Protection Against Electrostatic Hazards in Industrial Installations Safety Guidance ver. 1.1

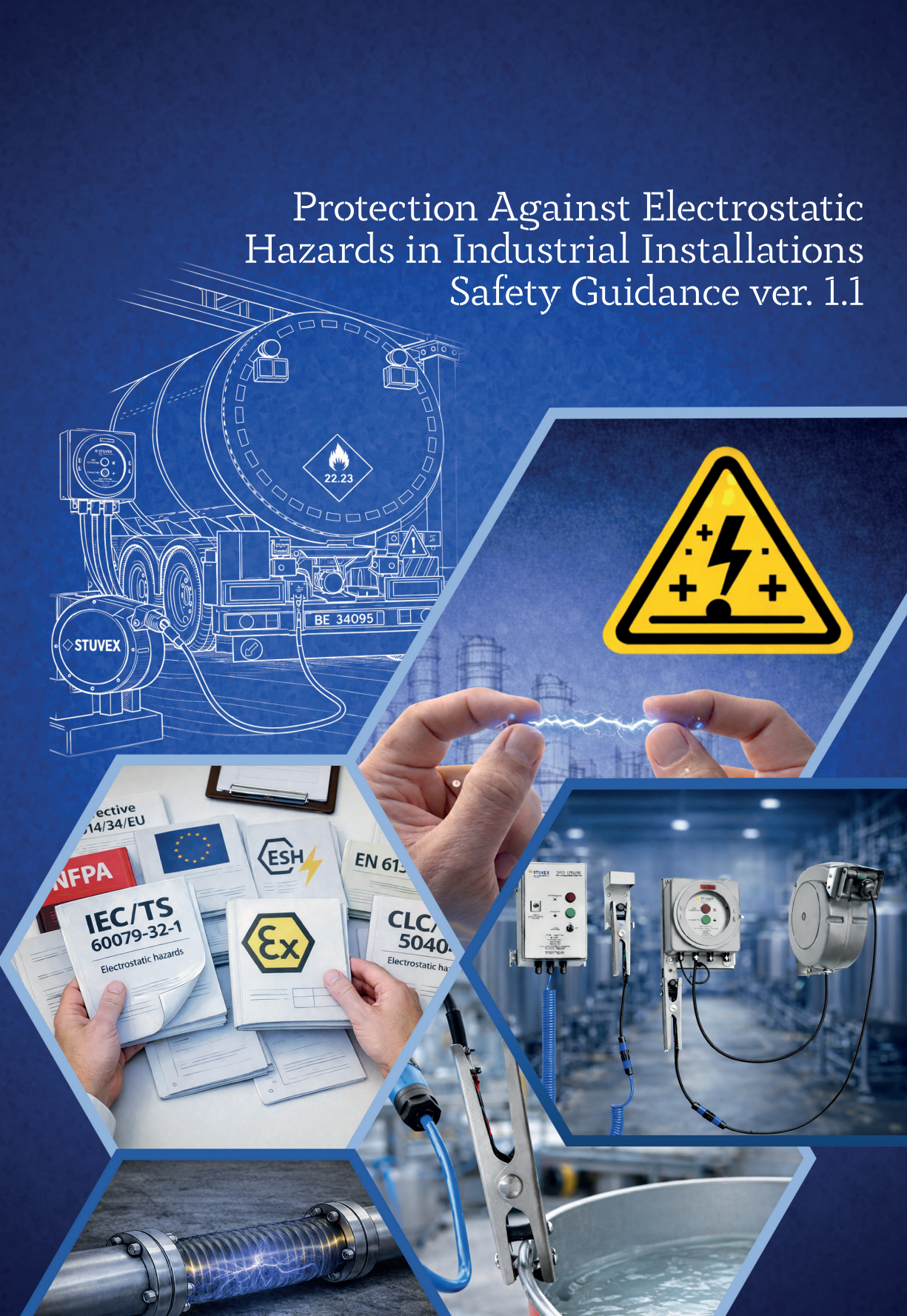


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Purpose and Scope of the Guide

The purpose of this guide is to present the fundamental principles for the design, operation and control of industrial installations in order to reduce the risk of ignition of explosive atmospheres caused by electrostatic discharges.

The document is intended as a **practical technical guide** for:

- maintenance and reliability engineers;
- process and plant designers;
- process technologists;
- safety, ATEX and occupational health and safety specialists;
- internal and external auditors.

The scope of this guide includes:

- technical fundamentals of electrostatic charging mechanisms in industrial processes;
- practical requirements for the grounding and bonding of equipment, vessels, tankers, drums and mobile objects;
- principles for controlling liquid flow velocities and the movement of bulk solids;
- specification of requirements for floors, footwear, clothing and ESH-related equipment;
- application of monitoring systems and process interlocks in cases of ineffective grounding;
- guidance on the use of ionisation, antistatic coatings, FIBC containers and conductive materials;
- description of safe operating practices and requirements for maintenance and verification measurements.

This guide focuses on areas that, in industrial practice, present the **highest electrostatic ignition risk**, and provides recommendations based on applicable standards as well as operational experience gained from ESH audits and incident analyses conducted in industrial installations.

In practice, the recommendations presented here reflect recurring findings from electrostatic safety audits and incident investigations performed in industrial installations operating under ATEX requirements.

Normative basis

1

Matters related to limiting electrostatic hazards in explosive atmospheres are governed by European Union legislation and described in national, European and international standards and technical documents.

1.1. European Union legal acts

The legal framework for explosion protection is based on the ATEX Directives:

- Directive 2014/34/EU (ATEX) on equipment and protective systems intended for use in potentially explosive atmospheres;
- Directive 1999/92/EC (ATEX USERS) laying down minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

1.2. Leading document for electrostatic hazards

The key reference document for identifying and controlling electrostatic hazards in explosive atmospheres is the Technical Specification:

- IEC/TS 60079-32-1 (CLC/TR 60079-32-1)
  Explosive atmospheres – Electrostatic hazards, guidance

Although this document does not have the status of an international standard, it constitutes a practical source of good practice for protection against electrostatic hazards in industrial installations and is widely used as supporting material for explosion risk assessment in installations subject to the requirements of the ATEX Directives.

1.3. Core standards used for ESH hazard assessment in Ex areas

In design practice and day-to-day operation, as well as in explosion protection documentation, the following Standards (EN) are most commonly applied

1.3.1. Classification of hazardous areas

- EN 60079-10-1 *Explosive atmospheres – Classification of areas*
  Part 10–1: Areas where flammable gases or vapours may be present
- EN 60079-10-2 *Explosive atmospheres – Classification of areas*
  Part 10–2: Areas where combustible dusts may be present

1.3.2. Explosion prevention methodology

- EN 1127-1 *Explosive atmospheres – Explosion prevention and protection – Basic concepts and methodology*

1.3.3. Requirements and terminology related to static electricity

- EN 13237 *Potentially explosive atmospheres – Terms and requirements for equipment and protective systems intended for use in potentially explosive atmospheres in relation to electrostatic hazards*;
- EN 61340-1 *Electrostatics – Part 1: General principles*

1.3.4. Test methods for electrostatic properties of equipment and PPE

- EN 61340-4-1 *Electrostatics – Test methods*
  Part 4-1: Standard test methods for specific applications - Electrical resistance of floor coverings and installed floors;
- IEC 61340-4-3 *Electrostatics – Test methods*
  Part 4-3: Footwear (methods for ESD-related testing);
- EN ISO 20345 *Personal protective equipment – Safety footwear*



1.4. Supporting and legacy documents

As supplementary references—particularly for existing installations or comparative assessments—the following are also used:

- EN 1081 *Resilient, laminate and textile floor coverings - Determination of electrical resistance*;
  (withdrawn; in practice commonly replaced by PN-EN 61340-4-1)
- NFPA 77 *Recommended Practice on Static Electricity* – guidance for design and operation of installations with electrostatic hazards, especially in the fuels and chemical sectors;
- CLC/TR 50404 *Code of Practice for the avoidance of hazards due to static electricity* – European guidance document (withdrawn), technically aligned with IEC/TS 60079-32-1

This guide does not replace the requirements of applicable standards; it provides their technical interpretation and practical application for industrial processes, particularly where explosive atmospheres may be present.

In this guide, the abbreviation ESH refers to electrostatic hazards in the context of ignition of explosive atmospheres.

ESH Checkpoint



Normative and documentary references

ACCEPTABLE

- The installation documentation identifies the applicable **ATEX Directives** and references documents addressing **electrostatic hazards.**
- The adopted technical solutions are referenced to **IEC/TS 60079-32-1** and the relevant **PN-EN / EN standards,** and are taken into account in the **Explosion Risk Assessment (ERA).**
- The scope of the applied requirements is consistent with the **hazardous area classification** and the provisions of the **Explosion Protection Document (EPD).**

NOT ACCEPTABLE

- Selective application of standard requirements without reference to the **ERA results** or without analysis of the entire technological process.
- Reference to **outdated or non-applicable documents** with respect to the installation scope and the identified hazardous areas.
- Inconsistencies between the applied ESH protective measures and the provisions of the **EPD.**

CRITICAL

- Lack of references to **electrostatic hazards** in the **Explosion Risk Assessment (ERA)** and in the **Explosion Protection Document (EPD)** for installations operating in **hazardous (Ex) areas.**

2 What is an electrostatic charge?

Electrostatic charge is an excess electric charge that can be either positive or negative and has a specific polarity and is not compensated by an opposite charge. The term “static” indicates that this charge has limited mobility, which results from the low electrical conductivity of the material or the high leakage resistance of a given object.

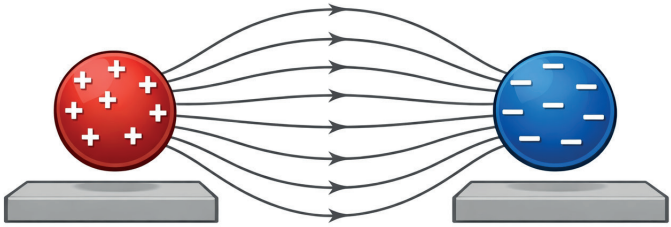


Figure 2-1.
Schematic representation of the electrostatic field between regions with opposite charges. Charge accumulation leads to the formation of a potential difference which, under favorable conditions, may result in an electrostatic discharge. This phenomenon constitutes the physical basis of electrostatic hazards in industrial installations.

In industrial environments, electrostatic phenomena are of significant importance due to their impact on process safety, the reliability of electronic equipment, and product quality. Uncontrolled electrostatic discharges can cause damage to components, disrupt system operation, and, in extreme cases, pose a threat to people and infrastructure by leading to fires or explosions.

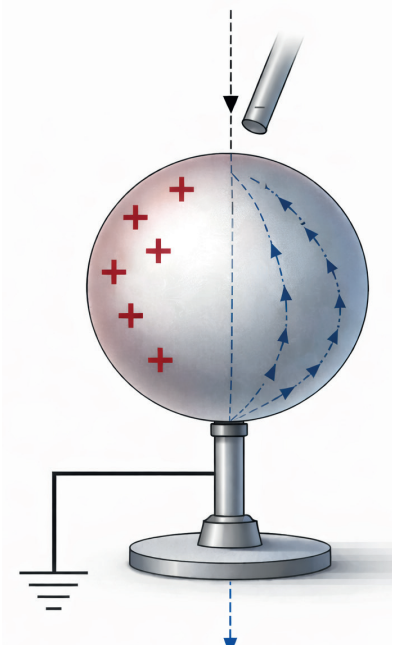


Figure 2-2.
On the left, a conducting sphere mounted on an insulated support and grounded is shown. Bringing a charged rod with a negative charge close to the sphere causes electrostatic induction. Free electrons in the sphere are repelled toward the ground, resulting in a local excess of positive charge on the surface of the sphere on the side closer to the rod. The arrows indicate the direction of charge carrier movement and the redistribution of surface charge. This is a classic example of charging by induction in the presence of grounding.

