



BSI Standards Publication

Explosive atmospheres

Part 32-1: Electrostatic hazards, guidance

National foreword

This Published Document is the UK implementation of CLC/TR 60079-32-1:2018. It is identical to IEC TS 60079-32-1:2013, incorporating amendment 1:2017. It supersedes PD CLC/TR 60079-32-1:2015, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment A1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee EXL/31/-/1, Electrostatic spray guns.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Atmosphères explosives - Partie 32-1: Risques
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European foreword

This document (CLC/TR 60079-32-1:2018) consists of the text of IEC/TS 60079-32-1:2013 and IEC/TS 60079-32-1:2013/A1:2017 prepared by IEC/TC 31 "Equipment for explosive atmospheres".

This document supersedes CLC/TR 60079-32-1:2015.

The technical specification IEC/TS 60079-32-1 is written as a general guidance document for products in general and process properties necessary to avoid ignition hazards arising from static electricity in a hazardous area.

The IEC standard IEC 60079-0 specifies the general requirements, including the requirements to avoid electrostatic charging, for construction, testing and marking of Ex equipment and Ex Components intended for use in explosive atmospheres.

In some cases, the requirements given in IEC 60079-0 are different from the information given in IEC/TS 60079-32-1.

It was decided to have all information also given complete in the guidance document and therefore the new Clause 14 was added to the IEC/TS 60079-32-1 summarizing the requirements given in IEC 60079-0 for Ex equipment and Ex-Components as additional information.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The texts of the International Technical Specifications IEC/TS 60079-32-1:2013 and IEC/TS 60079-32-1:2013/A1:2017 were approved by CENELEC as a Technical Report without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60243-1	NOTE	Harmonized as EN 60243-1.
IEC 60243-2	NOTE	Harmonized as EN 60243-2.
IEC 60247	NOTE	Harmonized as EN 60247.
IEC 61340-2-1	NOTE	Harmonized as EN 61340-2-1.
IEC 61340-4-5	NOTE	Harmonized as EN 61340-4-5.
IEC 61340-4-7	NOTE	Harmonized as EN 61340-4-7.
ISO 8028	NOTE	Harmonized as EN ISO 8028.
ISO 8330	NOTE	Harmonized as EN ISO 8330.
ISO 13688	NOTE	Harmonized as EN ISO 13688.
ISO 20344	NOTE	Harmonized as EN ISO 20344.
ISO 20345	NOTE	Harmonized as EN ISO 20345.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60079-0	2011	Explosive atmospheres - Part 0: Equipment - General requirements	EN 60079-0	2012
IEC 60079-10-1	-	Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres	EN 60079-10-1	-
IEC 60079-10-2	-	Explosive atmospheres - Part 10-2: Classification of areas - Combustible dust atmospheres	EN 60079-10-2	-
IEC 60079-14	-	Explosive atmospheres - Part 14: Electrical installations design, selection and erection	EN 60079-14	-
IEC 60079-20-1	-	Explosive atmospheres - Part 20-1: Material characteristics for gas and vapour classification - Test methods and data	EN 60079-20-1	-
IEC 60079-32-2	2015	Explosive atmospheres - Part 32-1: Electrostatics hazards - Tests	EN 60079-32-2	2015
IEC 60093	-	Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials	HD 429 S1	-
IEC 60167	-	Methods of test for the determination of the insulation resistance of solid insulating materials	HD 568 S1	-
IEC 61340-2-3	-	Electrostatics - Part 2-3: Methods of test for determining the resistance and resistivity of solid planar materials used to avoid electrostatic charge accumulation	EN 61340-2-3	-
IEC 61340-4-1	-	Electrostatics - Part 4-1: Standard test methods for specific applications - Electrical resistance of floor coverings and installed floors	EN 61340-4-1	-
IEC 61340-4-3	-	Electrostatics - Part 4-3: Standard test methods for specific applications - Footwear	EN 61340-4-3	-
IEC 61340-4-4	2012	Electrostatics - Part 4-4: Standard test methods for specific applications - Electrostatic classification of flexible intermediate bulk containers (FIBC)	EN 61340-4-4	2012

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
ISO 284	-	Conveyor belts - Electrical conductivity - Specification and test method	EN ISO 284	-
ISO 6297	-	Petroleum products - Aviation and distillate fuels - Determination of electrical conductivity	-	-
ISO 8031	-	Rubber and plastics hoses and hose assemblies - Determination of electrical resistance and conductivity	EN ISO 8031	-
ISO 9563	-	Belt drives - Electrical conductivity of antistatic endless synchronous belts - Characteristics and test method	-	-
ISO 12100-1	-	Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology	EN ISO 12100-1	-
ISO 16392	-	Tyres - Electrical resistance - Test method for measuring electrical resistance of tyres on a test rig	-	-
ISO 21178	-	Light conveyor belts - Determination of electrical resistances	EN ISO 21178	-
ISO 21179	-	Light conveyor belts - Determination of the electrostatic field generated by a running light conveyor belt	EN ISO 21179	-
ISO 21183-1	-	Light conveyor belts - Part 1: Principal characteristics and applications	EN ISO 21183-1	-
ASTM D257	-	Standard Test Methods for DC Resistance or Conductance of Insulating Materials	-	-
ASTM D2624-07a	-	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels	-	-
ASTM D4308-95	-	Standard Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter	-	-
ASTM E582-88	-	Standard test method for minimum ignition energy and quenching distance in gaseous mixtures	-	-
ASTM E2019-03	-	Standard test method for minimum ignition energy of a dust cloud in air	-	-
ASTM F150	-	Standard Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring	-	-
ASTM F1971	-	Standard Test Method for Electrical Resistance of Tires Under Load On the Test Bench	-	-
BS 5958-1	-	Code of practice for control of undesirable static electricity - Part 1: General considerations	-	-
BS 5958-2	-	Code of practice for control of undesirable static electricity - Part 2: Recommendations for particular industrial situations	-	-
BS 7506-2	-	Methods for measurements in electrostatics -- Part 2 Test methods	-	-

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
DIN 51412-1	-	Testing of petroleum products; determination - of the electrical conductivity - Part 1: laboratory method		-
DIN 51412-2	-	Testing of petroleum products; determination - of the electrical conductivity - Part 2: field method		-
-	-	Resilient floor coverings - Determination of the electrical resistance	EN 1081	-
-	-	Protective clothing - Electrostatic properties - Part 3: Test methods for measurement of charge decay	EN 1149-3	-
-	-	Protective clothing - Electrostatic properties - Part 5: Material performance and design requirements	EN 1149-5	-
-	-	Rubber and plastic hoses and hose assemblies for measured fuel dispensing systems - Specification	EN 1360	-
-	-	Rubber hoses and hose assemblies for aviation fuel handling - Specification	EN 1361	-
-	-	Non-electrical equipment for use in potentially explosive atmospheres - Part 1: Basic method and requirements	EN 13463-1	-
-	-	Thermoplastic and flexible metal pipework for underground installation at petrol filling stations	EN 14125	-
-	-	Conveyor belts for use in underground installations - Electrical and flammability safety requirements	EN 14973	-
ISGOTT	2006	International Safety Guide for Oil Tankers and Terminals (ISGOTT), fifth edition, International chamber of shipping, 2006	-	-
JNIOOSH TR 42		Recommendations for Requirements for Avoiding Electrostatic Hazards in Industry	-	-
NFPA 77	-	Recommended practice on static electricity	-	-
SAE J1645	-	Surface vehicle recommended practice - Fuel systems and Components - Electrostatic Charge Mitigation	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES –

Part 32-1: Electrostatic hazards, guidance

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 60079-32-1, which is a technical specification, has been prepared by IEC Technical Committee 31: Equipment for explosive atmospheres, and IEC Technical Committee 101: Electrostatics.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
31/1033/DTS	31/1076/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60079 series, under the general title *Explosive atmospheres*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

transformed into an International standard,
reconfirmed,
withdrawn,
replaced by a revised edition, or
amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This IEC Technical Specification is based on CENELEC TR 50404:2003, *Code of practice for the avoidance of hazards due to static electricity* and a number of other documents:

- from the UK: BS 5958, Parts 1 & 2:1991, *Control of undesirable static electricity*,
- from Germany: TRBS 2153:2009, *Preventing risks of ignition due to electrostatic charges*,
- from Shell International Petroleum: *Static electricity – Technical and safety aspects*,
- from the US: NFPA 77, *Recommended Practice on Static Electricity (2007)*,
- from Japan: JNIOOSH TR42, *Recommendations for Requirements for Avoiding Electrostatic Hazards in Industry (2007)*,
- from ASTM, EUROPIA, IEC, International chamber of shipping, ISO etc.

It gives the best available accepted state of the art guidance for the avoidance of hazards due to static electricity.

This document is mainly written for designers and users of processes and equipment, manufacturers and test houses. It can also be used by suppliers of equipment (e.g. machines) and flooring or apparel when no product family or dedicated product standard exists or where the existing standard does not deal with electrostatic hazards.

A second part, IEC 60079-32-2, *Electrostatic Hazards, Tests*, is under development.

EXPLOSIVE ATMOSPHERES –

Part 32-1: Electrostatic hazards, guidance

1 Scope

This part of IEC 60079 gives guidance about the equipment, product and process properties necessary to avoid ignition and electrostatic shock hazards arising from static electricity as well as the operational requirements needed to ensure safe use of the equipment, product or process. It can be used in a risk assessment of electrostatic hazards or for the preparation of product family or dedicated product standards for electrical or non-electrical machines or equipment.

The hazards associated with static electricity in industrial processes and environments that most commonly give problems are considered. These processes include the handling of solids, liquids, powders, gases, sprays and explosives. In each case, the source and nature of the electrostatic hazard are identified and specific recommendations are given for dealing with them.

The purpose of this document is to provide standard recommendations for the control of static electricity, such as earthing of conductors, reduction of charging and restriction of chargeable areas of insulators. In some cases static electricity plays an integral part of a process, e.g. electrostatic coating, but often it is an unwelcome side effect and it is with the latter that this guidance is concerned. If the standard recommendations given in this document are fulfilled it can be expected that the risk of hazardous electrostatic discharges in an explosive atmosphere is at an acceptably low level.

If the requirements of this document cannot be fulfilled, alternative approaches can be applied under the condition that at least the same level of safety is achieved.

Basic information about the generation of undesirable static electricity in solids, liquids, gases, explosives, and also on people, together with descriptions of how the charges generated cause ignitions or electrostatic shocks, is given in the annexes and in IEC/TR 61340-1.

This Technical Specification is not applicable to the hazards of static electricity relating to lightning or to damage to electronic components.

