electrical supply.

BS EN 50020:2002 – *Electrical apparatus for potentially explosive atmospheres – Intrinsic safety ‘i’*, states:

- CPC to be $\geq 4\text{mm}^2$ (length & further mechanical protection may warrant larger CSA)
- Insulation of dedicated CPC
- 1 Ω maximum (current practice is to achieve 0.1 Ω)
- All screens to be earthed
- All unused cores to be terminated at both ends and earthed as documentation stipulates

7. Summary

To summarise, earthing and bonding is required on all circuits, unless the site documentation or design states otherwise. Equipotential bonding should connect all exposed and extraneous-conductive parts, unless, again, the site documentation states otherwise. All conductors should be sized appropriately, in accordance with Regulation 543-01-03 of BS 7671. All earthing and bonding connections should be correctly installed and connections made at the designed-connection points; never rely on fortuitous contact. Where mechanical connection points, such as threaded conduit and SWA cable armouring lugs are utilised, continuity should be assured

8. Bibliography and further reading

The following publications will provide further information:

- *BS 7671: 2001 (2004) Requirements for electrical installations*
- *Guidance Note 3 – Inspection and Testing, Inc AMD No.2 : 2004, IEE Publications*
- *On-Site Guide to BS 7671: 2001 (2004), IEE Publications*
- *BS 7430: 1998 Code of practice for earthing*
- *BS EN 60079 Electrical apparatus for explosive gas atmospheres (suite of standards)*
- *ATEX 95 Directive*
- *ATEX 137 Directive*
- *BS EN 1127-1:1998 Explosive atmospheres. Explosion prevention and protection. Basic concepts and Methodology.*
- *BS 5958 Code of practice for Control of undesirable static Electricity (suite of standards)*
- *BS 7193 Specification for lined lightweight rubber overshoes and overboots*
- *BS 2050 Specification for electrical resistance of conducting and antistatic products made from flexible polymeric material*
- *BS 3187 Specification for electrically conducting rubber flooring*
- *BS 6651 Code of practice for protection of structures against lightning*
- *BS EN 50020:2002 Electrical apparatus for potentially explosive atmospheres – intrinsic safety ‘i’*
- *DSEAR Regulations 2002* ■