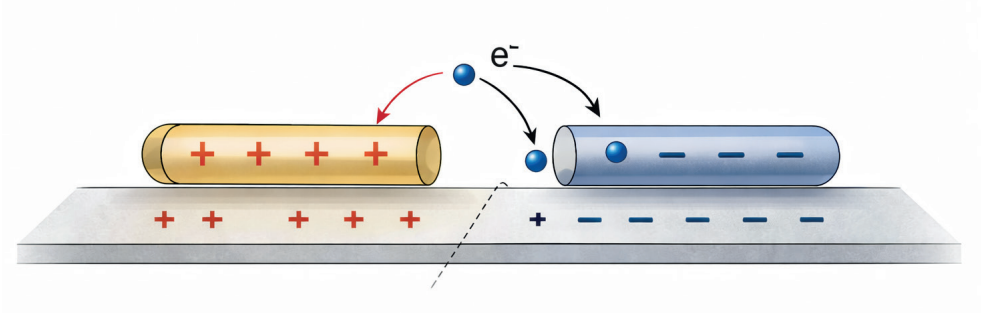


Figure 2-3.

The above figure shows two metal rods (or cylinders), one positively charged and the other negatively charged, placed on an insulating substrate. The transfer of electrons (e–) between the objects is indicated, illustrating charging by contact and the equalization of potentials. The distribution of "+" and "–" symbols on the surfaces and within the substrate indicates charge separation and the effect of electrostatic induction in neighboring materials.

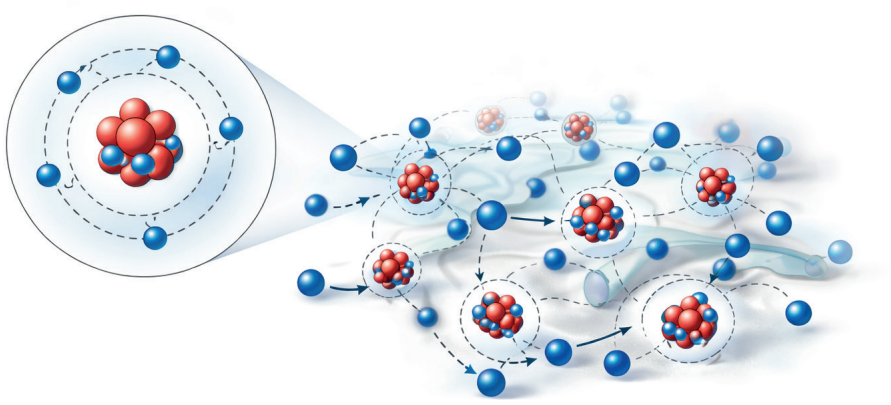


Figure 2-4.

Schematic representation of the atomic structure of a metal. Positively charged atomic nuclei composed of protons and neutrons, as well as electrons bound in electron shells, are shown. Free electrons, which can move between atoms within the metal crystal lattice, are also indicated. The illustration highlights the microscopic origin of electrostatic phenomena and electrical conductivity. The motion of free electrons is responsible for the redistribution of charge observed on a macroscopic scale during the charging of objects.

3 Charging Mechanisms and Physical Fundamentals

3.1. Electrostatic Charging Mechanisms in Industrial Installations

In industrial installations, electrostatic charges may be generated as a result of the following phenomena:

- separation of materials,
- friction, impact and detachment of particles,
- flow of liquids through pipelines and nozzles,
- separation of solid surfaces (films, floors and footwear).

These phenomena lead to electrostatic charging primarily as a result of contact and triboelectric charging, flow electrification and electrostatic induction. The intensity of charge generation depends on the electrical properties of materials (conductivity and resistivity), relative velocity of movement, contact surface area, installation geometry and environmental conditions. Air humidity plays a significant role, as it directly affects the ability of materials to accumulate and dissipate electrostatic charges.

In installations assessed in practice, inadequate dissipation paths-often overlooked during modifications or retrofits-were found to significantly increase charge accumulation on insulating surfaces.

For materials with high electrical resistivity, the charge relaxation time may be long, which promotes charge accumulation on insulating surfaces and increases the probability of electrostatic discharges.



Figure 3-1.
Triboelectric charging of a person during walking.

Charging mechanisms occur with particular intensity during:

- flow of liquids with low electrical conductivity (e.g. hydrocarbons and organic solvents) through pipelines, especially at high flow velocities and abrupt changes in direction;
- free discharge of liquids into vessels before immersion of the filling pipe, leading to flow electrification and splashing;
- transfer of bulk solids from significant heights via chutes, hoppers and slide valves;
- pneumatic conveying of powders and dusts;
- crushing, milling, screening and intensive mixing processes;
- processes involving large dielectric surfaces such as plastic conveyor belts, films, sheets and insulating coatings;
- movement of personnel on floors with inadequate electrostatic properties, particularly when unsuitable footwear is used.



Figure 3-2.
Triboelectric charging generated during transfer of bulk solids.

Accumulated electrostatic charges, in the absence of effective and controlled dissipation paths, may lead to electrostatic discharges (spark, corona or brush discharges). The nature and energy of the discharge depend on the system geometry, the type of charged materials and the possibility of charge dissipation to grounded conductive parts.



Figure 3-3.
Electrostatic charging caused by liquid flow during manual draining of a drum.



Figure 3-4.
Triboelectric charging caused by manual wiping of an intermediate bulk container (IBC).

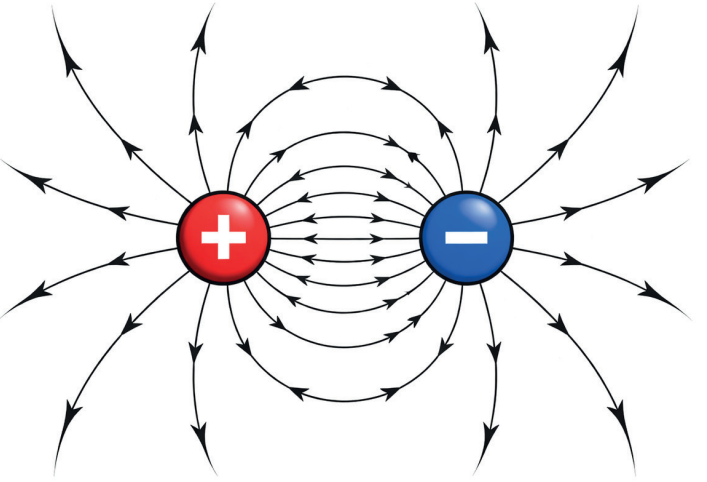


Figure 3-5.
Schematic representation of an electrostatic field between regions of opposite charge. Charge accumulation leads to the formation of a potential difference which, under favourable conditions, may result in an electrostatic discharge. This phenomenon constitutes the physical basis of electrostatic hazards in industrial installations.

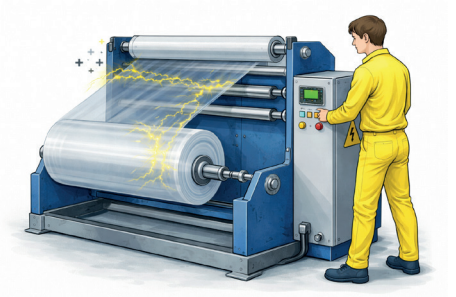


Figure 3-6.
Triboelectric charging caused by high-speed movement of polymer film on rollers



Figure 3-7.
Triboelectric charging during emptying of a flexible intermediate bulk container.

ESH Checkpoint

Charging mechnisms

ACCEPTABLE

- Sources of electrostatic charging have been identified at the design stage or during technological process analysis.
- The risk assessment takes into account the electrical properties of materials, flow velocities, and the installation geometry.
- Measures have been implemented to limit the generation and accumulation of electrostatic charges.

NOT ACCEPTABLE

- Treating electrostatic charging as a sporadic phenomenon not considered during normal operation of the installation.
- Failure to consider the influence of flow velocity, humidity, or changes in process configuration.

CRITICAL

- Failure to identify sources of electrostatic charging in installations operating in hazardous (Ex) areas.
- Operation of processes generating electrostatic charges without any measures to limit their accumulation.

3.2. Discharge Energy and Minimum Ignition Energy

For a conductive object, the energy of a potential electrostatic discharge can be described by the following relationship:

$$E = 0.5 \cdot C \cdot U^2$$

where:
C – electrical capacitance of the object relative to earth,
U – voltage of the object relative to earth.

This relationship defines the maximum energy stored on a conductive object that, under favourable conditions, may be released during an electrostatic discharge. In practice, the actual discharge energy may be lower; however, for risk assessment purposes, a conservative approach is generally applied.

In practical explosion risk assessments, this conservative approach is commonly adopted to compensate for uncertainties related to discharge geometry, environmental conditions and repeatability of ignition phenomena.

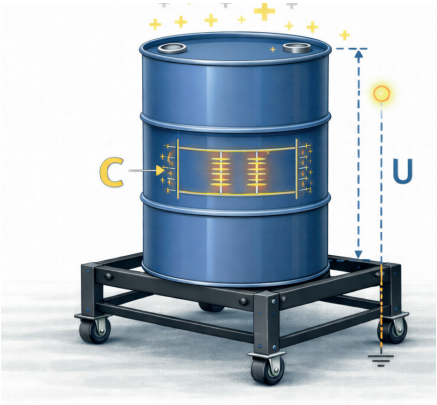


Figure 3-8.
Energy of a potential electrostatic discharge from a conductive object.



Figure 3-9.
Electrostatic spark discharge from a charged conductive object to a person

The **minimum ignition energy (MIE)** is defined as the lowest energy which, under standardised test conditions, is capable of igniting the most easily ignitable mixture of a given substance with air.

In engineering practice, a hazardous condition is considered possible when the energy of a potential electrostatic discharge $W_e \geq 0.1 \cdot MIE$, corresponding to the application of a safety factor of approximately $k \approx 0.1$.

It should be emphasised that the above relationship applies to discharges from conductive objects. For insulating materials and dielectric surfaces, discharge mechanisms and available energies may differ significantly and require separate assessment.

The lower the minimum ignition energy of the material, and the greater the electrical capacitance of the object and the attainable charging voltage, the more stringent the requirements must be with respect to earthing, material selection and operational procedures.

ESH Checkpoint

Discharge energy and MIE

ACCEPTABLE

- The ignition risk assessment considers the relationship between the potential electrostatic discharge energy and the minimum ignition energy (MIE) of the explosive atmosphere.
- The electrical capacitance of objects and the charge relaxation time are taken into account.
- Safety factors consistent with good engineering practice have been applied.

NOT ACCEPTABLE

- Hazard assessment based solely on indicative values, without reference to the actual technological process.
- Failure to consider changes in materials or process parameters.
- No distinction between different types of electrostatic discharges.

CRITICAL

- Operation of processes in which the potential discharge energy may exceed the MIE, without measures to limit the risk of ignition.
- Failure to consider long charge relaxation times in insulated or isolated systems

3.3. Charge Relaxation Time

The decay of the electrostatic charge on an object is described by the charge relaxation time, defined by the relationship:

$$\tau = R \cdot C$$

where:
R – resistance of the leakage path to earth,
C – electrical capacitance of the object.

The relaxation time defines the rate at which electrostatic charge is dissipated from an object. From the explosion safety perspective, systems with a short relaxation time—typically below 0.1 s—are favourable, as the charge is continuously dissipated and does not accumulate to a level relevant with respect to the minimum ignition energy (MIE). Experience from industrial installations shows that such favourable conditions are often unintentionally lost after modifications, repainting or partial replacement of installation components.

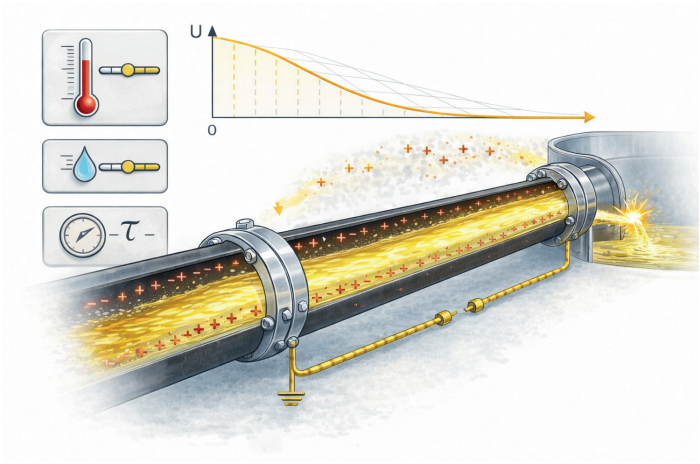


Figure 3-10. Electrostatic charge relaxation and voltage decay on an object as a function of leakage resistance and capacitance.

High leakage resistance values, in the range of 10^9-10^{11} Ω, combined with capacitances of several hundred picofarads, may result in the persistence of high electrostatic voltages, reaching several tens of kilovolts, for tens of seconds. Under such conditions, a single electrostatic discharge may release energy comparable to the minimum ignition energy of many flammable liquids and combustible dusts.