This Technical Specification is not intended to supersede standards that cover specific products and industrial situations.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

☐ A1 IEC 60079-0:2011 ☐ A1, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60079-20-1, *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*

Ⓐ₁ IEC 60079-32-2:2015 Ⓐ₁, *Explosive atmospheres – Part 32-2: Electrostatic hazards – Tests*

IEC 60093, *Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials*

IEC 60167, *Methods of test for the determination of the insulation resistance of solid insulating materials*

IEC 61340-2-3, *Electrostatics – Part 2-3: Methods of test for determining the resistance and resistivity of solid planar materials used to avoid electrostatic charge accumulation*

IEC 61340-4-1, *Electrostatics – Part 4-1: Standard test methods for specific applications – Electrical resistance of floor coverings and installed floors*

IEC 61340-4-3, *Electrostatics – Part 4-3: Standard test methods for specific applications – Footwear*

IEC 61340-4-4:2012, *Electrostatics – Part 4-4: Standard test methods for specific applications – Electrostatic classification of flexible intermediate bulk containers (FIBC)*

ISO 284, *Conveyor belts – Electrical conductivity – Specification and test method*

ISO 6297, *Petroleum products – Aviation and distillate fuels – Determination of electrical conductivity*

ISO 8031, *Rubber and plastics hoses and hose assemblies – Determination of electrical resistance*

ISO 9563, *Belt drives; electrical conductivity of antistatic endless synchronous belts; characteristics and test method*

ISO 12100-1, *Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology*

ISO 16392, *Tyres – Electrical resistance – Test method for measuring electrical resistance of tyres on a test rig*

ISO 21178, *Light conveyor belts – Determination of electrical resistances*

ISO 21179, *Light conveyor belts – Determination of the electrostatic field generated by a running light conveyor belt*

ISO 21183-1, *Light conveyor belts – Part 1: Principal characteristics and applications*

ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*

ASTM D2624-07a, *Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels*

ASTM D4308-95, *Standard Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter*

ASTM E582-88, *Standard test method for minimum ignition energy and quenching distance in gaseous mixtures*

ASTM E2019-03, *Standard test method for minimum ignition energy of a dust cloud in air*

ASTM F150, *Standard Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring*

ASTM F1971, *Standard Test Method for Electrical Resistance of Tires Under Load On the Test Bench*

BS 5958: *Code of practice for control of undesirable static electricity*
Part 1: *General considerations*
Part 2: *Recommendations for particular industrial situations*

BS 7506, *Methods for measurements in electrostatics – Part 2 Test methods*

DIN 51412-1, *Testing of petroleum products; determination of the electrical conductivity, laboratory method*

DIN 51412-2, *Testing of petroleum products; determination of the electrical conductivity; field method*

EN 1081, *Resilient floor coverings – Determination of the electrical resistance*

EN 1149-3, *Protecting clothes – Electrostatic properties – Part 3: Test method for measuring the charge dissipation*

EN 1149-5, *Protective clothing – Electrostatic properties – Part 5: Material performance and design requirements*

EN 1360, *Rubber and plastic hoses and hose assemblies for measured fuel dispensing systems – Specification*

EN 1361, *Rubber hoses and hose assemblies for aviation fuel handling – Specification*

EN 13463-1, *Non-electrical equipment for potentially flammable atmospheres – Part 1: Basic principles and general requirements*

EN 14125, *Underground pipework for petrol filling stations*

EN 14973, *Conveyor belts for use in underground installations – Electrical and flammability safety requirements*

International Safety Guide for Oil Tankers and Terminals (ISGOTT), fifth edition, International chamber of shipping, 2006.

JNIOOSH TR 42, *Recommendations for Requirements for Avoiding Electrostatic Hazards in Industry*

NFPA 77, *Recommended practice on static electricity*

SAE J1645, *Surface vehicle recommended practice – Fuel systems and Components – Electrostatic Charge Mitigation*

3 Terms and definitions

For the purposes of this document the following terms and definitions apply:

3.1

antistatic

conductive or dissipative

Note 1 to entry: Used to describe a material that is incapable of retaining a significant electrostatic charge when in contact with earth. In this context the word is commonly used to describe a type of footwear and antistatic additives (ASAs) for use with liquids.

Note 2 to entry: Preferred term is conductive or dissipative depending on which is correct.

3.2

conductive

having a resistivity or resistance below the dissipative range (see 3.7) allowing stray current arcs and electrostatic shocks to occur

Note 1 to entry: Conductive materials or objects are neither dissipative nor insulating and are incapable of retaining a significant electrostatic charge when in contact with earth.

Note 2 to entry: Boundary limits for the conductive range are given for solid materials, enclosures and some objects in 6.1 (Table 1), and for bulk materials in 9.1. For certain items, special definitions are maintained in other standards (see 3.3, 3.8 and 3.9).

Note 3 to entry: Product standards and other standards covering electrostatic properties often include specific definitions of “conductive” which apply only to items covered by those standards and may be different to the definitions given here. See e.g. ISO 8031 and ISO 8330 for hose and hose assemblies.

3.3

conductive footwear

footwear ensuring that a person standing on a conductive floor has a resistance to earth low enough to ensure dissipation of electrostatic charges even in particularly hazardous situations (e.g. when handling sensitive explosives) but not high enough to prevent a hazardous electrical shock at voltages less than 500 V

Note 1 to entry: See IEC 61340-4-3 and IEC 61340-4-5.

3.4

conductivity

electrical conductivity

reciprocal of volume resistivity, expressed in siemens per meter

3.5

conductor

conductive object

3.6

contaminated liquid

liquid containing more than 0,5 % by volume of free water or other immiscible liquids or more than 10 mg/l of suspended solids

3.7

dissipative electrostatic dissipative

having an intermediate resistivity or resistance that lies between the conductive and insulating ranges (see 3.2 and 3.15)

Note 1 to entry: Dissipative materials or objects are neither conductive nor insulating but, like conductive items, safely limit contact charging and/or dissipate even the maximum charging currents associated with their designed application when in contact with earth.

Note 2 to entry: Boundary limits for the dissipative range are given for solid materials, enclosures and some objects in Table 1, and for bulk materials in 9.1. For certain items, special definitions are maintained in other standards (see 3.3, 3.8 and 3.9).

Note 3 to entry: Product standards often include specific definitions of “dissipative” which apply only to items covered by those standards and may be different to the definitions given here.

3.8

dissipative clothing

clothing that meets the material and design requirements specified in EN 1149-5

3.9

dissipative footwear

footwear ensuring that a person standing on a conductive or dissipative floor has a resistance to earth low enough to ensure dissipation of electrostatic charges but high enough to prevent a hazardous electrical shock at voltages less than 500 V

Note 1 to entry: See IEC 61340-4-3 and IEC 61340-4-5.

Note 2 to entry: Antistatic footwear as described in ISO 20345 may fulfil this function.

3.10

electrostatic shock

pathophysiological effect resulting from an electric current caused by an electrostatic discharge passing through human or animal body

3.11

enclosure

all the walls, doors, covers, cable glands, rods, spindles, shafts, coatings etc. which surround and enclose equipment

Note 1 to entry: For electrical equipment, the enclosure is likely to be identical to the enclosure defined in IEC 60079-0.

Note 2 to entry: Containers, e.g. drums and FIBC, are not equipment enclosures and, therefore, are considered separately in 9.6.

3.12

hazardous area

area in which flammable or explosive gas/vapour-air or dust-air mixtures or aerosols are, or can be, present in such quantities as to require special precautions against ignition

Note 1 to entry: See IEC 60079-10-1 and IEC 60079-10-2. A short summary is given in Annex D.

3.13

high charging

a process that generates a higher rate of electrostatic charging than simple manual operations

EXAMPLE Rubbing, cleaning with a cloth, raising from a seat, walking, wiping of clothes etc.

Note 1 to entry: Typical examples of high charging operations include e.g. the flow of insulating liquids or powders and high voltage spray charging.

3.14

hybrid mixture

an explosible heterogeneous mixture, comprising gas or vapour with suspended particulate solid or liquid, in which the total flammable gas concentration is at least 10 % of its lower flammable limit (LFL) and the total suspended particulate concentration is at least 10 % of its minimum explosible concentration (MEC)

3.15

insulating

having a resistivity or resistance that is higher than the dissipative range (see 3.7)

Note 1 to entry: Insulating materials or objects are neither conductive nor dissipative. Electrostatic charges can accumulate on them and do not readily dissipate even when they are in contact with earth.

Note 2 to entry: Boundary limits for the insulating range are given for solid materials, enclosures and some objects in Table 1, for bulk materials in 9.1. For certain items, special definitions are maintained in other standards (see 3.3, 3.8 and 3.9).

Note 3 to entry: Product standards and other standards covering electrostatic properties often include specific definitions of “insulating” which apply only to items covered by those standards and may be different to the definitions given here. See e.g. ISO 8031 and ISO 8330 for hose and hose assemblies.

Note 4 to entry: The adjective “non-conductive” has often been used as a synonym for insulating. It is avoided in this document as it could be taken to mean either “insulating” or “insulating or dissipative” and this may lead to confusion.

3.16

isolated conductor

conductive object which can accumulate charge due to an earth leakage resistance exceeding the values given in Table 22

3.17

leakage resistance resistance to earth

resistance expressed in ohms between an electrode in contact with the surface to be measured and earth

Note 1 to entry: The resistance depends upon the volume or surface resistivity of the materials and the distance between the chosen point of measurement and earth.

Note 2 to entry: One common configuration (e.g. in IEC 61340-4-1, ISO 10965 and ASTM F150) uses a circular electrode, (65 ±5) mm in diameter.

3.18

minimum ignition energy

MIE

minimum energy that can ignite a mixture of a specified flammable material with air or oxygen, measured by a standard procedure

Note 1 to entry: See ASTM E582-88 for gases and vapours, IEC 61241-2-3, ASTM E2019-03 and EN 13821 for dust clouds.

3.19

multiphase liquid

mixture of immiscible liquids that form separate phases with a distinct interfacial boundary, and solids suspended in liquids, and gas bubbles suspended in liquids

Note 1 to entry: Liquid-in-gas suspensions (mists or sprays) are covered separately.

3.20

relaxation time

time during which the electrostatic charge on a solid surface or in the bulk of a liquid or powder decays exponentially to 1/e (i.e. about 37 %) of its original value (see A.2.2)

Note 1 to entry: For high charge generation with high resistivity liquids, relaxation may be hyperbolic rather than exponential.

3.21

surface resistance

resistance expressed in ohms between two electrodes in contact with the surface to be measured

Note 1 to entry: One common configuration (e.g. in IEC 60079-0 and IEC 60167) uses parallel electrodes, 100 mm long and 10 mm apart)

Note 2 to entry: The surface resistance is dependent upon the electrode configuration. The surface resistance measured with the example electrode configuration is ten times lower than the surface resistivity.

Note 3 to entry: Soft conductive rubber strip electrodes are preferred over silver paint electrodes.

3.22

surface resistivity

resistance across opposite sides of a surface of unit length and unit width commonly expressed in ohms (or ohms/square)

Note 1 to entry: This configuration is used e.g. in ASTM D257 and BS 7506-2.

3.23

volume resistivity

resistance of a body of unit length and unit cross-sectional area expressed in ohm metres

4 Nomenclature

Electrostatic safety regulations use many adjectives to classify the conducting ability of materials and objects. Different regulations and different industries use different adjectives and, even when the same adjectives are used, their definitions can vary. The nomenclature that is systematically followed in this document is given here in order to avoid confusion and to assist with translation:

Solid materials are classified as conductive, dissipative or insulating according to their volume resistivity (see 3.2, 3.7 and 3.15). Boundary limits are given in Table 1.

Solid objects and **textiles** are classified as conductive, dissipative or insulating according to their surface or leakage resistance, depending on application (see 3.2, 3.7 and 3.15). Boundary limits for enclosures and some objects are given in Table 1. For certain items, special definitions are maintained in other standards (see 3.3, 3.8 and 3.9).

Bulk materials (powders etc.) are classified as low, medium or high resistivity according to their volume resistivity (see 9.1 for boundary limits).

Liquids are classified as high, medium or low conductivity according to their electrical conductivity (see 7.1.4 for boundary limits).

NOTE More details about electrostatic properties, concepts and terms are given in Annexes A to G.

Resistances have mainly been stated in exponential form in other documents. However, exponents are small figures, and the exponents 6, 8 and 9 mainly used in electrostatics are easily misread in printed or projected documents, and even unreadable if they occur in notes. For this reason this document uses SI prefixes instead of exponents:

$$10^3 \Omega = 1 \text{ k}\Omega$$

$$10^6 \Omega = 1 \text{ M}\Omega$$

$$10^8 \Omega = 100 \text{ M}\Omega$$

$$10^9 \Omega = 1 \text{ G}\Omega$$

$$10^{11} \Omega = 100 \text{ G}\Omega$$

$$10^{12} \Omega = 1 \text{ T}\Omega$$

Current is, for the same reasons, also given in SI prefixes instead of exponents:

$$10^{-3} \text{ A} = 1 \text{ mA}$$

$$10^{-6} \text{ A} = 1 \mu\text{A}$$

$$10^{-9} \text{ A} = 1 \text{ nA}$$

$$10^{-12} \text{ A} = 1 \text{ pA}$$

5 General

Static electricity occurs commonly in industry and daily life. Many of the effects are harmless and either pass completely unnoticed or are simply a nuisance, but static electricity can also give rise to a hazardous situation. In such situations, the hazard can generally be reduced by charge relaxation (see Annex A).