It should be emphasised that the relaxation time depends on the continuity and quality of the entire charge dissipation path to earth. Discontinuities in earthing, the presence of insulating coatings, gaskets or contamination may significantly increase leakage resistance and, consequently, prolong the duration of hazardous electrostatic voltages.

ESH Checkpoint

Charge relaxation time

ACCEPTABLE

- Charge dissipation paths allow relaxation within a safety-relevant time.
- Resistive parameters of installation components are known and controlled.
- The influence of insulating surface resistivity is considered.

NOT ACCEPTABLE

- Lack of awareness of charge persistence on insulating surfaces.
- Failure to consider material resistivity effects on charge accumulation.
- Neglecting the impact of ageing and contamination.

CRITICAL

- Long-lasting high electrostatic voltages in the presence of explosive atmospheres

3.4. Types of Electrostatic Discharges

From the explosion safety perspective, particular attention shall be given to electrostatic discharges that may act as effective ignition sources for explosive atmospheres. The most relevant discharge types include **spark discharges**, **brush discharges** and **propagating brush discharges**, and in bulk solids handling also **cone (bulk) discharges**.

Spark discharges occur between conductive objects or between a conductive object and earth when at least one of the objects is electrically isolated from earth and a significant potential difference has accumulated. They are characterised by very short duration and high energy and are therefore considered the most hazardous type of electrostatic discharge. Effective earthing and equipotential bonding eliminate the possibility of spark discharges.

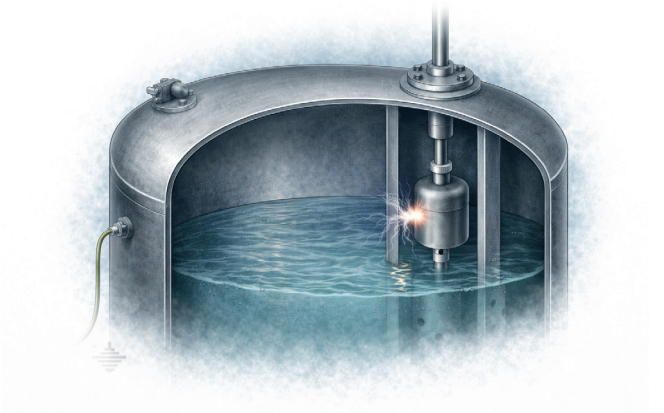


Figure 3-12.
Spark discharge occurring between an electrically isolated level-measuring element and a grounded still pipe inside a metal storage tank, caused by a high electrostatic potential difference across a small air gap.

Brush discharges occur on the surfaces of insulating or poorly conductive materials. They are diffuse in nature and have limited energy. As a rule, they are not capable of igniting most combustible dusts; however, they may constitute an effective ignition source for flammable vapours and gases, particularly those with low minimum ignition energy (e.g. explosion groups IIB and IIC).

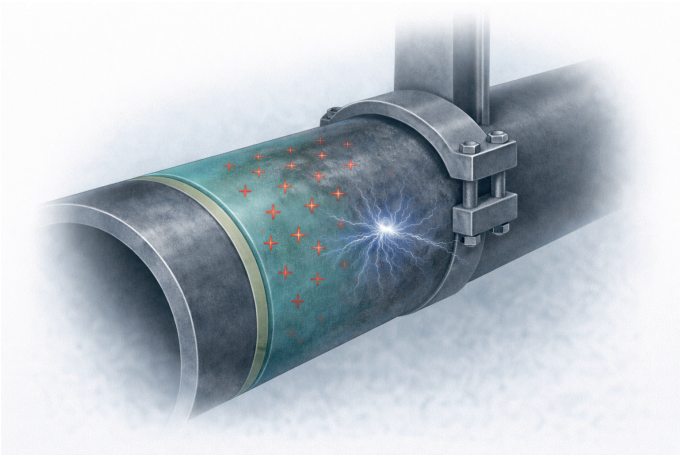


Figure 3-13.
Brush discharge on an insulating coating of a grounded metal pipeline, characterised by a diffuse, low-energy electrostatic discharge from the surface.

Propagating brush discharges occur on thin insulating layers applied to conductive substrates. They are characterised by rapid propagation of the discharge across the surface and may reach energies significantly higher than those of typical brush discharges. For this reason, they are considered particularly hazardous in the context of ignition of explosive atmospheres. This hazard is especially relevant for thin dielectric layers on metallic substrates. In engineering practice, the risk of propagating brush discharges is considered to increase significantly when the thickness of the insulating layer (e.g. paint or plastic coating) is below a few millimetres, typically of the order of ~8 mm.



Figure 3-14.
Example of a propagating brush discharge occurring on a thin insulating element connecting conductive components.

In practice, this type of discharge is frequently underestimated, particularly where thin coatings are applied for corrosion protection without considering their electrostatic behaviour. In bulk solids handling installations, an additional hazard may be posed by **cone (bulk) discharges**, which occur during the filling of silos and vessels with powders or granular materials. These discharges may have sufficient energy to ignite a dust cloud and shall be taken into account in the risk assessment.

Other forms of electrostatic discharges, such as **corona discharges**, due to their very low energy, are generally not considered effective ignition sources for explosive atmospheres. In special cases involving atmospheres with extremely low minimum ignition energy (e.g. hydrogen), their ignition relevance cannot be completely excluded.

Type of discharge	Typical source / conditions	Ignition potential	Remarks relevant for explosion risk assessment
Spark discharge	Conductive objects, at least one insulated from earth	High	Most hazardous; effective earthing and bonding eliminate the risk
Brush discharge	Insulating surfaces, plastics	Medium	Generally do not ignite dusts; hazardous for vapours and low-MIE gases (IIB, IIC)
Propagating brush discharge	Thin insulating layers on conductive substrates	High	Particularly hazardous; may ignite vapours and some dusts
Cone (bulk) discharge	Filling of silos, bulk material transfer	Medium-high	Relevant in dust-handling industries; possible ignition of dust clouds
Corona discharge	Sharp edges, high electric field strength	Low	Usually negligible; potential relevance at very low MIE (e.g. hydrogen)

Table 1. Types of Electrostatic Discharges and Ignition Risk



ESH Checkpoint

Types of electrostatic discharge

ACCEPTABLE

- The risk analysis distinguishes between types of electrostatic discharges relevant to the specific technological process.
- Their ignition potential is considered with respect to the type of explosive atmosphere

NOT ACCEPTABLE

- Treating all electrostatic discharges as equally hazardous or equally non-hazardous

CRITICAL

- Ignoring spark discharges and propagating brush discharges in hazardous (Ex) areas.

3.5. Classification of Materials from an ESH Perspective (Simplified)

Based on **EN 13237**, materials used in industrial installations may be classified, from an electrostatic hazard perspective, into the following groups:

- **Conductive materials** – volume resistivity below 10^5 Ω·m and surface resistance below 10^5 Ω;
- **Dissipative materials** – volume resistivity from 10^5 to below 10^9 Ω·m and surface resistance from 10^5 to below 10^{12} Ω;
- **Insulating materials** – volume resistivity equal to or greater than 10^9 Ω·m and surface resistance equal to or greater than 10^{12} Ω.

For elements such as floors, footwear and protective gloves, the following indicative classification is commonly applied:

- **Conductive** – $R < 10^5$ Ω;
- **Dissipative** – 10^5 Ω ≤ R < 10^8-10^9 Ω (range depending on function and applicable standard);
- **Insulating** – R ≥ 10^8-10^9 Ω.

In hazardous areas, the preferred solutions are:

- floors with leakage resistance typically in the range of 10^5–10^8 Ω;
- footwear with resistance in the range of 10^5–10^8 Ω; footwear classified as "antistatic" up to 10^9 Ω in accordance with EN ISO 20345 often requires additional verification under actual operating conditions.

Limit values shall always be confirmed with reference to the applicable standards and the specific properties of the substances and processes involved. In explosive atmospheres, the use of conductive or dissipative materials is preferred, provided that a reliable and permanent connection to earth is ensured. It shall be taken into account that the electrostatic properties of materials may change over time due to wear, contamination or environmental conditions.



Figure 3-14.

Simplified illustration of the ESH classification of materials: conductive (A), dissipative (B) and insulating (C). Highlighting the role of system continuity from the human body through clothing, footwear and floor to earth in controlling electrostatic charge accumulation.

Area / process	Example operation	Main charging source	Key Protection against electrostatic hazards measures
Flammable liquid filling	Filling a tank with solvent from a loading rack	Free liquid flow, jet breakup	Earthing of tank and piping, flow rate limitation during free flow, rapid immersion of filling pipe, earthing monitoring
Road tanker unloading	Fuel unloading to storage tank	Liquid flow in piping and connections	Tanker earthing monitoring system, pump interlock on loss of earthing, flow rate limitation
Powder transfer	Feeding big bags into a mixer	Particle-wall and particle-particle friction	Earthing of mixer and structure, correct FIBC type selection, reduced drop height, humidity control
Pneumatic conveying	Conveying flour or chemical powder to silo	Particle friction in pipeline	Conductive or dissipative pipelines, continuous earthing, control of conveying air velocity
Bag filters	Dedusting of production lines	Particle impact on filter media	Earthed filter housings, dissipative filter media, control of dust deposits
Large dielectric surfaces	Film unwinding on packaging line	Contact and separation of film	Ionisation systems, dissipative materials, earthing of metallic transport components
Personnel movement in Ex areas	Operator entry/exit to Zone 1 / 21	Walking on floors, clothing movement	Dissipative floors, footwear with suitable resistance, footwear testers at entry points, antistatic clothing
Maintenance activities	Cleaning and dismantling equipment in Ex area	Friction, tool-surface contact	Earthing of equipment and tools, suitable footwear and clothing, control of flammable residues, proper work organisation

Table 2. Example Processes and Recommended Protection against electrostatic hazards Measures

Summary

The ignition risk is determined not only by the presence of electrostatic charge, but also by the energy of a potential discharge in relation to the minimum ignition energy (MIE) and the time during which charge may accumulate. Key parameters include the electrical capacitance of the object, the resistance of the leakage path to earth and the electrical properties of the materials used.

Most Common Errors

- failure to consider electrostatic charging mechanisms at the design stage;
- treating electrostatic charging as an incidental rather than continuous phenomenon;
- neglecting the influence of flow velocity, humidity and installation geometry;
- failure to consider the human body as a potential source of electrostatic charge.

4 Earthing and Equipotential Bonding

4.1. Role of Earthing

Equipotential bonding of conductive parts, in combination with effective earthing, constitutes the primary protective measure against electrostatic ignition in industrial installations. Its fundamental function is to ensure the rapid and controlled dissipation of electrostatic charges generated on metallic surfaces, before they can reach a level capable of producing hazardous discharges.



Figure 4.1

Earthing and equipotential bonding of a metallic vessel. The vessel is earthed by means of a grounding strip and equipped with equipotential bonding between flanged connections to ensure electrical continuity and safe dissipation of electrostatic charges.

In the context of electrostatic hazards, bonding and earthing serve different but complementary functions. Bonding (equipotentialisation) is used to eliminate dangerous potential differences between conductive parts and to prevent spark discharges. Earthing provides a defined path for charge dissipation to earth. Bonding may be applied without earthing; however, earthing alone does not prevent spark discharges if bonding between conductive parts is insufficient.

In particular, earthing provides for:

- rapid and controlled dissipation of electrostatic charges;
- prevention of electric potential build-up that could lead to spark discharges;
- integration of conductive installation components into the equipotential bonding system and their connection to earth

An effective earthing system is characterised by:

- low resistance of the earthing path;
- electrical continuity of all bonding connections;
- resistance of connections to corrosion and mechanical damage;
- verified effectiveness confirmed by documented inspection and test results.

It shall be emphasised that the effectiveness of earthing must be ensured throughout the entire service life of the installation. Loss of continuity, the presence of insulating coatings, corrosion or improperly executed connections may significantly reduce the ability to dissipate electrostatic charges. In dynamic processes or intermittent operations (e.g. tanker loading and unloading), particular importance is attached to the use of solutions that allow continuous or real-time verification of earthing integrity.

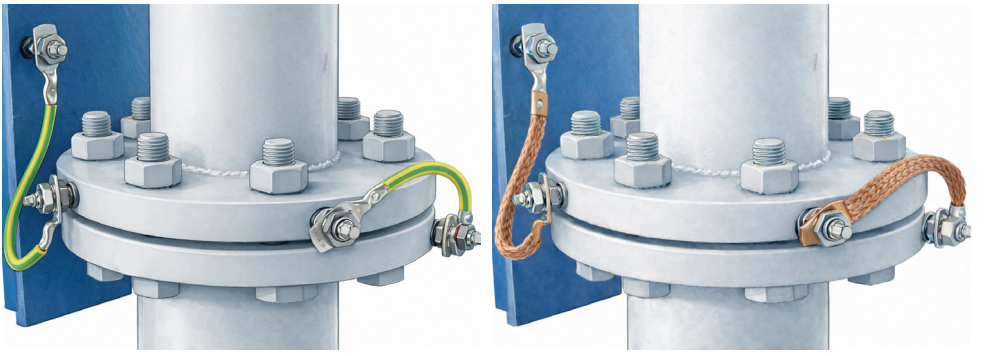


Figure 4.2

Equipotential bonding across a flanged connection. Flexible bonding conductors (wire or braided strap) are installed across the flanged joint to ensure equipotential bonding and prevent electrostatic discharges.

4.2. Bonding Resistance and Technical Requirements

In the majority of industrial processes, in particular those conducted in hazardous areas, it is generally accepted that the total resistance of the bonding and earthing path, measured from the protected object to the earth electrode, should not exceed 10 Ω. This requirement applies both to permanently installed equipment and to mobile or temporary objects connected to the earthing system by means of earthing clamps.

The 10 Ω criterion is used as a practical threshold for verifying the quality of a connection (contact/corrosion/looseness), regardless of the fact that, from the standpoint of charge dissipation itself, a higher resistance is often also sufficient – provided it is stable and controlled.

Field experience from industrial installations shows that resistance values exceeding this threshold are most often associated with poor contact quality, corrosion or intermittent bonding rather than with insufficient charge dissipation capability as such.

The adoption of the **10 Ω limit** is:

- consistent with established industrial practice;
- aligned with the operating range of typical certified earthing monitoring systems;
- sufficient to ensure rapid and effective dissipation of electrostatic charges under normal operating conditions.

In practical implementation, particular attention shall be paid to:

- proper preparation and cleanliness of contact surfaces;
- correct selection of earthing clamps, bonding straps and conductors;
- protection of connections against corrosion and contamination;
- avoidance of insulating coatings at bonding points;
- regular verification of continuity and earthing path resistance.

It shall be emphasised that compliance with the earthing resistance criterion is meaningful only when the bonding connections are **mechanically reliable and electrically continuous throughout the entire service life.** Loose clamps, corrosion, surface deposits or intermittent loss of contact may lead to temporary loss of earthing effectiveness, even if previous resistance measurements indicated compliance.

Such degradation mechanisms are typically identified during periodic inspections or after process interruptions, maintenance work or temporary reconfiguration of equipment.



Figure 4-3

Examples of incorrect earthing connections. Alligator clips and similar temporary solutions do not provide a durable, mechanically stable, or electrically reliable connection. The limited contact area, susceptibility to loosening, contamination, and corrosion lead to unstable connection resistance and a risk of intermittent loss of earthing effectiveness. Such clamps do not meet the requirements for permanent equipotential bonding connections and should not be used in industrial installations.

A large, flat contact surface, beneficial for high current transfer in battery applications, becomes a disadvantage for static earthing, as it cannot reliably penetrate paint layers, corrosion, or product residues. As a result, electrical contact may be unstable and can create a false sense of safety. In industrial practice, it is neither practical nor acceptable to clean bonding points before every operation.



Figure 4-4

Standard welding clamps and battery (alligator) clamps commonly used in industry are often applied for static earthing beyond their intended purpose. Their effectiveness for electrostatic discharge protection has not been validated by manufacturers and cannot be assumed, particularly in high-risk processes. Such clamps are typically made of mild steel, copper, or light alloys, which are prone to mechanical damage and chemical degradation in industrial environments.

If a clamp cannot ensure direct and durable metal-to-metal contact, it cannot guarantee safe dissipation of electrostatic charges. For this reason, simple welding and alligator clamps are not suitable for static earthing in accordance with ATEX and IEC 60079-32-1.



Figure 4-5

Only high-quality stainless steel earthing clamps should be used, such as the STUVEX Safe-Ground CMS1 clamp. The clamp shall be made of corrosion-resistant stainless steel and equipped with hardened jaws and sharp teeth made of reinforced stainless steel, ensuring reliable penetration through paint, rust, or contamination. This guarantees a low and stable contact resistance (< 10 Ω), safe dissipation of static electricity, and reliable performance in corrosive, chemical, saline, and ATEX environments

4.3. Integration with the Plant Earthing System and Equipotential Bonding

The electrostatic earthing system shall be integrated with the existing plant earthing infrastructure, in particular with:

- the protective earthing system of the electrical installation,
- the lightning protection system,
- the building foundation or ring earth electrode.

All conductive parts of the process installation, such as tanks, vessels, pipelines and supporting structures, shall be included in the equipotential bonding system and permanently connected to the plant earth electrode.

Equipotential bonding is intended to eliminate potential differences between individual items of equipment that could otherwise lead to spark discharge.

It shall be emphasised that earthing does not prevent the generation of electrostatic charges. Its function is to ensure their rapid and safe dissipation before the stored energy reaches a level capable of igniting a flammable atmosphere. In practice, effective protection depends not only on the connection to earth, but primarily on reliable equipotential bonding between all conductive parts, with earthing providing the reference for charge dissipation.

As a practical acceptance criterion, the resistance of the earthing path measured from a conductive item to the earth electrode should not exceed **10 Ω**. This value is indicative and shall be considered as part of the overall assessment of earthing system effectiveness rather than as an isolated requirement.

Common Deficiencies

- lack of continuity of bonding connections or their accidental disconnection;
- use of earthing connections without verification of their resistance,
- assuming that a metallic structure is earthed without measurement confirmation;
- omission of mobile and temporary equipment from the earthing system.

ESH Checkpoint

Earthing and equipotential bonding



ACCEPTABLE

- Earthing provides a permanent and continuous path for the dissipation of electrostatic charges.
- The resistance of the earthing path is verified by measurements and does not exceed 10 Ω.
- Earthing and bonding connections are resistant to corrosion and mechanical damage.

NOT ACCEPTABLE

- Lack of verification of earthing effectiveness by measurements.
- Use of temporary, provisional, or non-durable connections.

CRITICAL

- Performing technological operations without effective earthing.
- Possibility of loss of the earthing connection without automatic process shutdown or equivalent protective measures.

Element / Object	Parameter	Recommended Range (Indicative)	Purpose / Comment
Earthing path of conductive equipment	Resistance to earth	$R \leq 10\ \Omega$	Design and acceptance criterion for metallic equipment in hazardous areas and during handling of flammable media
Local bonding connections (clamp-drum, etc.)	Local connection resistance	$R \leq 10\ \Omega$	Values above 10 Ω may indicate corrosion, contamination or poor contact quality
Floors in hazardous areas	Leakage resistance Ru	Typically 10^5–$10^8\ \Omega$	Dissipative range enabling charge dissipation without excessively low impedance
Protective footwear in hazardous areas	Footwear resistance	Recommended 10^5–$10^8\ \Omega$	"Antistatic" footwear approved up to $10^9\ \Omega$ requires verification for Ex applications
Protective clothing	Fabric surface resistance	According to ESH standards, typically ≤ $10^9\ \Omega$	Conductive fibres or blends; parameters according to applicable standards
Dissipative coatings on dielectrics	Surface or leakage resistance	Typically 10^5–$10^9\ \Omega$	Must be bonded to earth and periodically verified (ageing, wear, cleaning)
Conductive pipelines	Resistance between sections	Typically a few ohms per section	Bonding required across flexible joints, compensators and insulated sections
Antistatic flexible hoses	End-to-end hose resistance	According to manufacturer, often ≤ 1 MΩ	Limits charge accumulation inside the hose; insulating hoses should be avoided in critical areas

Table 3. Recommended Resistance Ranges for Installation Elements



5 Transfer and Filling of Flammable Liquids

Before the start of filling operations, all conductive parts involved shall be equipotentially bonded, and connected to earth where required, and shall remain so throughout the entire operation.

In installations where flammable liquids with low electrical conductivity are transferred and filled, the generation of electrostatic charges is particularly intensive during:

- liquid flow through pipelines and fittings at high velocities;
- introduction of liquid into a tank as a free-falling stream before immersion of the filling pipe or hose;
- formation of splashing and turbulence at the point of liquid entry into the vessel.

In accordance with IEC/TS 60079-32-1 and established engineering practice:

- during the free-flow phase, the liquid velocity should not exceed approximately **1 m/s**;
- in the case of liquids with a very low minimum ignition energy (MIE ≤ 0.1 mJ), more stringent velocity limits are applied - in accordance with the tables/recommendations of IEC/TS 60079-32-1 and the technological procedure;
- once the filling pipe or hose is immersed in the liquid, the flow rate may be increased in accordance with the process operating instructions;
- the receiving vessel and the supply pipeline shall be earthed before the start of filling and shall remain earthed throughout the entire operation.

In practice, deviations from these principles most frequently occur during short-duration or non-routine operations, where earthing is treated as a formality rather than as an active process condition.

The stated velocity values are indicative and shall always be verified with respect to the physicochemical properties of the liquid, installation geometry and operating conditions.

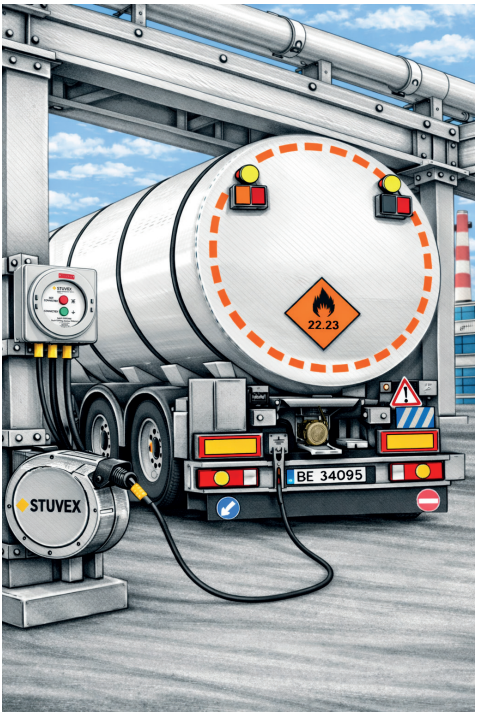


Figure 5-1.

Earthing monitoring system for road tanker loading and unloading.

An earthing monitoring system is installed at the transfer point to verify effective earthing of a road tanker before and during liquid loading or unloading. Visual indication shows the earthing status, while interlocks prevent the start or continuation of transfer operations if the earthing connection does not meet the required safety criteria.

Additionally:

- both the source vessel and the receiving vessel shall be earthed prior to the operation and remain earthed throughout;
- connection or disconnection of earthing clamps during liquid flow is prohibited;
- in installations with elevated risk (low MIE, Zone 0 or Zone 1), the use of earthing monitoring systems is recommended to prevent pump operation if earthing resistance criteria are not met.

Summary

Limiting the flow velocity and rapidly immersing the filling pipe reduce the intensity of electrostatic charging in the free-stream impact zone. Ensuring stable and continuous earthing prevents electrostatic charge accumulation to levels that could constitute an ignition hazard.

Common Deficiencies

- starting filling operations before effective earthing is established;
- excessive flow velocities during the free-flow phase;
- delayed immersion of the filling pipe or hose;
- treating earthing as a formal requirement rather than a process condition.

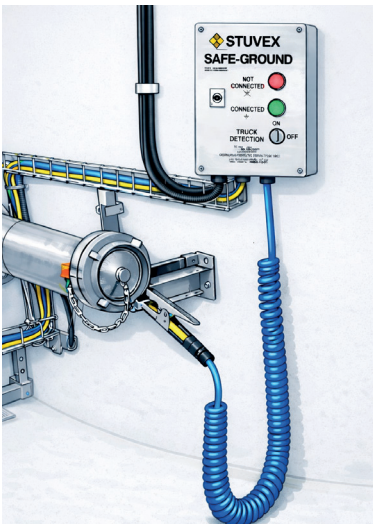


Figure 5-2.

Earthing monitoring during transfer and filling of flammable liquids. An earthing monitoring device verifies effective earthing of the road tanker and transfer equipment before and during liquid filling. Visual indication confirms earthing status, while interlocks prevent the start or continuation of transfer if earthing criteria are not met, reducing the risk of electrostatic ignition during flammable liquid handling.