Hazards caused by electrostatic charge include:

- a) ignition and / or explosion of flammable atmospheres, see IEC 60079-0 and EN 13463-1;
- b) electrostatic shock in combination with another hazard (e.g. fall, trip) – see ISO 12100-1;
- c) electrostatic shock giving rise to injury or death, see ISO 12100-1;
- d) damage to electronics (not covered by this document).

In addition, static electricity can introduce operational problems during manufacturing and handling processes, e.g. by causing articles to adhere to each other, or by attracting dust.

Static electricity is generated by:

- a) the contact and separation of solids e.g. the movement of conveyor belts, plastics film, etc. over rollers, the movement of a person;
- b) the flow of liquids or powders, and the production of sprays;
- c) induction phenomena, i.e. objects reach high potential or become charged due to being in an electric field.

The accumulation of electrostatic charge can give rise to hazards and problems in a wide range of industries and working environments, and to ignition and explosion hazards particularly in chemicals, pharmaceuticals, petroleum and food processing industries.

Because of the large number of industrial processes that could be involved it is not possible to give detailed information relevant to all of them. Instead, this document attempts to describe the problems associated with each process, and to give advice on how to avoid them. This information should enable the plant operator to take whatever precautions could be necessary to avoid ignitions of potentially flammable atmospheres and electrostatic shocks.

For convenience this document is divided into a number of clauses. These deal with problems associated with the following:

- a) the handling of solids;
- b) the storage and handling of liquids;
- c) the handling of gases and vapours;
- d) the storage and handling of powders;
- e) the storage and handling of explosives

- f) electrostatic problems caused by people;
- g) avoidance of electrostatic shock;
- h) earthing and bonding of plant and machinery;
- i) measuring methods.

This document also contains some fundamental information relating to electrostatic charging and its problems. This is contained in Annexes A to G and it should enable the reader to better understand the advice given and also to extend the advice to processes that have not been dealt with in the guidance.

As this document is very complex, correctly evaluating the electrostatic hazards of products and processes may not be easy for new readers. For this reason a universally applicable informative Annex F has been appended which references the relevant sections of this document in the correct order.

It is very seldom that an electrostatic hazard can be treated by itself. Precautions against electrostatic hazards should be in addition to other precautions, e.g. explosion protection. They should also be consistent with precautions taken to avoid other hazards that may be present, such as ignitions due to other causes, and toxicity. It is important that all sources of risk in a system of work are considered and that a balanced approach to safety that covers all risks is adopted. In particular, care should be exercised in the provision of earthing systems where they can interfere with other protective systems, e.g. cathodic protection or intrinsically safe electrical equipment.

6 Static electricity in solid materials

6.1 General considerations

Solid materials are usually characterised as insulating, dissipative or conductive according to their volume resistivity. Enclosures are usually classified according to their surface resistance or resistivity (measured according to IEC 60079-0, IEC 60167, IEC 60093 or IEC 61340-2-3 or equivalent methods). Measuring details will also be dealt with in IEC 60079-32-2². The two surface classifications are equivalent because the surface resistivity is ten times higher than the surface resistance for the specified electrode geometries. For other specific applications different definitions may be applicable (e.g. leakage resistance in the case of floors). The thresholds most commonly used for these purposes are shown in Table 1.

² To be published.

Table 1 – Boundary limits at $(23 \pm 2) ^\circ\text{C}$ and $(25 \pm 5) \% \text{RH}$ for the characterisation of solid materials and examples for the classification of objects

Object	Unit	See subclause	Conductive	Dissipative ^a	Insulating ^a
Material	Volume Resistivity ($\Omega \text{ m}$)	6.2.1	$< 100 \text{ k}\Omega \text{ m}$	$100 \text{ k}\Omega \text{ m to } < 1 \text{ G}\Omega \text{ m}$	$\geq 1 \text{ G}\Omega \text{ m}$
Enclosure	Surface Resistance (Ω)	6.2.1	$< 10 \text{ k}\Omega$	$10 \text{ k}\Omega \text{ to } < 100 \text{ G}\Omega$	$\geq 100 \text{ G}\Omega$
	Surface Resistivity (Ω)	6.2.1	$< 100 \text{ k}\Omega$	$100 \text{ k}\Omega \text{ to } < 1 \text{ T}\Omega$	$\geq 1 \text{ T}\Omega$
Clothes	Surface Resistance, (Ω)	11.5	Not available	$< 2,5 \text{ G}\Omega$	$\geq 2,5 \text{ G}\Omega$
Footwear	Leakage resistance (Ω)	11.3	$< 100 \text{ k}\Omega$	$100 \text{ k}\Omega \text{ to } < 100 \text{ M}\Omega$	$\geq 100 \text{ M}\Omega$
Gloves	Leakage resistance (Ω)	11.6	$< 100 \text{ k}\Omega$	$100 \text{ k}\Omega \text{ to } < 100 \text{ M}\Omega$	$\geq 100 \text{ M}\Omega$
Floor	Leakage resistance (Ω)	11.2	$< 100 \text{ k}\Omega$	$100 \text{ k}\Omega \text{ to } < 100 \text{ M}\Omega$	$\geq 100 \text{ M}\Omega$
Pipes	Resistance per length (Ω/m)	7.7.2.1	$< 1 \text{ k}\Omega/\text{m}$	$1 \text{ k}\Omega/\text{m to } < 1 \text{ M}\Omega/\text{m}$	$\geq 1 \text{ M}\Omega/\text{m}$
Hoses^b	Resistance per assembly (Ω)	7.7.3.1	$< 1 \text{ k}\Omega$	$1 \text{ k}\Omega \text{ to } < 1 \text{ M}\Omega$	$\geq 1 \text{ M}\Omega$
^a Where local ambient conditions are significantly different from the stated worst case test condition of $(23 \pm 2) ^\circ\text{C}$ and $(25 \pm 5) \% \text{RH}$, other test conditions may be used after a careful hazard evaluation. In some countries, especially during winter, a relative humidity of $(12 \pm 3) \%$ at $(23 \pm 2) ^\circ\text{C}$ is an appropriate test environment for qualifying equipment. As the resistance of non-metals usually depends strongly on the measuring voltage, the measuring voltages (typically 500 to 1 000 V) should be chosen to be consistent with the purpose of the measurement and stated with the test result. ^b According to ISO 8031, the values for hoses are measured at $(50 \pm 5) \% \text{RH}$ and are the latest ones taken from Table 15 in 7.7.3.1. In the past, slightly different values have been used in ISO and CENELEC documents. Other classifications may be used by industry standards for specific applications (e.g. in ISO 8031 conductive hoses for industry applications, dissipative antistatic hoses for automobile applications) which does not necessarily imply electrostatic safety.					

Enclosure criteria are to prevent tribo-charging and thus do not necessarily dissipate charge deposited from unspecified processes within the enclosure.

Different values measured at 50 % RH have been applied in the past in the absence of a dehumidified test chamber and are considered to err on the safe side. This approach has now been discontinued, and limits at 50 % RH are, except for hoses, given in other documents only. They should only be used if an appropriate climate is not available. As the chargeability of materials is higher at 20 % RH compared to 30 % RH, the former value of 30 % RH has been reduced to $(25 \pm 5) \% \text{RH}$. A relative humidity at the lower part of the interval should be applied during measurements whenever possible.

When characterizing non-homogenous materials the measured values should be averaged and rounded to the nearest order of magnitude unless otherwise specified by the test method. Non-homogeneous materials may exhibit different resistivity in different directions

Instead of measuring resistance, the rate of charge decay may be used to characterize the dissipative behaviour of clothing (see EN 1149-3 and EN 1149-5).

Electrically insulating solid materials are commonly used in many forms, including pipes, containers, sheets, coatings and liners. The use of electrically insulating solid materials in hazardous areas can give rise to many electrostatic hazards, in particular:

- a) conductive objects could be isolated from earth by the material and could then reach a high electrical potential and give rise to sparks (see A.3.2);
- b) charges on the surface of the material could lead to brush discharges (see A.3.4);
- c) a combination of conductive and insulating materials in the presence of prolific charge generators (see 12.3) could lead to energetic propagating brush discharges (see A.3.5).

Measures to address these hazards are given in 6.2, 6.3 and 6.4.

If insulating materials are used, a risk assessment is necessary to identify if there is any process that can lead to direct production of or indirect induction of electrostatic charging on insulated materials that are present in the location.

6.2 The use of conductive or dissipative materials in place of insulating ones

6.2.1 General considerations

It is generally good practice to minimise the use of insulating materials in hazardous areas. While this may be achieved primarily by the use of inherently conductive materials (e.g. metals), many materials which used to be available only in insulating forms (e.g. rubbers or plastics) are now available in grades which meet the requirements to be considered conductive or dissipative as given in Table 1. This increase in conductivity is typically achieved either by adding conductive ingredients (e.g. carbon black) to its composition, or by applying hygroscopic agents to its surface that attract atmospheric moisture – conductive polymers, laminates with conductive elements and metallised films have all been developed for improved static dissipation.

It is important that such conductive and dissipative materials are earthed reliably according to Clause 13 and are long lasting according to Clause 13. Also, if conductive or dissipative coatings are used to make an insulating material non-chargeable, it is important that such coatings are properly earthed, and that their durability and suitability for use in hazardous areas (particularly Zone 0 and Zone 1) is demonstrated for the particular application.

Another consideration is that the use of a high proportion of additives such as carbon black may degrade the physical properties (primarily strength and chemical resistance) of the material. This may render such materials unsuitable for certain applications. This can be avoided by using intrinsically conductive polymers as a conducting ingredient or coating. Care should be taken to ensure sufficiently high concentrations of dissipative additives and their uniform distribution.

NOTE It is not possible to determine whether materials may be dissipative or conductive by their colour. Black polymers may not be dissipative, and modern conductive or dissipative materials may be available in a variety of colours.

Fabrics, e.g. filter cloth, can be made dissipative by incorporating stainless steel or other conductive or dissipative fibres in the fabric. Care has to be taken to ensure that, as a result of washing or mechanical stress, the overall conductivity of the fabric is maintained and isolated patches of conductive fibres are not formed.

6.2.2 Dissipative solid materials

A solid material is defined as dissipative if its surface resistance, surface resistivity or volume resistivity meet the combined criteria set out in 6.1.

In general, providing that dissipative materials are connected to earth according to Clause 13, no further protective measures need to be taken. However, in processes involving high speed separation (e.g. conveyor and transmission belts, see 6.4) lower resistivities and resistances can be required.

NOTE 1 For materials with resistivities at the top end of the dissipative range there will be significant constraints on the possible geometry of a manufactured item if the requirements of Clause 13 are to be met (e.g. long pipes or thin filaments will not meet the earthing requirements whilst thin sheets with a large earth contact area will).

In some cases, particularly with plastic films or sheeting, a material is added to attract atmospheric moisture to the surface, thus increasing surface conductivity. Care should be taken where this type of dissipative plastic film or sheeting is used in low humidity conditions: in environments with low humidity (typically <30 %), it can become insulating and accumulate electrostatic charge.

It should be ensured that a dissipative coating cannot be washed away or rubbed off and cannot lose its effectiveness over time. Otherwise such a coating would only be appropriate as a temporary measure to reduce accumulation of static electric charge.