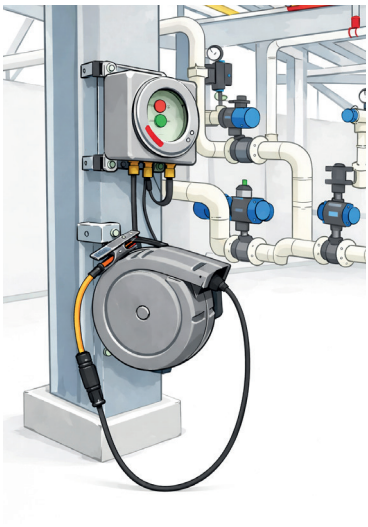


Figure 5-3.

Monitored earthing system intended for use with road tankers during flammable liquid transfer operations. The figure illustrates the earthing system. The system is designed to provide controlled earthing of a road tanker; the earthing connection shall be established prior to commencement of the transfer and shall remain continuously effective for the full duration of the operation.

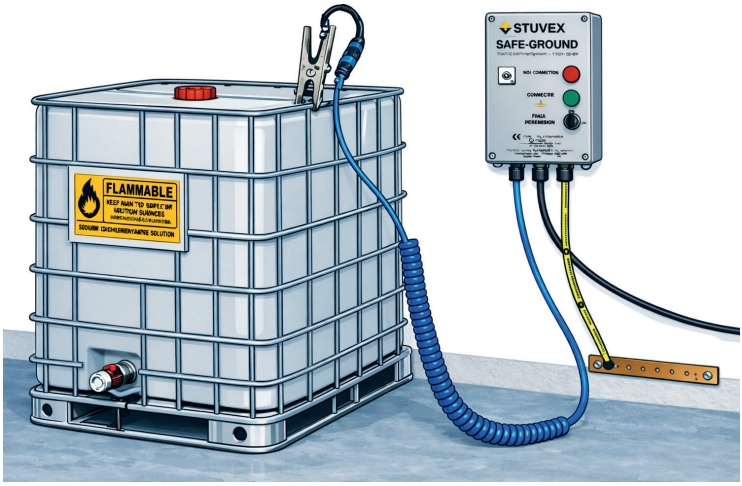


Figure 5-4.

Earthing monitoring during filling or emptying of an IBC. An earthing clamp is connected to the conductive frame of an IBC, while an earthing monitoring device continuously verifies the earthing connection. Visual indication confirms correct earthing status, and process interlocks prevent transfer operations if the earthing criteria are not met, reducing the risk of electrostatic ignition during handling of flammable liquids.

ESH Checkpoint

Transfer and filling of flammable liquids

ACCEPTABLE

- The flow velocity of liquids during the free-fall phase is limited in accordance with applicable safety guidelines.
- The filling pipe or hose end is immersed in the liquid as early as practicable in order to limit electrostatic charging.
- Tanks and filling lines are earthed before the operation starts and remain earthed throughout the entire operation.

NOT ACCEPTABLE

- Starting filling operations without verification of effective earthing.
- Delayed immersion of the filling pipe or uncontrolled increase of flow velocity.

CRITICAL

- Filling of liquids with a low MIE without the possibility of automatic process shutdown in the event of loss of earthing.
- Connecting or disconnecting earthing connections while liquid flow is in progress.



Figure 5-5.

Correct earthing of drums prior to flammable liquid transfer. The illustration shows correct connection of an earthing clamp to a metal drum before liquid transfer. Although the actual operation involves pump draining in the background, the earthing is shown on an unobstructed drum to clearly demonstrate the required practice: earthing shall be established before the operation starts and maintained throughout the entire transfer.

6 Handling and Transfer of Bulk Solids

During the handling and transfer of powders and granular materials, electrostatic charges are generated intensively as a result of particle friction:

- between particles themselves;
- against equipment surfaces;
- against the walls of chutes, hoppers and silos.

The risk of electrostatic charge accumulation increases particularly under the following conditions:

- low ambient humidity;
- small particle size;
- high material flow velocities;
- presence of extensive insulating surfaces.

It shall be taken into account that even materials regarded as difficult to ignite or non-combustible may, in finely divided powder form, create explosive atmospheres in which electrostatic discharges can act as effective ignition sources.

Operational experience shows that this risk is frequently underestimated in installations where materials are handled intermittently or where the same equipment is used for different products.

To limit electrostatic charging during bulk solids handling, the following measures are recommended:

- avoidance of large gravitational drop heights;
- use of gently sloped chutes with the lowest practicable discharge height;
- limitation of material flow velocities in gravity-fed and pneumatic systems;
- use of pipelines, chutes and components made of antistatic materials (conductive or dissipative);
- earthing of all metallic parts of the installation, including internal components such as paddles, probes, electrodes and filter elements;
- regular cleaning of equipment to remove deposits and build-up that may form additional insulating layers.



Figure 6-1.

Example of uncontrolled powder transfer with a large gravitational drop height, creating conditions conducive to electrostatic charge accumulation and potential ignition of combustible dusts.



Figure 6-2.

Uncontrolled powder transfer with a large free-fall drop height, promoting electrostatic charge generation and accumulation. In the presence of combustible dust, such conditions increase the risk of ignition and dust explosion.

Summary

In bulk solids handling operations, controlling the intensity of electrostatic charging through flow velocity management and appropriate chute geometry is essential. Equally important is the provision of effective paths for electrostatic charge dissipation via earthed conductive surfaces. In practice, deficiencies in chute geometry and earthing of internal components are among the most common findings during electrostatic safety audits of bulk solids handling systems.

Common Deficiencies

- use of large gravitational drop heights without control of electrostatic charging;
- use of insulating components in areas of intensive friction;
- lack of earthing of internal equipment components;
- neglecting the removal of deposits forming insulating layers.



Figure 6-3.

Big bag (FIBC) unloading operation using Type A bags. The presence of ATEX-certified (Ex) vacuum equipment indicates potentially combustible dust; however, no visible earthing or bonding arrangements are provided for electrostatic charge dissipation.

ESH Checkpoint

Transfer of bulk solid materials



ACCEPTABLE

- The geometry of chutes and hoppers limits the drop height and the intensity of material friction.
- All metallic parts of the installation, including internal components, are effectively earthed.
- Materials with conductive or dissipative properties are used to control electrostatic charging.

NOT ACCEPTABLE

- Use of insulating components in areas of intensive material friction without compensating measures.
- Lack of control of deposits and build-ups leading to the formation of insulating layers.

CRITICAL

- Transfer of combustible dusts in hazardous (Ex) areas without providing an effective path for electrostatic charge dissipation.
- Ignoring the risk of cone discharges during filling of silos or containers.

Pneumatic Conveying

7

Pneumatic conveying of bulk solids promotes intensive electrostatic charge generation because:

- material particles move at high velocities relative to the pipeline surfaces;
- intense friction occurs both between particles and against the walls of the conveying system.

An additional risk factor is that, in pneumatic conveying systems, the material is often present as a dispersed dust cloud across the entire cross-section of the pipeline. This condition favours the formation of extensive explosive atmospheres with a high ignition potential.

To reduce electrostatic hazards in pneumatic conveying systems, the following measures are recommended:

- use of pipelines and system components made of conductive or dissipative materials;
- ensuring electrical continuity of all metallic connections and their effective, permanent earthing,



Figure 7-1.

Pneumatic filling of a silo from a road tanker. High conveying velocities generate electrostatic charge during filling. If dust is present and earthing is inadequate, electrostatic discharge and ignition may occur.

- avoiding unnecessary sharp bends and abrupt changes in flow direction;
- limiting the conveying medium velocity to values specified in the technological documentation, particularly for powders with low minimum ignition energy (MIE);
- use of coatings and materials with controlled electrostatic properties where insulating components are technologically unavoidable, so that accumulated charge can be dissipated in a controlled manner.

Summary

In pneumatic conveying systems, effective protection against electrostatic discharges relies on the use of antistatic components and on ensuring electrical continuity and reliable earthing throughout the entire conveying installation.

Common Deficiencies

- use of pipelines made of insulating materials without compensating measures;
- lack of electrical continuity of metallic components;
- excessive conveying velocities;
- failure to consider the impact of route changes and sharp bends.

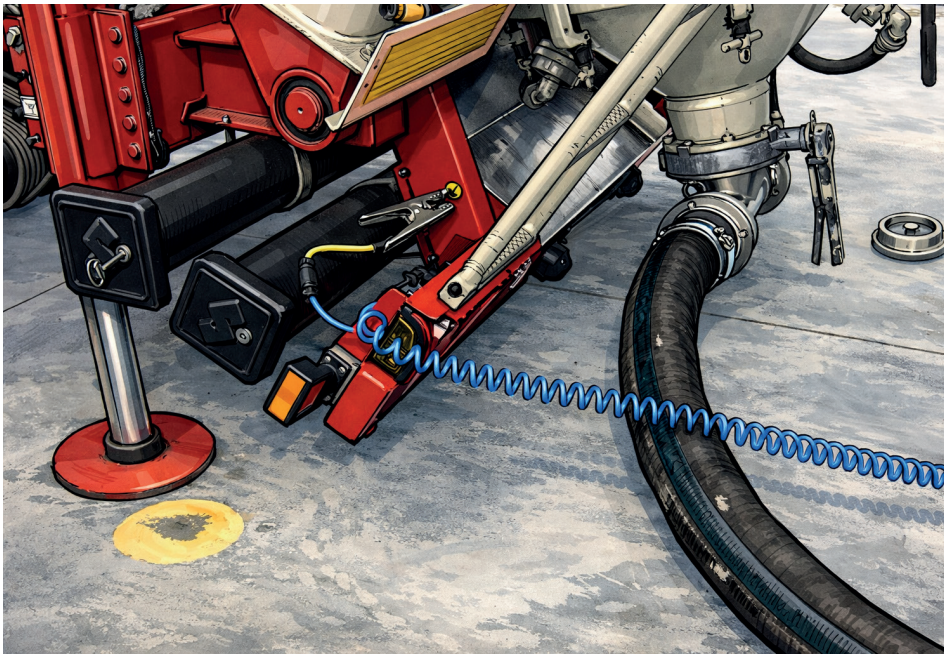


Figure 7-2.

Flexible hose with earthing connection. The earthing clamp is connected to a dedicated earthing point on the road tanker, ensuring electrical continuity and safe dissipation of electrostatic charge during pneumatic conveying

ESH Checkpoint

Pneumatic conveying

ACCEPTABLE

- Pipelines and installation components are made of conductive or dissipative materials.
- Electrical continuity of connections and permanent earthing are ensured.
- Conveying velocities are adapted to the properties of the conveyed material.

NOT ACCEPTABLE

- Use of insulating pipelines without additional measures to control electrostatic charging.
- Lack of electrical bonding of flexible sections, hoses, or expansion joints.

CRITICAL

- Pneumatic conveying of combustible dusts without providing a continuous path for electrostatic charge dissipation.
- Lack of control over route changes, including sharp bends in the installation that promote intensive electrostatic charging.

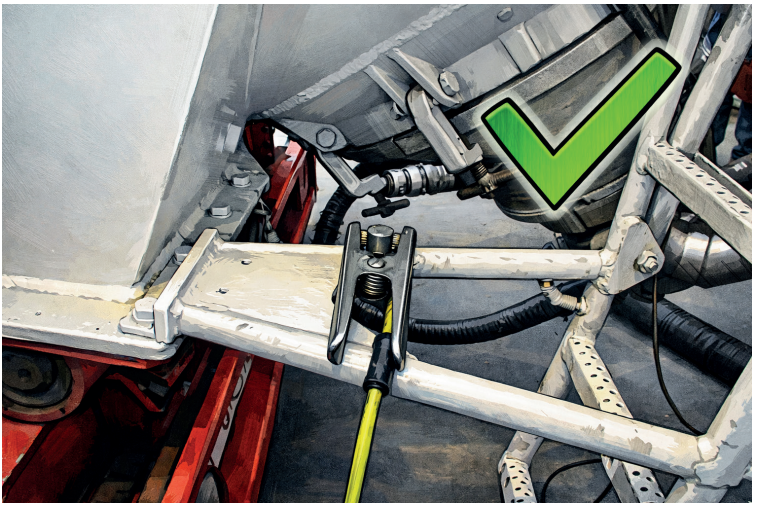


Figure 7-3.

Flexible hose with earthing connection. The earthing clamp is connected to a dedicated earthing point on the road tanker, ensuring electrical continuity and safe dissipation of electrostatic charge during pneumatic conveying

Floors, Footwear and Clothing

8

8.1. Floors

Floors used in hazardous areas shall exhibit dissipative properties that enable the controlled dissipation of electrostatic charges from the human body and mobile objects to the facility earthing system. The floor forms part of an integrated electrostatic protection system, which also includes suitable footwear and a reliable connection to the earthing network. In this context, dissipation of charge from personnel is achieved via equipotential bonding through a resistive path (human–footwear–floor system), rather than by direct earthing of the person.

In accordance with EN 61340-4-1 and EN 1081:

- the leakage resistance of floors in controlled areas should typically be within the range of 1×10^5 to 1×10^8 Ω;
- the test method, electrode configuration and environmental conditions, including temperature and humidity, shall be clearly defined and documented in the test report.
-

During operation, the following practices shall be observed:

- avoiding the use of mats, coverings or coatings with insulating properties;
- using cleaning agents that do not form insulating surface layers;
- providing multipoint bonding of the floor to the earthing system, appropriate to the floor area;
- performing periodic measurements of floor leakage resistance.

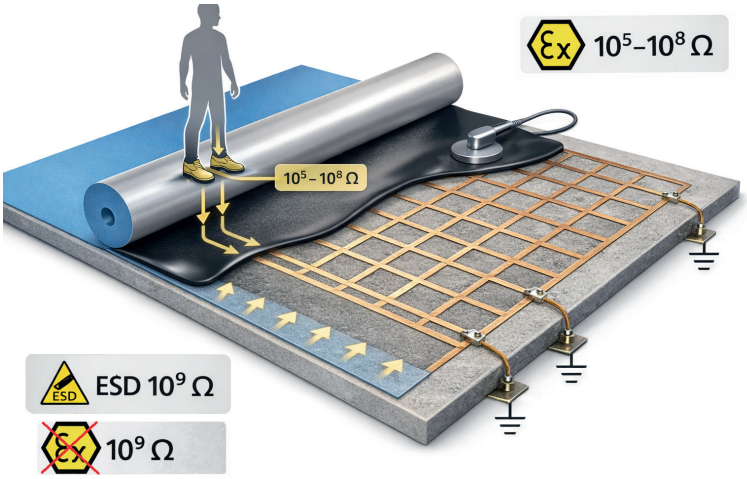


Figure 8-1.

Floors Dissipative floor system in hazardous areas enabling controlled electrostatic charge dissipation from personnel to the earthing system via the human–footwear–floor path, with leakage resistance in the range of 10^5 to 10^8 Ω in accordance with EN 61340-4-1 and EN 1081.

A resistance range of 10^5 to 10^8 Ω ensures effective dissipation of electrostatic charges within a time frame relevant to ignition hazard prevention. Resistance ranges commonly applied in Protection against electrostatic hazards for electronic components, extending up to 10^9 Ω, are not designed with explosive atmosphere ignition conditions in mind and shall not be directly transferred to hazard assessments in Ex areas. This distinction is often overlooked in practice, particularly where ESH requirements originally developed for electronics protection are applied without adaptation to explosive atmosphere conditions.

8.2. Footwear

Footwear used in hazardous areas shall enable the controlled dissipation of electrostatic charges from the human body to the floor and subsequently to the facility earthing system. The effectiveness of this process depends on the interaction between the footwear and a floor with appropriate electrostatic properties.

According to EN ISO 20345, antistatic footwear is defined by an electrical resistance in the range of 1×10^5 to 1×10^9 Ω. However, for applications in explosive atmospheres, the use of footwear with resistance limited to the range of 1×10^5 to 1×10^8 Ω is recommended, as this range ensures effective charge dissipation within a time frame relevant to ignition hazard prevention.



Figure 8-2.

Footwear resistance testing at the entrance to a hazardous area. An operator checks the electrostatic resistance of footwear using a dedicated testing station before entering a hazardous area. Such controls help ensure effective dissipation of electrostatic charge from the human body through footwear and the floor, reducing the risk of ignition.

In practical applications, the following measures are recommended:

- verification of footwear resistance by measurement, particularly after periods of use;
- use of control devices at entrances to higher-risk areas to measure the resistance of the human-footwear-floor system;
- consideration of the effects of wear, contamination and humidity on the electrostatic performance of footwear.

8.3. Clothing

Clothing used in hazardous areas shall limit the accumulation of electrostatic charges on the human body, particularly during operations associated with increased electrostatic charging. Although clothing is rarely a direct ignition source, inadequate electrostatic properties may significantly hinder the dissipation of charge from the human body to earth.

To reduce electrostatic hazards, the following measures are recommended:

- use of fabrics incorporating conductive or dissipative fibres;
- selection of materials with controlled electrostatic properties, taking into account the influence of ambient humidity;
- avoidance of removing, opening or rapidly handling clothing within Zones 0, 1, 20 and 21;
- periodic inspection of clothing condition, particularly after laundering and during service life.



Figure 8-3.

Antistatic protective clothing used in a hazardous area. The worker is wearing antistatic protective clothing designed to limit electrostatic charge accumulation on the body. When combined with suitable footwear and a dissipative floor, such clothing supports a continuous and controlled path for electrostatic charge dissipation to earth.

Summary

The effectiveness of electrostatic protection of personnel depends on the continuity of the system: human body–clothing–footwear–floor–earth. Inadequate parameters of any of these elements may interrupt the charge dissipation path and lead to the accumulation of electrostatic charge to a level relevant to ignition risk.

Most common errors

- use of insulating floors within hazardous areas;
- use of untested, worn or contaminated footwear;
- uncritical transfer of electronics ESD protection requirements to explosive atmospheres;
- use of high-resistivity clothing without monitoring its condition during service.

ESH Checkpoint



Floors, footwear and clothing

ACCEPTABLE

- Floors have dissipative properties appropriate for hazardous (Ex) areas.
- Footwear and workwear allow electrostatic charges to be dissipated.
- Continuity of the human-footwear-floor-earthing system is ensured.

NOT ACCEPTABLE

- Applying requirements intended for electronics ESD protection without reference to electrostatic ignition hazards.
- Lack of periodic verification of the electrostatic parameters of floors and footwear.

CRITICAL

- Use of insulating floors or footwear in hazardous (Ex) areas.
- Lack of access control for personnel entering hazardous areas.

Floor (Ru)	Footwear (R)	Assessment for hazardous areas (example)	Comment
10^5–10^6 Ω	10^5–10^7 Ω	Favourable system – short relaxation time	Effective charge dissipation, assuming other installation requirements are met.
10^7–10^8 Ω	10^5–10^8 Ω	Commonly acceptable, requires verification by measurement	Monitoring of the human-footwear-floor system recommended; footwear testers at access points.
≥ 10^9 Ω (floor)	10^5–10^8 Ω	Unfavourable	Even with suitable footwear, charge may persist; corrective actions required.
10^5–10^8 Ω	≥ 10^9 Ω (footwear)	Unfavourable	Footwear acts as an insulator; dissipative footwear required.

Table 4. Example combinations of "human–footwear–floor"

Ionisation

9

Air ionisation is a supplementary measure used to limit the accumulation of electrostatic charge on large surfaces of insulating materials, in particular:

- plastic films and sheets;
- webs, belts and continuous material strips;
- extensive surfaces of insulating coatings.

Ionisation is based on introducing ionised air into the vicinity of the charged surface, enabling neutralisation of electrostatic charges accumulated on insulating materials for which direct charge dissipation by earthing is not feasible.

The effectiveness of ionisation is local and depends on whether the ionised airflow actually reaches the charged surface. Operational experience shows that the effectiveness of ionisation is often overestimated, particularly in installations where airflows are disturbed by machine guards, enclosures or ventilation systems.

Ionisation systems should be:

- selected according to the technological process and the properties of the processed material;
- installed at an appropriate distance and orientation relative to the surface to be neutralised;

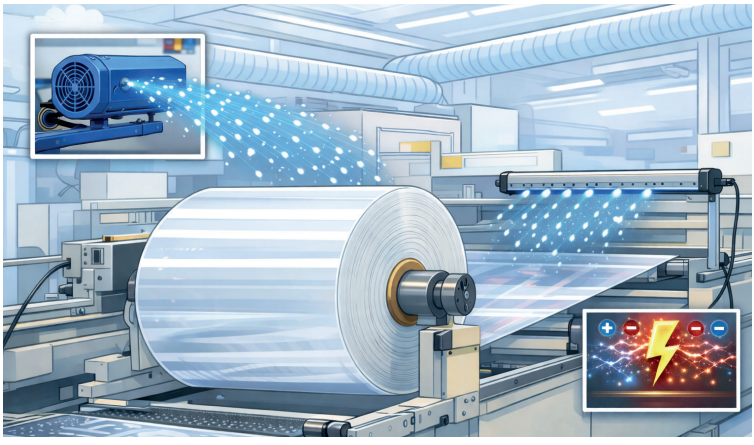


Figure 9-1.

Air ionisation for electrostatic charge control on continuous insulating materials. Ionising air is directed onto a moving plastic film to neutralise electrostatic charges on large insulating surfaces where earthing is not possible. Ionisation supports charge control locally and must be correctly positioned, maintained and verified; it does not replace basic measures such as earthing and bonding.

- operated in accordance with the manufacturer's instructions, including regular cleaning and maintenance;
- periodically verified by effectiveness measurements, such as charge decay time or electrostatic field strength.

Summary

Ionisation does not replace fundamental electrostatic protection measures such as earthing, dissipative flooring, and appropriate footwear and clothing. It is a complementary solution, applied where large insulating surfaces are present, and should be treated as part of a broader electrostatic protection system.

Most common errors

- treating ionisation as a substitute for earthing;
- incorrect positioning of ionisers relative to the charged surfaces;
- lack of verification of system effectiveness;
- operation of ionisation devices without regular cleaning and maintenance.

ESH Checkpoint



Ionisation

ACCEPTABLE

- Ionisation is used as a supplementary measure in the presence of large insulating surfaces.
- Ionising systems are correctly positioned and regularly maintained.
- The effectiveness of ionisation is periodically verified by measurements.

NOT ACCEPTABLE

- Treating ionisation as a substitute for earthing or equipotential bonding.
- Lack of control over the operational effectiveness of ionising devices.

CRITICAL

- Use of ionisation as the sole protective measure in high ignition risk processes.
- Operation of faulty, damaged, or contaminated ionisers.

Flexible Intermediate Bulk Containers (FIBC)

10

Flexible Intermediate Bulk Containers (FIBCs, big bags) are available in several types, differing in their electrostatic properties and conditions of safe use:

- **Type A** – containers without any special electrostatic properties;
- **Type B** – containers with limited dielectric strength of the fabric;
- **Type C** – containers incorporating a conductive structure intended for earthing;
- **Type D** – containers with dissipative properties, not requiring earthing, subject to strictly defined conditions of use.

Figure 10.1

Type A – Big Bag containers without any special electrostatic properties during bulk material loading



The selection of the appropriate FIBC type shall always take into account:

- the **minimum ignition energy (MIE)** of the handled or stored bulk material;
- the **explosion group** and **classification of the hazardous area**;
- material flow conditions and the nature of the technological process.

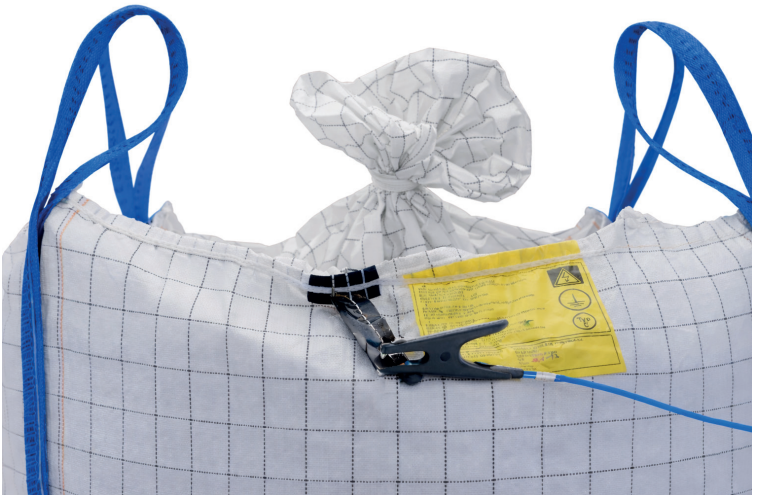


Figure 10.2

Type C – containers incorporating a conductive structure intended for earthing; the earthing clamp is connected to the designated earthing point.