Dissipative agents used in packaging should be compatible with the product contained within the package. Absorption of the dissipative agents by product with which it is in contact may cause product contamination and / or loss of dissipative properties of the package.

NOTE 2 New static dissipative additives are available which increase the volume resistivity and are, therefore, less sensitive to humidity but are also affected by aging as are other additives.

NOTE 3 The resistance of dissipative materials made from rubber vulcanized with carbon black may increase with decreasing temperature. Such materials may, for example, be dissipative ($\sim 100 \text{ M}\Omega$) at 20°C but insulating ($\sim 10 \text{ T}\Omega$) at 0°C .

6.2.3 Earthing of conductive and dissipative items

All metal and other conductive or dissipative material should be connected to earth according to Clause 13 with the exception of very small items. The capacitance of isolated items depends on their size, surrounding materials and proximity to other conductors and may be very different under installed or non-installed conditions. The maximum allowable capacitance of isolated items depends on the ignitability of the gases, vapours and dust expressed by the representative gas groups I, IIA, IIB and IIC (IEC 60079-20-1, see D.3) or dust group III (IEC 60079-0) and the classification of the hazardous area (IEC 60079-10-1 and IEC 60079-10-2, see D.2) as shown in Table 2, taking account of the following:

- a) Capacitances below 3 pF need not be earthed provided that the object cannot reach a hazardous potential and is not situated in Zone 0 when gases or vapours belonging to Group IIC are used.
- b) In Zone 1 where gases or vapours belonging to Group IIA are used, and in Zones 20 and 21 the maximum allowed isolated capacitance may be increased to 6 pF provided high charging processes do not occur.
- c) In dust Zones 20 and 21 and in Group I the maximum allowed isolated capacitance may be further increased to 10 pF provided that either high charging processes do not occur or only powders with minimum ignition energies higher than 10 mJ are handled.
- d) The limits in Table 2 are not absolute values that prevent incendive discharges, but they merely reduce the risk of occurrence to a generally accepted low level.
- e) Hand held devices and hand tools are expected to be earthed via the user. In any case of doubt the user should ensure earthing of the device when working in hazardous areas.
- f) People are conductive items having sufficient capacitance to produce an incendive discharge. They, therefore, should be earthed according to Clause 11 before entering a hazardous area Zone 0, 1, 20, 21 or Group I.

Capacitances should be measured according to IEC 60079-0, 26.15.

NOTE It is scheduled to revise this method and move it to IEC 60079-32-2³.

³ To be published.

Table 2 – Maximum allowed isolated capacitance in Zones with explosive atmosphere

	Group I	Group IIA	Group IIB	Group IIC	Group III	Additional condition
Zone 0	10 pF	3 pF	3 pF	No isolated conductive objects allowed	-	No high charging processes
Zone 1		6 pF	3 pF	3 pF	-	
Zone 2		No requirements if charging processes capable of generating hazardous potentials are unlikely to occur during normal operation including maintenance and cleaning			-	
Zones 20,21 MIE < 10 mJ		-	-	-	6 pF	
Zones 20,21 MIE > 10 mJ		-	-	-	10 pF	
Zone 22		-	-	-	No requirements if charging processes capable of generating hazardous potentials are unlikely to occur during normal operation including maintenance and cleaning	
NOTE 1 The subdivisions are based on the maximum experimental safe gap (MESG) or the minimum ignition current ratio (MIC ratio) of the explosive gas atmosphere in which the equipment may be installed (see IEC 60079-20-1). More details can be found in C.6 and D.3.						
NOTE 2 Manual rubbing is usually not considered to be a high charging process.						

For dissipative materials with a surface resistance exceeding 10 GΩ earthing may not be necessary. In any case of doubt an additional test is necessary to prove electrostatic safety of unearthed objects (e.g. 6.3.9).

6.3 Precautions required when using insulating solid materials

6.3.1 General

The restrictions on the use of insulating materials in hazardous areas depend on the classification of the hazardous area according to IEC 60079-10-1 and IEC 60079-10-2:

- in Zone 0, insulating solid materials should only be used if charging processes capable of generating hazardous potentials will not occur either during normal operation including maintenance and cleaning or even in the case of rare malfunctions;
- in Zone 1, insulating solid materials should only be used if charging processes capable of generating hazardous potentials will not occur either during normal operation including maintenance and cleaning or in the case of likely malfunctions;
- in Zone 2, insulating solid materials should only be used if charging processes capable of generating hazardous potentials are unlikely to occur during normal operation including maintenance and cleaning.
- in Zones 20, 21 and 22 consideration should be given to spark, brush, cone, and propagating brush discharges (see A.3). However, practical experience, experimental evidence and the absence of incidents indicate that brush discharges do not ignite even ignition sensitive powder clouds in the absence of any flammable gas or vapour.

NOTE 1 Synthetic fabrics used in cloths for cleaning or wiping can develop sufficient static electric charge to produce discharges capable of igniting solvent vapours. Typically, charge generation increases with the speed and vigour of the wiping action. The material being cleaned or wiped, if insulating, also can accumulate sufficient charge to produce an incendive discharge. Cotton or synthetic fabric treated with a static dissipative compound may be required if static electric charge generation needs to be controlled, especially if flammable insulating solvents are being used for cleaning or wiping.

NOTE 2 The presence of contamination (e.g. grease or moisture) may affect the potential ignition hazard when using insulating materials.

NOTE 3 Conductive solids, objects or liquids may form hazardous isolated conductive islands if present on charged insulating surfaces.

In addition, to prevent incendive discharges the precautions given in 6.3.2 to 6.3.4 should be taken in all Zones where the use of insulating solid materials is unavoidable. The precautions given in 6.3.2 to 6.3.4 relate to the avoidance of incendive brush discharges, that given in 6.3.4 also relates to propagating brush discharges.

6.3.2 Restrictions on the size of chargeable insulating surfaces

Where the use of chargeable insulating material in a hazardous area is necessary, the maximum allowable size of insulating surface depends on the ignitability of the gases and vapours expressed by the representative groups I, IIA, IIB, IIC (IEC 60079-20-1) or the representative dust group III (IEC 60079-0) and the classification of the hazardous area (IEC 60079-10-1 and IEC 60079-10-2, see D.2) as shown in Table 3, taking account of the following:

- a) for sheet materials the area is defined by the exposed (chargeable) area;
- b) for curved or irregularly shaped objects the area is the projection of the object giving the maximum area;
- c) for long narrow materials, such as cable sheaths or pipes, the maximum size is defined by the transverse dimension (i.e. the diameter for a cable sheath or pipe); although when it is coiled it should be treated as for a sheet;
- d) even smaller diameters can be required for narrow pipes or tubes containing flowing liquids or powders;
- e) normal electric cables are usually acceptable in all zones. See IEC 60079-14. Very thick insulating layers on thick cables should, however, be tested experimentally e.g. according to IEC 60079-0:2007, 26.14.

NOTE It is scheduled to revise this method and move it to IEC 60079-32-2⁴.

It is essential that non-conductive solid materials used in hazardous areas do not exceed the maximum area or width values given in Table 3 for the zone within which it is used unless it can be experimentally shown that hazardous electrostatic charges are not to be expected (see 6.3.9) or charging mechanisms will not occur at any time. An example of the last-named case is signs or lamps at the ceiling which are normally not exposed to any charging mechanisms. In this case, a warning "Clean with a water-wet cloth only and allow to dry naturally" is sufficient to avoid charging when cleaning.

⁴ To be published.

Table 3 – Restriction on size of insulating solid materials in hazardous areas

Zone	Group I		Group IIA		Group IIB		Group IIC		Group III	
	Max area (mm ²)	Max width (mm)	Max area (mm ²)	Max width (mm)	Max area (mm ²)	Max width (mm)	Max area (mm ²)	Max width (mm)	Max area (mm ²)	Max width (mm)
0	10 000	30	5 000	3	2 500	3	400	1	-	-
1			10 000	30	10 000	30	2 000	20	-	-
2			No size limit (but see 6.3.1)		No size limit (but see 6.3.1)		No size limit (but see 6.3.1)		-	-
20 21 22	-	-	-	-	-	-	-	-	No size limit (but see 6.3.1)	

NOTE 1 The width criterion applies to thin pipes, cable sheaths, and other insulating materials having small widths or diameters.

NOTE 2 Equipment marked IIB is suitable for applications requiring Group IIA equipment. Similarly, equipment marked IIC is suitable for applications requiring Group IIA or Group IIB equipment.

NOTE 3 These border limits are also used e.g. in IEC 60079-0, CENELEC TR 50404, TRBS 2153, JNIO SH TR42, and BS 5958.

NOTE 4 The subdivisions are based on the maximum experimental safe gap (MESG) or the minimum ignition current ratio (MIC ratio) of the explosive gas atmosphere in which the equipment may be installed (see IEC 60079-20-1). More details can be found in C.6 and D.3.

NOTE 5 The limits in Table 3 are not absolute values that prevent incendive discharges, they merely reduce it to a generally accepted low level.

NOTE 6 The present state of knowledge indicates that there is no ignition risk due to brush discharges in the case of sensitive dusts providing that there are no flammable gases or vapours (see Annex A.3.4). However, charge generation processes stronger than manual rubbing may create incendive propagating brush discharges under certain circumstances (see 6.3.4.2).

6.3.3 Earthed metal meshes

The areas given in Table 3 can be increased by a factor of four by incorporating an earthed mesh (or metal frame) into the insulating solid or by wrapping such a mesh around its surface. In addition:

- the layer thickness above the mesh should be restricted to the values given in 6.3.4.2 to prevent brush discharges; and
- propagating brush discharges should be prevented according to 6.3.4.3; and
- special care should be taken to prevent or detect breaks which could lead to isolated conductive parts which present a greater electrostatic hazard than an insulating surface.

6.3.4 Insulating coatings on earthed conductive surfaces

6.3.4.1 General

Layers or coatings of insulating solids on earthed conductive surfaces (in particular metal surfaces) can give rise to brush and / or propagating brush discharges depending on several factors.

6.3.4.2 Avoidance of brush discharges

With regard to brush discharges, practical experience shows that these discharges are unlikely to be incendive if:

- high electrostatic charging processes are avoided (e.g. repeated filling and emptying of a conductive drum containing an insulating liner); and,

- b) the thickness of the layer does not exceed a value of 2 mm in the case of gases and vapours of groups I, IIA and IIB and a value of 0,2 mm in the case of gases and vapours of group IIC. For dusts there is no thickness limitation unless the powder layer can form a high resistance continuous film, e.g. by self-polymerization or reaction with water.

NOTE 1 Manual rubbing is usually not considered to be a high charging process.

NOTE 2 The thinner the coating the less incensive are the brush discharges created by manual rubbing of the surface, and the more incensive are the propagating brush discharges created by stronger electrostatic charging processes on the surface.

In those cases no special protective measures are necessary within hazardous areas. However, in the case of fluorinated polymers an experimental evaluation of the chargeability is recommended, e.g. according to IEC 60079-0:2007, 26.14.

NOTE It is scheduled to revise this method and move it to IEC 60079-32-2⁵.

6.3.4.3 Avoidance of propagating brush discharges

Propagating brush discharges can occur when high or repeated electrostatic charging processes act on insulating layers or coatings on conductive surfaces. These discharges can be prevented by one or more of the following measures:

- a) Avoid having thin insulating coatings on metals or other conductive materials. Propagating brush discharges tend to occur with thin coatings; they can normally be prevented by having thicknesses greater than 10 mm;
- b) Reduce the surface or volume resistivity of the coating. It is not known precisely what levels are required to prevent the occurrence of propagating brush discharges, but the values for dissipative materials given in Table 1 and a leakage resistance less than 100 GΩ are known to be sufficiently low;
- c) Use a coating with a low dielectric strength (breakdown voltage for solid homogenous materials less than 4 kV, in the case of woven fabrics 6 kV, see A.3.5). Such coatings electrically break down before a propagating brush discharge can develop. The dielectric strength should be measured according to IEC 60243-2 in combination with IEC 60243-1, or IEC 60079-32-2⁵.
- d) Avoid high or repeated charging processes (e.g. air ions in the vicinity of high voltage electrodes, high speed flowing liquids and pneumatic transfer of powders, and paper or plastic foils transported by machines).

NOTE 1 Due to their slight porosity, layers of solvent or water based paint or loose powder usually have a low breakdown voltage so that propagating brush discharges are difficult to obtain from such layers.

NOTE 2 Coatings formed by baking on an applied powder and enamel usually have too high a breakdown voltage to avoid propagating brush discharges.

NOTE 3 Polymer films which are wound on to a reel or are lifted from a conductive or insulating surface can acquire bipolar charges i.e. equal and opposite charges on the two surface of the film. This can lead to brush discharges and occasionally even to propagating brush discharges.

NOTE 4 Manual rubbing is not normally considered a high charging process.

6.3.5 Conductive or dissipative coatings on insulating materials

Special care is necessary when applying a conductive or dissipative coating on an insulating surface to ensure a uniform distribution of the conductive particles. Non-uniform distribution may lead to isolated conductive islands which can be charged easily by insulated surfaces in their vicinity. Such isolated conductive islands present a greater electrostatic hazard than an insulating surface.

Conductive coatings should be earthed as other conductors in accordance with Clause 13.

⁵ To be published.

6.3.6 Static dissipative agents

Dissipative antistatic agents are frequently used on clothing and floors and to increase the conductivity of liquids and materials. Care should be taken to guarantee the presence of a sufficient concentration of these agents to achieve the desired function. For example, dissipative agents may become diluted or washed out. Therefore, their effectiveness needs to be monitored and maintained. Non-migratory permanent antistatic polymer additives have recently been developed to overcome these limitations.

6.3.7 Humidification

The surface resistivity of some insulating solid materials can be reduced to dissipative levels if the relative humidity is maintained above about 65 %. Even though damp air is not conductive, water / moisture may adsorb on the surface of many materials depending on the hygroscopic nature of the material. This may be sufficient to prevent accumulation of static electricity, provided there is a suitable path to earth.

However, whereas the surface of some materials (e.g. glass or natural fibres) can adsorb enough moisture to ensure a surface conductivity that is sufficient to prevent accumulation of static electricity, other materials do not (e.g. polytetrafluoroethylene or polyethylene) and are capable of accumulating a static electric charge even at high relative humidity. Also, when the humidity falls below about 30 %, materials which are susceptible to humidification generally return to being highly insulating. Increasing the relative humidity, therefore, is not effective in all cases and, in general, it should not be used as the sole protective measure. This is particularly important in Zone 0.

6.3.8 Ionisation / Charge Neutralisation

6.3.8.1 General

Ionisation of the air is a method of making the air locally ion-rich so that charges on insulating solid materials can be neutralised. It is particularly useful for neutralising charge on insulating plastic sheets or films. Methods that may be employed include those given in 6.3.8.2 to 6.3.8.5. Neutralisation cannot succeed if the rate at which charge is generated exceeds the rate at which ions are supplied to the air, or can migrate to the charged surface, or if sufficient ions of the desired polarity are not present. Consequently, correct installation and regular maintenance is essential for those devices, taking into consideration factors that can influence their effectiveness such as environmental conditions (e.g. dust and temperature) and positioning of the device in relation to the material processed, machine parts, and people.

The reduction of charge at any one point in the operation does not prevent generation of charge in later steps of the process, so ionisers may be required at a number of locations. Positioning is important, and effectiveness of individual installations should be confirmed by field measurement of residual charge or voltage. In particular, for films and sheets it is necessary to ensure that ions are directed at the correct side to avoid forming a bipolar layer which could give rise to propagating brush discharges.

Corona points remain functional only as long as they are clean and sharp. Accumulation of contaminants (e.g. ink, coating solution, or paper dust) and corrosion products should be controlled by an effective maintenance program.

Ionisers should be selected by their charge generation rate or by their charge decay time. They should not be used in Zone 1, IIC unless the risks have been evaluated by an expert. Furthermore they should not be used in Zone 0 as the only safety measure.

6.3.8.2 Passive ionisers

Pointed electrodes such as earthed sharp needles, fine wires or conductive tinsel produce corona discharges when placed in the electric field from a highly charged surface. These provide ions which neutralize the charge on the body. This method, however, is limited to

effectiveness and may, in addition produce discharges if passive ionisers are not properly earthed.

6.3.8.3 Active ionisers

Active ionisers produce ions by applying a high voltage to a number of corona points. Commercial systems commonly use alternating voltages in the range 5 kV to 10 kV. The use of a high voltage power supply eliminates the limitation of passive neutralizers in control of charges having fields below the corona onset threshold. The currents from the corona points are limited either by high resistance or capacitive coupling.

Active ionisers should be suitable for the location in which they are used and should be designed and constructed to prevent being a possible source of ignition. They require careful design to ensure that the supply of ions is balanced with the requirements of the process.

6.3.8.4 Radioactive / soft x-ray ionisers

Radioactive and soft x-ray sources ionise the surrounding air and can be used to dissipate the charges from a charged body. Such ionisation itself does not present an ignition hazard but is, however, limited in its effectiveness (performance deteriorates with the decay of the radioactive material).

6.3.8.5 Ionised air blowers

Ionised air blowers using either high voltages or radioactive sources are used mainly for dissipating charges from awkwardly shaped objects. However, the ion concentration can rapidly decrease downstream due to recombination or adsorption of the ions by the walls. As a result, it is difficult to convey the ionised air over large distances. The parts containing the high voltages should be placed in a non-hazardous area unless they have been appropriately certified.

NOTE The function of an ioniser can be tested by the method described in IEC 61340-4-7.

6.3.9 Methods to determine the incendivity of discharges

If the requirements in 6.3.2 to 6.3.8 are not applicable, an experimental determination of a value for the incendivity of possible discharges may be helpful.

One method is to charge the sample under worst case conditions as highly as possible (at least to the maximum level that could occur in service) to provoke discharges to an earthed sphere approaching and to pass such provoked discharges through gas mixtures of known MIE value. This method is described in IEC 61340-4-4.

The maximum charge transferred by a discharge is often used to give an indication of the incendivity of spark and brush discharges instead of using an explosive gas mixture. This method is described in IEC 60079-0:2007, 26.14. Table 4 shows a summary of all applicable threshold limits.

NOTE It is scheduled to revise this method and move it to IEC 60079-32-2⁶.

Special care should be taken to ensure that the test sample is charged as highly as possible, that induced charges are compensated for and that only one single discrete discharge is recorded.

⁶ To be published.

Table 4 – Maximum acceptable transferred charge

Explosion Group	EPL Ma EPL Mb Mining	EPL Ga Zone 0	EPL Gb Zone 1	EPL Gc Zone 2	EPL Da Zone 20	EPL Db Zone 21	EPL Dc Zone 22
I	60 nC	-	-	-	-	-	-
IIA	-	25 nC	60 nC	60 nC	-	-	-
IIB	-	10 nC	25 nC	25 nC	-	-	-
IIC	-	No measurabl edischarge	10 nC	10 nC	-	-	-
III	-	-	-	-	60 nC ^a	200 nC ^a	200 nC ^a

^a Values only valid for spark discharges from unearthed conductive or dissipative parts

NOTE 1 The limits for Zone 1 and Zone 21 ensure that incendive discharges should not occur during normal operation. The limits for Zone 0 and 20 are further reduced to account for abnormal situations and the high level of safety required for these zones.

NOTE 2 For the explanation of EPL see IEC 60079-0 or Annex E.

NOTE 3 All of the values contain a certain safety margin. Recent work indicates that the value hitherto used for IIB contains a lower safety margin than all other values. To equalize all safety margins the values for IIB have been reduced from 30 nC to 25 nC.

6.4 Conveyor belts and transmission belts

6.4.1 General

Belts used for transmission of power or the transportation of solid materials can generate a considerable amount of charge and become an ignition hazard due to the continuous separation of the contacting surfaces (primarily a driving shaft and a belt). The amount of charge acquired depends on the material of the conveyor belt as well as the materials of the driving shaft and the rollers, and increases with the velocity and tension of the belt and the width of the area of contact.

The charge acquired by the belt can only be safely dissipated to earth via the earthed conductive rollers if the conveyor belt is sufficiently dissipative. Material that is spilled from the end of a conveyor belt into a hopper or chute can carry a significant charge. Conductive or dissipative belts cannot be expected to remove charge from an insulating conveyed product.

6.4.2 Conveyor belts

Conveyor belts are endless belts which run over rollers (usually metallic) and transport materials. A conveyor belt is considered to be dissipative if

- the surface resistances on both sides of the belt are below 300 MΩ measured according to ISO 284 and EN 14973, or
- the surface resistances on both sides of the belt are below 75 MΩ measured with the electrode configuration in 3.21, or
- in cases where the belt consists of layers of different materials the belt is considered to be dissipative if the resistance (measured at 23 °C and 50 % relative humidity) between the two opposite outer surfaces is below 1 GΩ.

NOTE Surface resistances measured according to ISO 284 and EN 14973 are at (23 ± 2) °C and (50 ± 5) % relative humidity and with an inner circular electrode of 25 mm in diameter, outer ring electrode with 125 mm inner and 150 mm outer diameter. Surface resistances measured with the electrode configuration described in 3.21 are exactly four times lower.

Table 5 shows a summary of all measures that are required for conveyor belts according to the classification of the hazardous area according to IEC 60079-10-1 and IEC 60079-10-2.

Table 5 – Requirements for conveyor belts

Belt Speed	Zone 0	Zone 1		Zone 2	Zone 20		Zone 21	Zone 22
		IIC	IIA & IIB		MIE <10 mJ	MIE >10 mJ		
≤0,5 m/s	Dissipative ^a belt and conductive pulleys, no belt connectors		Dissipative ^a belt and conductive pulleys, belt connectors permitted	No requirements beyond those outlined in 6.4.1 unless experience shows that incendive discharges occur frequently	Dissipative ^a belt and conductive pulleys, belt connectors permitted		No requirements beyond those outlined in 6.4.1 unless experience shows that incendive discharges occur frequently	
0,5 – 5 m/s	Not permitted				Not permitted	Dissipative ^a belt and conductive pulleys, no belt connectors		
5 – 30 m/s		Dissipative ^a belt and conductive pulleys, no belt connectors						

^a dissipative according to the definition of 6.4.2

NOTE No information is available for belt velocities >30 m/s.

For explosion Group I, the requirements of Zone 1 (IIA & IIB) apply. However, insulating coal dust conveyors transporting hardly ignitable conductive coal dust and similar conveyors may be used if a risk assessment provides a low risk of ignition.

Table 5 and the requirements in 6.4.2 do not apply to belts which dissipate charge by corona. Such belts have to be tested by experts e.g. by measuring their chargeability under worst case conditions.

A layer of wax or dirt on the belt could increase the chargeability of the belt and also its resistance and this could increase the charging hazard. Care should be taken to ensure that repairs do not increase the values given. It is essential that layers of insulating adhesives used to connect the belt do not interrupt the conductive path.

Light conveyor belts as described in ISO 21183-1 frequently have to comply with highly specialised customer's demands. For these cases, the specific standards ISO 21178, *Light conveyor belts – Determination of electrical resistances* and ISO 21179, *Light conveyor belts – Determination of the electrostatic field generated by a running light conveyor belt* exist and shall be used.