In practical operation:

- **Type C FIBCs** require an effective and continuous connection to earth prior to the start of filling or emptying and throughout the entire operation;
- **Type D FIBCs** may be used without an earthing conductor only under the conditions specified in the manufacturer's documentation and in compliance with applicable standards and guidelines; they do not eliminate all electrostatic hazards and require strict operational discipline.

In practice, deviations from these requirements most frequently occur during short-duration or non-routine operations, where earthing discipline is relaxed or incorrectly assumed.

Summary

The use of an inappropriate FIBC type may lead to electrostatic discharges with sufficient energy to ignite a dust-air cloud.

Selection of FIBCs shall always be based on an assessment of the material's minimum ignition energy, the hazardous area classification, and the characteristics of the technological process.

Most common errors

- selecting the FIBC type without analysis of MIE and hazardous area classification;
- using Type C FIBCs without effective earthing;
- using Type D FIBCs outside the conditions permitted by the manufacturer;
- treating FIBCs as inherently "self-safe" equipment.

ESH Checkpoint

Flexible intermediate bulk containers (FIBC)



✓ ACCEPTABLE

- Selection of the FIBC type is based on the analysis of the MIE, hazardous area classification, and the nature of the process.
- Type C FIBCs are earthed before the operation starts and remain earthed throughout the operation.
- Type D FIBCs are used only under conditions permitted by the manufacturer.

⚠ NOT ACCEPTABLE

- Selection of FIBCs without reference to the properties of the dust and the actual process conditions.
- Treating type D FIBCs as a universal solution regardless of electrostatic hazards.

⊗ CRITICAL

- Use of an inappropriate FIBC type in the presence of explosive atmospheres.
- Performing operations with type C FIBCs without effective earthing.

FIBC type	Electrostatic hazard characteristics	Typical applications	Limitations / remarks
A	No special electrostatic hazard–related properties	Materials with high MIE, outside Ex areas	Not suitable in the presence of explosive gas, vapour or sensitive dust clouds
B	Limited dielectric strength	Dusts with higher MIE, lower-risk areas	No conductive discharge path; insufficient for very low MIE materials and many Ex zones
C	Earthed container (conductive structure)	Filling/emptying powders in Zones 1, 21, 22	Requires reliable earthing before and during operation; earthing path must meet defined criteria
D	Dissipative container	Use in zones with defined explosion group limitations	No earthing cable required, but strict application limits apply; manufacturer's requirements must be followed

Table 5. Example selection of flexible FIBCs

Maintenance and control measurements

11

Maintaining the effectiveness of protection against electrostatic hazards requires regular technical inspections and systematic control measurements of the applied protective measures. These activities constitute an integral part of the operation of industrial installations, particularly in hazardous areas.

The scope of inspections and measurements should include, as a minimum:

- resistance of earthing paths;
- contact resistance between metallic parts of equipment and process installations;
- leakage resistance of floors;
- resistance of the person–footwear–floor system;
- surface and volume resistivity of dissipative materials and coatings;
- operational parameters of earthing monitoring systems;
- effectiveness of ionisation systems, assessed by charge decay time or electrostatic field strength.



Figure 11.1

Measurement of earthing resistance using the 3-pole method with clamp meters, performed without disconnecting the test joint, particularly recommended for explosive atmospheres.



Figure 11.2

A technician measures the leakage resistance of a floor using a test meter and a weighted electrode to verify electrical safety.

The scope and frequency of measurements shall be adapted to the nature of the technological processes, the intensity of operation and the results of the explosion risk assessment, and shall be reviewed whenever changes are introduced to the installation or its mode of operation.



Figure 11.3

Measurement of earthing resistance using clamp meters.

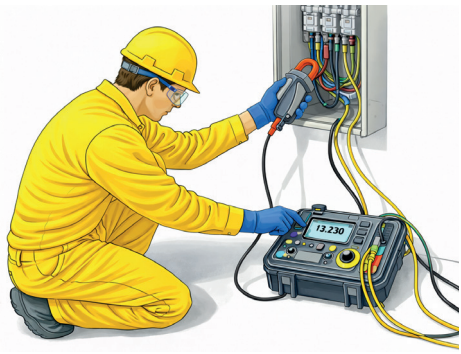


Figure 11.4

Technician measuring continuity and resistance of protective earthing conductors (PE) in an electrical distribution board using a clamp-on measuring instrument.

Measurement results shall be:

- documented in formal reports specifying the applied test method and measurement conditions;
- compared with previous results in order to identify trends and gradual degradation;
- analysed for deviations indicating corrosion, mechanical damage, material ageing or changes in installation configuration.

Summary

The absence of systematic inspections and measurements may lead to a gradual loss of effectiveness of electrostatic protection measures without the operator's awareness. Proper organisation of measurements and result analysis constitutes a fundamental element of systematic ESH safety management in industrial installations.

Most common errors

- lack of regular measurements or performing them only sporadically;
- failure to analyse trends in measurement results;
- omission of measurement conditions in documentation;
- treating a single measurement as confirmation of long-term effectiveness.

Recommended inspection and measurement frequencies

The frequency of inspections and measurements of electrostatic protection measures shall be defined based on the explosion risk assessment, process characteristics and operational experience. As a minimum, the



Figure 11.5

Walking Test – Measurement of electrostatic charge accumulation on the human body while walking on antistatic flooring, in accordance with PN-EN 61340-4-5.



Figure 11.6

Measurement of resistance to ground through a person standing in protective footwear on an antistatic floor.

following schedule is recommended.

Element / parameter	Commissioning / acceptance	Periodic inspection	After changes or incidents
Earthing path resistance (equipment, tanks, pipelines)	Mandatory	At least annually	Mandatory
Bonding continuity between metallic parts	Mandatory	At least annually	Mandatory
Earthing clamps, cables and connection points	Mandatory	Every 6-12 months	Mandatory
Leakage resistance of floors in hazardous areas	Mandatory	Every 12-24 months	Mandatory
Resistance of footwear (person-footwear-floor system)	Mandatory	According to site rules, typically daily or at entry	Mandatory
Surface / volume resistivity of dissipative materials and coatings	Mandatory	Every 12-24 months	Mandatory
Earthing monitoring systems (functional test)	Mandatory	Every 6-12 months	Mandatory
Ionisation systems (charge decay / field strength)	Mandatory	Every 6-12 months	Mandatory
FIBC earthing connections (type C)	Mandatory	Before each operation	Mandatory
Visual inspection of ESH-relevant elements	Mandatory	Routine, operator-based	Mandatory

Table 6. Recommended frequency of inspections and measurements for electrostatic hazard control

NOTE: Shorter intervals may be required for installations operating continuously, exposed to corrosion, mechanical damage, contamination, or handling substances with very low minimum ignition energy (MIE).

ESH Checkpoint

Maintenance and inspections



ACCEPTABLE

- Regular inspections and measurements of the effectiveness of electrostatic hazard control measures are defined and implemented.
- Measurement results are documented together with the applied method and test conditions.
- Trends in measurement results are analysed over time.
- Functional tests of monitoring systems are performed periodically.

NOT ACCEPTABLE

- Measurements performed irregularly or without a defined frequency.
- Lack of comparison of results with previous measurements.
- Lack of documentation of measurement conditions.
- Limiting functional checks to visual inspection only.

CRITICAL

- Lack of verification of earthing effectiveness during operation.
- Continuation of operation despite negative measurement results or active monitoring system alarms.
- Loss of earthing or equipotential bonding connections without process shutdown.
- Lack of inspections after installation modifications or after potentially hazardous events where electrostatic ignition may have occurred.

Operational practices

12

In addition to technical protection measures, the effectiveness of electrostatic hazard control largely depends on proper execution of technological operations and consistent compliance with established operating rules. Operational practices represent the final and critical layer of protection, determining the actual level of safety during day-to-day plant operation.

Basic operational principles include:

- prohibition of liquid transfer or bulk material handling without prior and effective earthing of tanks, drums, road tankers and containers;
- limitation of liquid flow velocity during the free-flow phase in accordance with defined process requirements;
- earthing of mobile equipment such as trolleys, frames, temporary structures and tools;
- application of transfer, mixing and conveying techniques that minimise turbulence and excessive material drop heights;
- control of insulating objects within the working area, particularly plastic packaging, mats and unnecessary covers;
- correct selection, use and maintenance of personal protective equipment, including electrostatically dissipative footwear and clothing;
- regular training of personnel to recognise operational situations that promote electrostatic charge generation and accumulation.



Figure 12.1

The illustration depicts a liquid pumping operation in which each drum is electrically bonded and earthed prior to the initiation of liquid transfer. In this case, the drums are being emptied, and effective earthing ensures controlled dissipation of electrostatic charges generated during liquid discharge, preventing hazardous charge accumulation.



Figure 12.2 Operational practice – visual indication of earthing status. The earthing system is equipped with an interlock that prevents material transfer if earthing is not effective. A visual indication informs the operator about the earthing status, supporting correct operation and confirming that transfer conditions are met.

Summary

The effectiveness of normative and technical measures depends on their consistent application during routine operation. Well-defined operating procedures and systematic personnel training are essential complements to technical solutions within an overall electrostatic hazard control system.

Common mistakes

- bypassing procedures during routine or time-critical operations;
- relying solely on operator experience without formal rules;
- lack of refresher and periodic training;
- tolerance of temporary or improvised organisational solutions.

ESH Checkpoint



Operational practices and training

ACCEPTABLE

- Documented operating procedures addressing electrostatic hazards are in place.
- Personnel are regularly trained in electrostatic hazard awareness and control, appropriate to their tasks.
- Compliance with procedures is supervised.

NOT ACCEPTABLE

- Relying solely on operator experience without formal procedures.
- Tolerating deviations from established rules and procedures.

CRITICAL

- Lack of training and procedures in installations with explosion hazards.
- Deliberate bypassing of technical or organisational safeguards.

Responsibilities and roles in electrostatic hazard control

13

Effective protection against electrostatic hazards requires clearly defined responsibilities at all organisational levels. Electrostatic safety is not solely a technical issue but a coordinated management, operational and maintenance responsibility.

Plant management / employer

- Provides the organisational, technical and financial resources necessary to implement and maintain an electrostatic hazard control system.
- Ensures that electrostatic hazards are addressed within the overall safety management system and the Explosion Risk Assessment.
- Approves this guideline and ensures its application in all areas exposed to electrostatic risk.
- Ensures access to competent personnel with appropriate knowledge of electrostatic hazards.

Process technology / process engineering

- Identifies processes, operations and technological parameters relevant to electrostatic charge generation and accumulation.
- Assesses the impact of technological, material and process changes on electrostatic hazards.
- Participates in the selection of Protection against electrostatic hazards measures appropriate to the process and material properties.
- Provides data required for the preparation and updating of the Explosion Risk Assessment and related documentation.

HSE / fire protection / ATEX functions

- Supervise compliance of applied solutions with legal requirements and applicable standards.
- Coordinate the development, updating and review of documentation related to electrostatic hazards.
- Initiate corrective and preventive actions in the event of non-conformities or incidents related to electrostatic hazards.
- Participate in the investigation of incidents and near-miss events related to static electricity.



Maintenance / technical services

- Are responsible for the technical condition of earthing systems, bonding connections and other Protection against electrostatic hazards measures.
- Ensure periodic measurements, inspections and verification of Protection against electrostatic hazards effectiveness.
- Correct identified technical non-conformities within defined timeframes.
- Document inspection, measurement and maintenance activities.

Line supervisors / foremen

- Provide day-to-day supervision of Protection against electrostatic hazards practices at workplaces.
- Ensure compliance with procedures and work instructions.
- Respond to identified deviations and initiate corrective actions.
- Report incidents and near-miss events related to electrostatic hazards.

Employees

- Apply electrostatic protection principles defined in this guideline and workplace instructions.
- Use Protection against electrostatic hazards measures in accordance with their intended purpose.
- Report observed irregularities, damage or doubts regarding the effectiveness of Protection against electrostatic hazards.

Common organisational failures in electrostatic hazard control

- Blurred responsibilities between departments (no clearly assigned ESH owner).
- Treating Protection against electrostatic hazards solely as a technical issue without operational oversight.
- Failure to update the Explosion Risk Assessment after technological or material changes.
- Lack of communication between process engineering, HSE and maintenance.
- Limiting ESH activities to the design phase without operational control.
- No response to warning signals, alarms or near-miss events.
- Shifting responsibility for electrostatic hazard control solely onto line-level personnel.