6.4.3 Transmission belts

Transmission belts are V-belts and flat belts which drive rotating parts or machines. The amount of charge acquired by the belt due to the continuous separation of the contacting surfaces depends on the material of the belt and pulleys and increases with the velocity and tension of the belt and the width of the contact area. According to ISO 9563 and ISO 1813 a transmission belt material is deemed to be dissipative if:

$$R \times B / L \leq 600 \text{ k}\Omega$$

where L is the distance between two conductive electrodes (e.g. graphite, silver paint, metal electrode) on a transmission belt, B is the width of the flat belt or double the width of the side face of the V-belt, and R the measured resistance between the electrodes at $(23 \pm 2) ^\circ\text{C}$, with no moisture condensation.

NOTE In older documents (e.g. CENELEC TR 50404), the acceptance criteria was $R \times B \leq 100 \text{ k}\Omega \text{ m}$, where R is the resistance measured at the inner side of the mounted transmission belt between an electrode halfway between the two pulleys and earth and B is the width of the flat belt or double the width of the side face of the V-belt.

fulfilment of this $R \times B$ criterion depends on the distance between the two pulleys it is impossible to characterise a belt material as dissipative. For this reason ISO 9563 and ISO 1813 give a dissipative criteria which is independent from the length of the belt. If the distance between two pulleys exceeds 0,67 m the requirements of both ISO standards are automatically fulfilled by the $R \times B$ criterion in older documents stated above.

Table 6 shows a summary of all measures that are required according to the classification of the hazardous area according to IEC 60079-10-1 and IEC 60079-10-2:

Table 6 – Requirements for transmission belts

Belt Speed	Zone 0	Zone 1		Zone 2	Zone 20		Zone 21	Zone 22
		IIC	IIA & IIB		MIE < 10 mJ	MIE > 10 mJ		
≤ 0,5 m/s	Dissipative ^a belt and conductive pulleys, no belt connectors	Not permitted	Dissipative ^a belt and conductive pulleys, belt connectors permitted	Protective measures beyond those outlined in 6.4.1 not required unless experience shows that incendive discharges occur frequently	Dissipative ^a belt and conductive pulleys, belt connectors permitted			Protective measures beyond those outlined in 6.4.1 not required unless experience shows that incendive discharges occur frequently
0,5 – 5 m/s	Dissipative ^a belt and conductive pulleys, no belt connectors							
5 – 30 m/s	Not permitted		Dissipative ^a belt and conductive pulleys, no belt connectors		Not permitted	Dissipative ^a belt and conductive pulleys, no belt connectors		
^a dissipative according to the definition in 6.4.3								
NOTE No information is available for belt velocities >30 m/s.								

For explosion Group I, the requirements of Zone 1 (IIA & IIB) apply.

Table 6 and the requirements in 6.4.3 do not apply to belts which dissipate charge by corona. Such belts have to be tested by experts e.g. by measuring their chargeability under worst case conditions.

In cases where the belt consists of layers of different materials the belt is considered to be dissipative if the resistance across it does not exceed 1 GΩ (resistance measured at 23 °C and 50 % relative humidity).

A layer of wax or dirt on the belt could increase the chargeability of the belt and also its resistance and this could increase the charging hazard. Care should be taken to ensure that repairs do not increase the values given. It is essential that layers of insulating adhesives used to connect the belt do not interrupt the conductive path.

7 Static electricity in liquids

7.1 General considerations

7.1.1 Occurrence of flammable atmospheres

NOTE General information about the flammability and ignitability of gas and vapour atmospheres is given in Annex C.

Many operations with flammable liquids produce flammable atmospheres by evaporation of the liquid being handled. The flash point provides an approximate indication of the minimum liquid surface temperature required to produce a flammable atmosphere by this process. However, because of the uncertainties involved in flash point measurement, differences between flash point test conditions and those in a real industrial situation and the

establishing liquid surface (rather than bulk) temperature, it is prudent to assume that a flammable atmosphere could exist even when the liquid temperature is below the flash point by a certain safety margin. The margin depends on the level of uncertainty about temperature, liquid composition etc. For well-controlled conditions a margin of 5 °C for pure liquids and at least 11 °C for mixtures is typically needed.

Where tanks are exposed to direct sunlight and liquid temperatures are not monitored it should be assumed that a flammable atmosphere could be present when handling liquids with flash points up to 60 °C. In areas of high ambient temperature and strong sunlight, flammable atmospheres may occur even with liquids that have flash points above 60 °C.

When handling a liquid at a temperature that is well above its flash point, the saturated vapour may give an over-rich (i.e. non-flammable) atmosphere. However, the actual atmosphere above the liquid may not be saturated (e.g. because of ventilation) and so may be flammable. It is therefore necessary to assume that the atmosphere could be flammable unless it can be shown otherwise. Consequently, for low flash-point liquids, the presence of an over-rich atmosphere should not generally be relied upon as the only control measure.

In some circumstances, the flammable atmosphere is not due to the liquid being handled but due to residues of volatile liquid or vapour from earlier operations with the same equipment or from nearby operations. Residual vapours can occur during switch loading, in which a liquid having a high flash point (e.g. diesel) is loaded into a tank which previously contained a liquid with a low flash point (e.g. gasoline). A high proportion of road tanker fires has been associated with switch-loading.

7.1.2 Ignition sensitivity and limitations to the scope of advice

The sensitivity of a flammable atmosphere to electrostatic ignition depends on the concentration and minimum ignition energy (MIE – see C.6) of the flammable material. A helpful rule of thumb is that the most easily ignitable vapour concentration is approximately double the concentration at the lower flammable limit. Because of the concentration effect, a mixture made with a high MIE material at its most easily ignitable concentration may be more sensitive to ignition than a mixture made with a low MIE material at a vapour concentration that lies only just within the flammable range.

For equilibrium vapour/air mixtures created by flammable liquids, the most easily ignitable vapour concentration is typically achieved at temperatures of approximately 10 °C to 20 °C above the flashpoint. Flammable liquids of intermediate volatility tend to produce their most easily ignitable mixtures at common ambient temperatures: such liquids include toluene (flashpoint 6 °C), propyl acetate (flashpoint 10 °C) and acetonitrile (flashpoint 2 °C).

The general precautions given in this chapter are designed to prevent the ignition of materials with MIEs of 0,20 mJ or more when present at the most easily ignitable vapour concentration. They are thus applicable to the most easily ignitable mixtures in air of the vapours of common flammable liquids such as paraffinic and aromatic solvents, hydrocarbon fuels and many organic solvents (see list of MIE in Table C.2). At typical ambient temperatures, the safety margins are at a minimum when handling flammable liquids of intermediate volatility such as those listed above. In such operations, particular care should therefore be taken to ensure that all recommended precautions are diligently followed.

Although Explosion Groups are not assigned on the basis of MIE (see C.6), the precautions required in the presence of most Explosion Group IIA vapours are likely to be similar to those given here for MIEs of 0,20 mJ and above. Additional precautions are, however, likely to be required where the atmosphere above the liquid is more sensitive to ignition. This situation will arise, for example, with the most readily ignitable mixtures in air of volatile materials that have MIEs of less than 0,20 mJ (most Explosion Group IIB and IIC materials) or with oxygen-rich mixtures. Although general advice has not been developed for these more sensitive atmospheres, recommendations are given for a few specific activities. Where they are given, the additional precautions for the more sensitive materials are explicitly identified as such in the text.

7.1.3 Charging mechanisms

Liquids can become electrostatically charged when they move relative to contacting solids or if there are two or more immiscible liquid phases and there is movement. The spraying of liquids can also create a highly charged mist or spray. Further details of charge generation and charge accumulation in liquids are given in A.1.3 to A.1.7 (generation) and A.2.2 (accumulation).

7.1.4 Charge accumulation and conductivity classifications

The level of charge accumulation in a particular liquid, and therefore the electrostatic hazard that can be created, is strongly dependent upon its electrical conductivity and dielectric constant (relative permittivity), ϵ_r . To describe the possible hazards and associated means of prevention, the conductivities of liquids have been classified as follows:

high conductivity	$> 10\,000 \text{ pS/m}$;
medium conductivity	between $25 \times \epsilon_r \text{ pS/m}$ and $10\,000 \text{ pS/m}$;
low conductivity	$< 25 \times \epsilon_r \text{ pS/m}$.

For liquids with a dielectric constant of around 2, (e.g. hydrocarbons), these classifications reduce to:

high conductivity	$> 10\,000 \text{ pS/m}$;
medium conductivity	between 50 pS/m and $10\,000 \text{ pS/m}$;
low conductivity	$< 50 \text{ pS/m}$.

For liquids with a dielectric constant that is substantially higher than 2 or for liquids whose dielectric constant is unknown, the border limit for low conductivity is usually set to 100 pS/m . The upper border limit of medium conductivity remains at $10\,000 \text{ pS/m}$.

NOTE 100 pS/m is considered sufficient for unknown cases because few, if any, low conductivity liquids have a relative permittivity significantly higher than 4.

Hazardous levels of charge accumulation are most commonly associated with liquids of low conductivity. However, they can occur with medium or high conductivity liquids in processes that produce mists or sprays, when transporting medium conductivity liquids through insulating pipes or during two-phase mixing operations.

In general, polar solvents such as alcohols, ketones and water have a high conductivity, while saturated hydrocarbon liquids and purified aromatics have a low conductivity. The conductivities and relaxation times for a number of liquids are given in Table 7.

NOTE 1 A more complete list including a wider range of liquids and dielectric constant data is given in NFPA-77.

NOTE 2 Biofuels and hydrocarbon fuels blended with biocomponents can have a wide range of conductivity depending on their composition.

NOTE 3 Test methods for measuring the conductivity of a liquid are given in e.g. ASTM D4308-95, DIN 51412-1, DIN 51412-2 and ISO 6297.

Table 7 – Conductivities and relaxation times of some liquids

Liquid	Conductivity (pS/m)	Relaxation time (seconds)
Low conductivity		
highly purified paraffins	0,01	2 000
typical paraffins	0,1 to 10	2 to 200
purified aromatic compounds (toluene, xylene etc.)	0,1 to 10	2 to 200
typical aromatic compounds	5 to 50	0,4 to 4
gasoline	0,1 to 100	0,2 to 200
kerosene	0,1 – 50	0,4 to 200
gas oil	1 to 100	0,2 to 20
white oils	0,1 to 100	0,2 to 200
lubricating oils	0,01 to 100	0,02 to 2 000
ethers except glycols	0,1 to 100	0,2 to 200
proprietary aromatic solvent mixtures	1 to 1 000	0,02 to 20
natural gas condensate without corrosion inhibitor	10 to 100	0,2 to 2
Medium conductivity		
gasoline containing performance additives or 5 % ethanol	50 to 1 000	0,02 to 0,4
fuels and oils containing dissipative additives	50 to 1 000	0,02 to 0,4
heavy (black) fuel oils	50 to 10 000	2×10^{-4} to 0,4
esters	100 to 1 000 000	2×10^{-5} to 0,2
High conductivity (μ S/m)		
crude oil	$\geq 0,001$	$\leq 0,02$
gasoline containing 10 % ethanol or more	$\geq 0,01$	$\leq 0,002$
natural gas condensate with corrosion inhibitor	$\geq 0,001$	$\leq 0,02$
glycols and glycol ethers	1 to 100	2×10^{-7} to 2×10^{-5}
alcohols	1 to 100	2×10^{-7} to 2×10^{-5}
ketones	0,1 to 100	2×10^{-7} to 2×10^{-4}
pure water	5	10^{-6}
water (not distilled)	≥ 100	$\leq 2 \times 10^{-7}$
NOTE Although ketones and esters usually have a high conductivity middle- and long-chained ketones and esters are often highly chargeable		

A liquid of high or medium conductivity should be considered as a conductive or dissipative item and needs to be earthed.

7.1.5 Incendive discharges produced during liquid handling operations

When a tank is being filled with a charged liquid of low conductivity, the charge that accumulates in the liquid inside the tank creates electrical fields and potentials both in the liquid and in the vapour space of the tank. With high liquid surface potentials, brush discharges can occur between the surface of the charged liquid and metallic parts of the tank structure. Studies indicate that aliphatic hydrocarbons such as propane can be ignited by brush discharges to a grounded electrode if the liquid surface potential exceeds 25 kV.

An ignition hazard can arise at much lower potentials (typically 5 kV to 10 kV) if isolated conductors such as floating metal cans or improperly bonded components are present in the tank, or if the container has an insulating lining, no contact point for earthing the liquid, and is splash filled with a liquid that is sufficiently conductive to produce sparks.

7.2 Summary of precautions against ignition hazards during liquid handling operations

7.2.1 Earthing and avoidance of isolated conductors

Isolated conductors such as metal tanks, tank structures or any other isolated metal objects either deliberately or accidentally associated with liquid handling can be raised to high potentials by charges on the liquid. This can lead to spark discharges. These are particularly hazardous because they can usually ignite flammable vapours at much lower potentials than brush discharges. Therefore, all conductive parts of a liquid handling system should be adequately connected to earth (see Clause 13). People handling flammable liquids should also be earthed (see 11.1).

Tanks should be regularly inspected to ensure there are no loose, unbonded conductive objects, e.g. a can, floating on the liquid.

7.2.2 Restricting charge generation

Charge generation can be restricted by controlling the relevant process parameters. Suitable control measures include:

- 1) tank filling operations:
 - a) restrict the linear flow velocity in the feeding line of the tank by restricting the pumping rate or by increasing the diameter of the feeding line (see 7.3.2.2.3 and 7.3.2.3.2 to 7.3.2.3.5);
 - b) provide sufficient residence time for charge relaxation downstream of pumps and filters (see 7.5 and A.2.2);
 - c) avoid having a dispersed second immiscible phase in the liquid; this can be caused, for example, by stirring up the water present in the bottoms of oil tanks. Where the avoidance of a second dispersed phase is not possible restrict the velocity further (see 7.3.2.2.2 and 7.3.2.3.5.3);
 - d) avoid splash filling by employing bottom entry or by using a fill pipe extending close to the bottom of the tank. If a short, top-entry fill-pipe must be used in the presence of a flammable atmosphere, reduce the flow velocity to 2 m/s and take the additional precautions in 7.3.2.3.2 (e.g. direct the liquid flow along the container wall). In the case of high conductivity liquids it is sufficient to provide a contact area to earth in the bottom of the container.
- 2) stirring or agitating operations (see 7.9):
 - a) limit the power input to or tip speed of the stirrer (e.g. in BS 5958, a maximum power of 0,37 kW/m³ was required for a suspension with a conductivity of 1 000 pS/m);
 - b) avoid the presence of a second immiscible phase in the liquid;
 - c) use a high conductivity continuous phase (conductivity exceeding 10 000 pS/m).
- 3) tank cleaning operations with liquid jets (see 7.10):
 - a) limit the liquid pressure and throughput of the washing machines to the values recommended in 7.10;
 - b) avoid the build-up of a second immiscible phase in the washing liquid, particularly if the washing liquid is recirculated;
 - c) avoid unbroken jets that may form large isolated volumes of liquid (see 7.10).

7.2.3 Avoidance of a flammable atmosphere

The most effective way of avoiding ignition hazards is to prevent the occurrence of a flammable atmosphere, for example:

- a) avoid vapour spaces in the system;
- b) inert the vapour space of the tank using inert gases such as nitrogen, carbon dioxide or purified flue gas (note the precautions given in 8.4);
- c) avoid switch loading and common vapour collection systems that allow ignitable vapour-air mixtures to enter tanks not designed for this service;
- d) after handling volatile liquids, clean and ventilate tanks to remove residual flammable liquids, gases and vapours;
- e) ensure that sufficient fresh air is drawn continuously through the system. Regular gas tests and possible forced ventilation may be necessary;
- f) purging a tank with air to avoid a flammable atmosphere should be done with caution in a tank that contains, or has previously contained, a flammable liquid with a low flash point due to the risk of residual liquid being present.

7.2.4 Promoting charge dissipation

In situations where it is not possible to avoid a flammable atmosphere, the risk of ignition can be controlled by limiting charge accumulation. For the components of the handling system, this involves bonding solid conductors and people to ground and, if necessary, replacing insulating system components with earthed dissipative or conductive components. For the liquids themselves, the most effective way of promoting dissipation is to increase the conductivity of the liquid by the use of commercially available static dissipative additives (SDA). When added to a liquid in very low concentrations of the order of parts per million, these additives can readily increase the conductivity to levels that prevent the hazardous build-up of charge (see 7.1.4).

NOTE 1 SDA are widely used in aviation fuels, and at the concentrations normally used the effects on both aircraft engine and filter/water separator performance are acceptable.

NOTE 2 Some SDA may lose efficiency in certain situations, e.g. at low temperatures, after contact with water, after clay filtration or due to interaction with other components.

Alternative methods of enhancing charge dissipation are to replace an insulating (low conductivity) solvent with a more conductive (medium or high conductivity) one or to add a miscible conductive solvent to an insulating one. The amount of conductive solvent needed will depend on the liquids involved and the conductivity level required.

7.3 Tanks and Containers

7.3.1 General

The possible hazards and the associated means of protection are divided according to whether the tanks, or their coatings and linings, are classified as conductive, dissipative or insulating (see 3.2, 3.7 and 3.15). Fully conductive tanks have a resistance to earth of 1 k Ω or less from everywhere on the shell; fully dissipative tanks have a resistance to earth of 1 M Ω or less from everywhere on the shell.

Following this classification, this section is divided into chapters as follows:

Conductive tanks and containers: 7.3.2

Tanks and containers made entirely of dissipative material: 7.3.3

Tanks and containers with insulating surfaces: 7.3.4

Use of liners in containers: 7.3.5

Operations that give rise to electrostatic hazards inside a tank include filling, transportation (of the tank and contents), emptying, gauging and sampling. If there could be a flammable atmosphere inside a tank when carrying out these operations, the precautions given below should be taken.

NOTE If there cannot be a flammable atmosphere (see 7.1.1), the precautions given in 7.3 are not necessary.

Other operations such as circulation of liquid, stirring, mixing, crystallisation and cleaning are dealt with in 7.9 and 7.10.

The standard restrictions on flow velocities given in 7.3.2 primarily apply to hydrocarbons. They may, however, be applied with caution to other solvents and fuels having kinematic viscosities less than about 6 mm²/s at 20 °C but care may be needed with materials such as biofuel components (see C.8) or blends that are chemically different from hydrocarbons and for which there is limited experience of handling in high throughput systems. Further restrictions are known to be necessary for controlling charging in high viscosity liquids such as luboils (see 7.4).

7.3.2 Conductive tanks and containers

7.3.2.1 General

In order to describe the possible hazards and associated means of prevention, conductive tanks have been classified according to size as follows:

	Vertical axis cylindrical tanks and non-cylindrical tanks with square or nearly square cross-section (see NOTE 3)	Horizontal axis cylindrical tanks or non-cylindrical tanks with elongated cross section (see NOTE 3)
Large tanks (7.3.2.2)	diameter > 10 m	capacity > 500 m ³ (125 000 USG)
Medium tanks (7.3.2.3)	1,3 m < effective diameter ≤ 10 m	2 m ³ (500 USG) < capacity capacity ≤ 500 m ³ (125 000 USG)
Small tanks and containers (7.3.2.4)	effective diameter ≤ 1,3 m	capacity ≤ 2 m ³ (500 USG)

NOTE 1 In older documents, e.g. CENELEC TR 50404, the upper limit for medium tanks was 50 m³ and the lower limit 1 m³. Recent work (see A.2.2) has suggested that both the upper and lower boundary limits for medium tanks should be increased and that diameter limits are better than capacity limits for vertical axis tanks (voltages depend more strongly on diameter than capacity). The capacity limits given above for horizontal axis tanks correspond approximately to the diameter limits for vertical axis tanks combined with the lowest typical heights of these tanks.

NOTE 2 The capacity boundary limits are given in both m³ and US gallons. They have been rounded to give convenient numbers in each set of units. As a consequence the boundary values are similar but do not exactly correspond. Either may be adopted at the users discretion.

NOTE 3 “Nearly-square” tanks have a length to width ratio not exceeding 1.5. “Elongated” tanks have a length to width ratio of more than 1.5. The rules given for square tanks are safe for elongated tanks of the same cross-sectional area but may be found to be conservative.

7.3.2.2 Large conductive tanks

7.3.2.2.1 General

Irrespective of the conductivity of the liquid or the tank structure, the following general precautions should be taken:

- earth the tank and all associated structures such as pipes, pumps, filter housings, etc. (see Clause 13);
- ensure that people entering or working near an opening of the tank are earthed (see Clause 11);

- c) avoid splash filling by employing side-entry near the bottom, bottom-entry or by using a fill pipe reaching close to the bottom of the tank.

7.3.2.2.2 Fixed roof tanks

For medium or low conductivity liquids, inspect the tank regularly, especially after each opening of the manhole, for loose metal objects, e.g. cans, that could act as floating isolated conductors.

For low conductivity liquids the following additional precautions are necessary:

- 1) Pump and filter location. Locate pumps, filters and other strong charge generating elements at an adequate residence time upstream of the tank inlet to allow the extra charges to relax before the liquid enters the tank (see 7.5 and A.2.2).
- 2) Restrict the flow velocity. For an incoming flow of uncontaminated, single phase liquid, the flow velocity should be restricted to 1 m/s for an initial filling period that lasts until:
 - a) the fill pipe and any other structure on the base of the tank has been submerged to twice the fill pipe diameter;
 - b) any water which has collected in the pipework has been cleared.

NOTE 1 Restriction a) is designed to prevent discharges to the fill pipe or the structure and to reduce the disturbance of water or sediment.

NOTE 2 For b), it is necessary to wait either for a period of half an hour or until two pipe volumes have been loaded into the tank, whichever is the shorter.

After this initial filling period, the velocity for an uncontaminated, single-phase liquid may be raised above 1 m/s. The maximum safe velocity has not been accurately determined but extensive experience has shown that hazardous potentials do not occur if the velocity is below 7 m/s.

Because of the high charge generation that occurs in two phase flows (see A.1.4) the flow velocity for an incoming two phase or contaminated liquid (see 3.6) should be restricted to 1 m/s during the whole filling period.

- 3) Inlet design. Liquid should enter the tank horizontally to minimise both the possible disturbance to water bottoms or sediment and the jetting of highly charged incoming liquid to the surface. A good arrangement in this respect is to use a horizontal tee or cruciform end to direct the incoming liquid horizontally around the walls.
- 4) Control water bottoms. If there are water bottoms or sediment present in the tank, the level of the bottom layer should be carefully controlled by monitoring and draining to keep it at least two pipe diameters below the inlet. The inlet design requirements described in 3 should then ensure that the water bottom or sediment is not unduly disturbed by the incoming liquid during filling.
- 5) If a flammable atmosphere is present and it cannot be ensured that sediments or water bottoms will not be disturbed, then the velocity should be limited to 1 m/s when filling.

NOTE It is not usually necessary to restrict flow speeds to 1 m/s throughout the fill just because a second phase is present in the form of water bottom or sediment in the tank. The risks associated with water bottoms can normally be dealt with by precautions 3 and 4.

- 6) If it can be avoided, liquid of low density should not be loaded into a tank containing a liquid of substantially higher density, because the resultant buoyancy effect would carry the incoming highly charged liquid to the liquid surface leading to a higher surface potential. For the same reason, loading warmer liquids into tanks partially filled with colder liquids, and entrainment of air or other gas into the incoming liquid should also be avoided where possible. If such operations cannot be avoided, the inlet flow speed should be reduced to 1 m/s to minimise charge generation.

7.3.2.2.3 Tanks with floating roofs or internal floating covers

In a tank with a floating roof or internal floating cover, the flammable atmosphere is shielded from the potentials developing during filling by the floating roof or cover. Therefore, after the initial period of filling and when the roof or cover is afloat there is no need for a restriction on

the flow velocity. However, the velocity should be restricted to 1 m/s until the roof is afloat. To ensure the desired shielding effect, it is essential that the floating roof or internal cover is made from conductive material and is properly earthed (see Clause 13).

Sometimes floating spheres or balls are used in tanks to minimise evaporation. It is essential that they are made of dissipative or conductive material. These spheres should only be used on high conductivity liquids since, on a medium or low conductivity liquid, a ball or a group of balls could become isolated from earth thus leading to the possibility of sparks.

7.3.2.2.4 Summary of precautions for large conductive tanks

Table 8 summarises the precautions necessary for filling large conductive tanks with low conductivity liquids. If the electrical conductivity is raised above the low conductivity range, e.g. by using a static dissipative additive (SDA, see 7.1.4 and 7.2.4), these precautions are not necessary. However, in this case, it is essential to ensure reliable addition of the SDA because failure to incorporate the additive into the liquid could lead to a fire or explosion. The precautions for low conductivity liquids should be retained if there is any doubt about the reliability of the additive addition.

Table 8 – Precautions for filling large conductive tanks with low conductivity liquids

Precautions	Applicability to tank	
	With floating roof or internal cover	With fixed roof, no floating cover
Keep flow velocities below 1 m/s	Essential until the roof or cover is afloat	Essential during the initial filling period, and when loading a contaminated or two phase liquid or a liquid with a substantially lower density than that already in the tank
Keep flow velocities below 7 m/s	Unnecessary when the roof or cover is afloat NOTE A flow rate limit will often be needed to avoid damaging the roof by too rapid movement.	Recommended in all cases in which the 1 m/s limit does not apply
Ensure an adequate residence time between strong charge generators (e.g. microfilters) and the tank	Essential until the roof or cover is afloat NOTE The residence time can be calculated using a velocity of 1 m/s in this instance.	Essential
Avoid disturbing water bottoms with incoming product, entrained air or by blowing out lines with gas	Essential until the roof or cover is afloat	Essential
Avoid charging low density liquids into tanks containing substantially higher density liquids (see 7.3.2.2.1)	Unnecessary	Recommended as far as practicable. If unavoidable keep the flow velocity below 1 m/s (see row 1 of this table)

7.3.2.3 Medium-sized conductive tanks

7.3.2.3.1 Scope

Medium sized conductive tanks (see 7.3.2.1 for size definitions) include both fixed storage tanks and mobile tanks such as road or rail tankers. Although aircraft fuel tanks generally fall within the medium size range, the loading of aircraft tanks is covered separately in 7.8.1.

7.3.2.3.2 Precautions for fixed tanks

7.3.2.3.2.1 Precautions for all types of liquid

- a) Earthing: The earthing requirements given in 7.2.1 and item a) of 7.3.2.2 should be adopted.

- b) Pipes and hoses: Pipes and hoses should comply with 7.7.2 and 7.7.3 respectively.
- c) People: Hazards due to the charging of people should be avoided by compliance with the requirements in Clause 11.
- d) Filling velocity: Flow velocities should be kept within the limits outlined in 7.3.2.3.5.2.

NOTE The flow limits vary with the tank design, pipe diameter and the nature of the liquid.

- e) Air and gas: Do not clear lines with air or other gas unless it is certain that the operation will not overpressure the equipment. Nitrogen or nitrogen-air "mixed gas" should be considered for line clearing rather than compressed air. To avoid excessive flow velocities (relative to the limits given in 7.3.2.3.5.2), use the smallest source pressure that will successfully clear the line. Minimize the volume of entrained gas delivered sub-surface in the receiving tank.
- f) Gauging and sampling: Gauging and sampling can introduce additional hazards. These should be dealt with as described in 7.6.

7.3.2.3.2.2 Additional precautions for low conductivity liquids

- a) Filters and other high charging equipment: Fine filters, pumps and other high charging equipment installed in the pipeline upstream of a tank can generate high levels of charge. To deal with this, follow the advice given in 7.5.
- b) Tank drainage: If the product is not fully miscible with water and it is possible that a water bottom may form (e.g. if the incoming product contains water or if there is dissolved water or contact with moist air and variable water solubility due to temperature cycling), the tank should be provided with a low level drain to enable the water bottom to be removed. The level of the water bottom should be monitored and controlled to keep it below the product inlet by at least two pipe diameters.
- c) Tank inlet: The inlet should be located low in the tank but above the level to which a water bottom will be permitted to accumulate. This can be achieved either by top filling via a fill pipe reaching close to the bottom of the tank or by bottom filling (including side filling close to the bottom). The inlet should be designed to feed incoming liquid horizontally into the tank both to minimise the jetting of highly charge product to the surface and to minimise the disturbance of water bottoms or sediment. A tee-shaped inlet that directs the liquid parallel to the side walls is ideal in this respect.

NOTE For fixed tanks with side entry inlets, the use of a tee is more practical than the deflector plate because it keeps highly charged liquid near the tank base and minimises suspension of any water and sediment from the tank floor.

- d) Splash Filling:
 - For most applications, splash filling should be avoided by using a low level inlet with the incoming flow directed horizontally as described in the previous paragraph (see also 7.2.2).
 - Splash top filling is sometimes essential for process reasons (e.g. to avoid interference with stirrers in chemical reaction vessels). In this case:
 - i) The fill pipe should enter the vessel close to a side-wall and the incoming liquid should be directed downwards and slightly towards the wall (at an angle of 15° to 30° to the vertical).
 - ii) The operation should be assessed in detail to determine an acceptable loading velocity. This should not exceed 50 % of the velocity derived from the normal velocity or v_d limits (see 7.3.2.3.5) and should not be more than 2 m/s.
 - iii) The distance from the end of the fill pipe (and other protrusions) to the maximum liquid level should be at least 200 mm so that discharges from the liquid surface are unlikely to occur.

Flammable liquids of low volatility (e.g. luboils) that are incapable of producing a flammable vapour atmosphere at the maximum handling temperature can be splash filled without the above additional loading restrictions (which are for cases where there could be a flammable atmosphere). However, with this approach it is essential to ensure that there are no other sources of flammable vapour and that the loading

process does not produce enough mist or suspended droplets to render the atmosphere flammable.

7.3.2.3.3 Precautions for road tankers

The precautions for road tankers are the same as for fixed tanks (7.3.2.3.2) except for the use of different velocity limits as described in 7.3.2.3.5.4 and the following additional requirements:

1) Earthing and bonding

- a) The bonding resistance between the chassis, the tank and the associated pipes and fittings on the truck should be less than 1 M Ω . For wholly metallic systems, the resistance should be 10 Ω or less and if a higher value is found further investigations should be made to check for possible problems of e.g. corrosion or loose connection.
- b) An earthing cable should be connected to the truck before any operation (e.g. opening man lids, connecting pipes) is carried out. It should provide a resistance of less than 10 Ω between the truck and the gantry's designated earthing point and should not be removed until all operations have been completed.
- c) It is recommended that the earth cable required in b) be part of a static earth monitoring system that continuously monitors the resistance between the truck and a designated earthing point on the gantry and activates interlocks to prevent loading when this resistance exceeds 10 Ω . It is further recommended that the static earth monitoring system should be capable of differentiating between connection to the truck's tank (or earth connection point) and other metal objects. This type of system will prevent operators from connecting the earthing system to objects (e.g. the mud-guards) that may be electrically isolated from the truck's container.

2) Top loading

- a) The loading arm (or dip leg or drop pipe) should be inserted to the bottom of the tank before starting liquid flow.
- b) The drop pipe should:
 - i) be positioned vertically,
 - ii) reach the bottom of the compartment;
 - iii) have a tee-piece or similar deflector on the bottom to deflect the flow along the base of the compartment.

3) Lightning

When there is the possibility of lightning, road tankers should not be loaded in the open air with a liquid that can give rise to a flammable atmosphere outside the tank compartment. Loading may take place under canopies or where an adequate cone of lightning protection is provided.

7.3.2.3.4 Precautions for rail tankers

The precautions for rail tankers are the same as for fixed tanks (7.3.2.3.2) except for the use of different velocity limits (see 7.3.2.3.5.5) and the following additional requirements:

1) Bonding

- a) The rails of the track should be bonded to each other and to the gantry with a bonding resistance of less than 1 M Ω .
- b) The bonding resistance between the wheels, the tank and the rest of the car should be less than 1 M Ω . Independent bonding of the rail tank car is not needed as it is provided by the rails.

2) Circulating/stray currents

- a) An insulating flange may be installed in the filling line to prevent stray currents. In this case the fill nozzle should be bonded to the rail-car before filling commences.

- b) The siding used for tank car filling should be isolated from the rest of the railway track in order to avoid stray currents. This insulation should not be short circuited by rail equipment or rail cars.

3) Top loading

The loading arm (drop pipe) should be inserted to the bottom of the tank before starting liquid flow. The drop pipe should:

- a) be positioned vertically (automated top loading systems may insert the lance at a slight angle);
- b) reach the bottom of the compartment;
- c) have a tee-piece or similar deflector on the bottom to deflect the flow along the base of the compartment.

4) Lightning

When there is the possibility of lightning, rail tankers should not be loaded in the open air with a liquid that can give rise to a flammable atmosphere outside the tank compartment. Loading may take place under canopies or where an adequate cone of lightning protection is provided.

7.3.2.3.5 Flow velocity and vd limits

7.3.2.3.5.1 General explanatory notes

Flow limits are expressed either directly in terms of velocity or indirectly in terms of limits on the product of velocity and pipe diameter (vd). The key factors that influence these limits are:

- a) The size and shape of the tank: The most critical size tends to lie in the range 3 to 10 m³ and tall, narrow tanks give the highest voltages. Potentials are generally lower in larger or smaller tanks, in horizontally elongated tanks or in tanks for which the length and width (or diameter) are greater than the height.

NOTE Extremely narrow tanks would also give low voltages but the height to width ratios needed to realise this case fall outside the normal practical range.

- b) The presence of a central conductor: In a near-cubic tank (i.e. all major dimensions of similar magnitude), the presence of a substantial conductor running vertically down the centre reduces the maximum potential by about a factor of two. Because of the reduced potential, a higher maximum fill velocity may be permitted. A central conductor is much less effective at reducing potentials in elongated horizontal tanks or tanks with a small height to width ratio. Examples of operations that can benefit from the presence of a central conductor are road tanker top-loading (the filling arm provides the conductor) and road tanker bottom-loading in compartments with dip tubes.
- c) The nature of the liquid: The conductivity is important as is the presence or absence of multiple phases. In addition, the oil industry has found an increased risk of electrostatic ignition when loading vehicles with middle-distillate fuels that have low sulphur content (< 50 ppm).

NOTE The increased risk with low-sulphur diesel is thought to arise fundamentally from factors associated with diesel processing and there is, as yet, no evidence that other low sulphur liquids are similarly affected (e.g. gasolines, pure chemicals or solvents may be low in sulphur but there is no evidence that they have an increased risk of electrostatic ignition).

- d) Whether the tank is fixed or mobile: Filling facilities for fixed tanks can be designed for a specific duty whereas facilities for mobile tanks have to deal with a range of tank sizes and shapes. For mobile tanks, the velocity or vd limit should be suitable for the worst case that could be encountered. Also mobile tanks tend to be elongated horizontally for stability in transit (e.g. rail tanker compartments) whereas fixed tanks are often tall and narrow (height/diameter > 1).

Because of these practical differences, there are separate velocity or vd limits for fixed tanks, road tankers and rail tankers. Also, for both road and rail tankers, there are separate limits for middle-distillate hydrocarbons and other liquids.