ESH Checkpoint



Responsibilities and roles

ACCEPTABLE

- Roles and responsibilities for electrostatic hazard control are clearly defined.
- Responsibilities are communicated and understood within the organisation.
- Protection against electrostatic hazards is integrated into the safety management system.

NOT ACCEPTABLE

- Unclear allocation of responsibilities between departments.
- Lack of oversight of duties related to electrostatic hazard control.

CRITICAL

- No formally assigned responsibility for electrostatic hazard control.
- No organisational response to Incidents related to electrostatic hazards or near-miss events.

Earthing monitoring devices and systems

14

Earthing monitoring systems are applied to ensure continuous verification of the effectiveness of earthing connections in technological installations where electrostatic hazards are present. Their purpose is not to improve the quality of earthing itself, but to promptly detect loss or degradation of the earthing connection and to prevent operation of the process under unsafe conditions.

Such systems provide:

- automatic verification of earthing continuity;
- continuous supervision of earthing path resistance;
- transmission of earthing status signals to process control systems.

Typical functions of earthing monitoring systems

Earthing monitoring systems typically include:

- verification of compliance with the defined earthing resistance criterion (e.g. $R \leq 10\ \Omega$);
- visual and audible indication of correct earthing status and fault conditions;
- capability to inhibit the start or continuation of a technological process in the event of insufficient earthing;
- recording of states and events for technical analysis and safety audits.



Figure 14-1.

Earthing monitoring device for road tanker unloading. An earthing monitoring system continuously verifies the earthing connection between the road tanker and the facility earthing system. The device provides visual indication of earthing status and is integrated with process interlocks to prevent unloading if the earthing connection is lost or does not meet the required resistance criteria.

In installations with elevated risk levels—such as tanker unloading, filling of low-conductivity liquids with low minimum ignition energy, or filling of flexible intermediate bulk containers (FIBC) in Zones 1 and 21–earthing monitoring systems represent a critical layer of protection against electrostatic ignition hazards.

Summary

The application of earthing monitoring devices reduces risks arising from operational errors and discontinuities in earthing connections. Integration of these systems with process interlocks enforces the principle that a technological process shall not be started or continued unless effective earthing is confirmed.

Common failures

- treating earthing monitoring systems as optional equipment;
- lack of integration with process interlocks;
- ignoring alarm indications;
- failure to analyse and utilise recorded event data.



Figure 14.2

Dedicated grounding point on a tanker truck, used to connect grounding systems and prevent electrostatic discharge during loading and unloading operations.

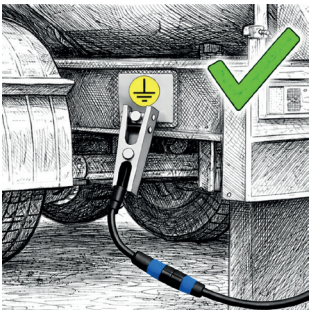


Figure 14.3

Dedicated grounding point located at a different position on the tanker truck, used for connecting grounding systems and preventing electrostatic discharge during loading and unloading operations.



Figure 14.4

Incorrect grounding connection. The indicated location is not a dedicated grounding point and must not be used for grounding tanker trucks during loading or unloading operations.

Process area / location	Monitored object	Monitoring function	Recommended action if earthing is lost
Road tanker unloading	Tanker, earthing clamp	Continuous measurement of tanker-earth resistance	Pump or valve interlock, visual and audible alarm
Drum / IBC filling	Drum, IBC frame	Verification of earthing continuity	Interlock of pump or dosing valve, “no earthing” indication
Big-bag feeding to mixer	Type C FIBC, suspension frame	Verification of FIBC earthing connection	Blocking of slide gate or bag opening, local alarm
Mixing station in Ex area	Mixer, process vessel	Monitoring of mixer earthing status	Mixer stop or start inhibition if criteria not met
Lines with large foil surfaces	Metallic parts of transport system	Detection of earthing path interruption	Line stop or speed reduction until earthing is restored

Table 7. Examples of process areas and functions of earthing monitoring systems.

ESH Checkpoint

Earthing monitoring systems

✓ ACCEPTABLE

- Continuous monitoring of earthing path resistance throughout the entire operation,
- Automatic inhibition of process start or continuation when safety criteria are not met,
- Recording of events and alarm states for technical analysis and audits.

⚠ NOT ACCEPTABLE

- Reliance solely on manual checks without continuous technical supervision,
- Lack of integration between earthing monitoring and process automation.

⊗ CRITICAL

- Possibility to start or operate the process without effective earthing,
- Disabling or ignoring alarm signals during operation.



Figure 14.5

Multipoint earthing monitoring system for drum filling operations. The operator connects earthing clamps to metal drums, while a multipoint earthing monitoring system allows several earthing connections to be monitored by a single control unit. The system continuously verifies earthing status, provides visual indication, and prevents filling if the earthing criteria are not met.

Final summary

15

This guide presents the principles for the design, operation and maintenance of industrial installations in which there is a risk of ignition or explosion related to the presence of electrostatic charges. The document addresses in particular the following topics:

- mechanisms of electrostatic charge generation and fundamental physical relationships;
- the role of earthing and equipotential bonding as primary measures for controlling electrostatic hazards;
- requirements related to the transfer and filling of flammable liquids, handling of bulk solids, and pneumatic conveying;
- principles for the selection, use and operation of floors, footwear, clothing and materials with dissipative properties;
- application of supplementary measures such as air ionisation and flexible intermediate bulk containers (FIBC);
- the significance of earthing monitoring systems and process interlocks;
- requirements for inspections, maintenance, control measurements and operational practices.

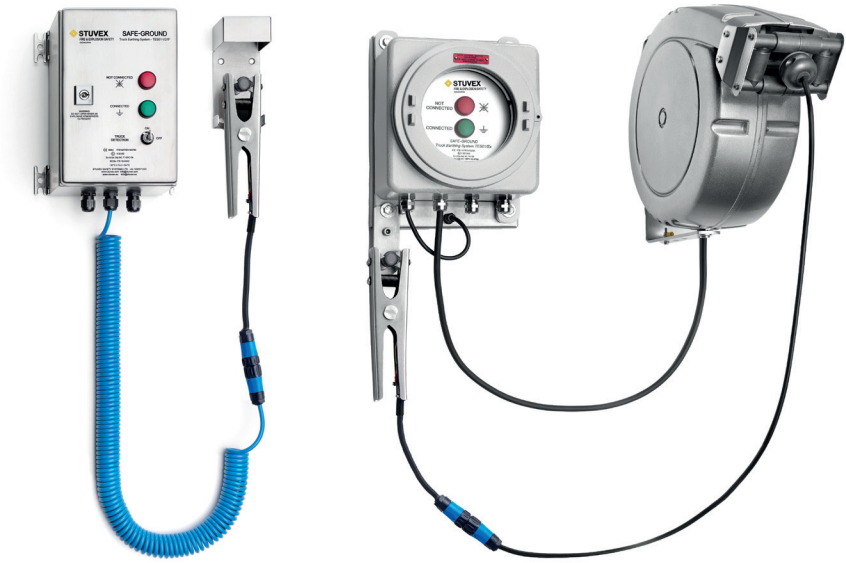


The content reflects recurring findings from industrial audits and assessments, where electrostatic hazards were identified not as isolated technical issues, but as a combination of design choices, operational practices and maintenance discipline.

The objective of this document is to support designers, operators and technical services in the selection, implementation and maintenance of electrostatic protection measures in accordance with applicable standards and recognised industrial good practice.

Application of the principles described herein, combined with a properly conducted explosion risk assessment, systematic control measurements and regular ESH audits, enables a significant reduction in the likelihood of ignition of explosive atmospheres caused by electrostatic discharges. Protection against electrostatic hazards should be regarded as a continuous process, requiring ongoing attention during the design, operation and maintenance phases of industrial installations.

This guide is intended to provide technical guidance and does not replace applicable legal or normative requirements.



Annex A – earthing monitoring systems and their integration with the process control system

A.1. Introduction

In industrial installations where operations generating electrostatic charges are performed, the mere provision of an earthing connection is not sufficient unless it is accompanied by continuous verification of the quality and continuity of that connection during operation.

Operational experience from industrial installations shows that loss of earthing continuity is one of the most frequent initiating factors in electrostatic near-miss events, particularly during non-routine or short-duration operations.

IEC/TS 60079-32-1 clearly indicates that in operations with an increased level of risk, such as the filling and emptying of road tankers, handling of low-conductivity liquids, transfer of powders, or mixing of flammable materials—technical measures should be applied to minimise the possibility of operational errors. This includes the use of automatic systems for monitoring the earthing condition.

Earthing monitoring systems:

- confirm correct connection of the object to earth;
- verify compliance with the defined earthing resistance criterion;
- monitor continuity of the connection throughout the entire operation;
- can be integrated with process automation systems to enable interlocks;
- significantly reduce ignition risk resulting from human error.

This annex presents a practical approach to the selection and integration of earthing monitoring systems, with particular emphasis on solutions designed for use in hazardous areas. An example of such an approach is represented by industrial-grade earthing monitoring systems, such as the Safe-Ground family (Stuvex), applied in process plants requiring a high level of integration between Protection against electrostatic hazards and process safety.

A.2. Normative requirements for earthing control

According to IEC/TS 60079-32-1, for operations in which the potential energy of an electrostatic discharge may exceed a safe level relative to the minimum ignition energy (MIE), it is necessary to:

- ensure earthing of the object before starting the operation,
- confirm the effectiveness of the earthing connection,
- maintain the connection for the entire duration of the process;
- apply technical measures that minimise the possibility of operator error.

The specification allows both:

- passive solutions, based on manual connection and periodic measurements;
- active solutions, providing continuous monitoring of earthing resistance and connection integrity.

In industrial practice, particularly in high-risk installations, active solutions are considered a natural complement to procedural controls.

A.3. Earthing resistance criterion

In most process installations, the following acceptance criterion is applied:

$$R \leq 10\ \Omega$$

This value:

- ensures rapid dissipation of electrostatic charges;
- is consistent with normative requirements and recognised industrial practice;
- falls within the operating range of typical earthing monitoring systems;
- accounts for variability in environmental and operational conditions.

From a practical audit perspective, resistance values above this level are most often associated with degraded clamps, contaminated contact points or intermittent connections rather than with deficiencies in the earthing concept itself.

In particularly sensitive processes, this criterion is commonly combined with automatic process interlocks.

A.4. Approaches to earthing control – a practical perspective

Various manufacturers offer solutions that meet the same basic normative requirements for monitoring continuity and earthing resistance.

Differences between systems mainly relate to:

- level of integration with the process control system;
- implementation of safety interlocks;
- degree of automation of supervision;
- robustness against operational errors.

For small-scale installations, local point solutions may be sufficient. In more complex applications—such as tanker loading stations, multi-position filling systems, or installations with high personnel turnover—a system-based approach to ESH control becomes essential.

A.5. Typical application areas for earthing monitoring systems

The following examples illustrate typical process locations where the use of earthing monitoring systems represents recognised good engineering practice.

Location / area	Monitored object	Monitoring function	Recommended action in case of loss of earthing
Road tanker unloading	Tanker, earthing clamp	Continuous resistance measurement and object identification	Pump/valve interlock, visual and audible alarm
Drum / IBC filling	Drum, IBC frame	Continuity monitoring	Pump start interlock
Big-bag filling (FIBC Type C)	FIBC, suspension frame	Monitoring of FIBC earthing connection	Slide valve lock, alarm
Mixing stations	Mixer, process vessel	Earthing status monitoring	Mixer stop
Lines with large plastic surfaces	Metallic line components	Detection of interruption in earthing path	Line stop

Table A.1. Example process locations and earthing monitoring functions

A.6. Integration of earthing monitoring systems with the process

A.6.1. Tanker loading and unloading stations

A typical sequence includes:

1. Connection of an active earthing clamp to the road tanker.
2. Automatic measurement of earthing resistance.
3. Additional object verification (e.g. capacitive identification).
4. Indication of readiness status.
5. Process release by the control system.
6. Continuous monitoring during the operation.
7. Immediate shutdown upon loss of connection.

Object identification, characteristic of systems such as Safe-Ground, significantly reduces the risk of incorrect connection and enhances operational safety.

In practice, the effectiveness of this sequence depends not only on correct system configuration, but also on consistent operational discipline and regular verification after maintenance work or configuration changes.

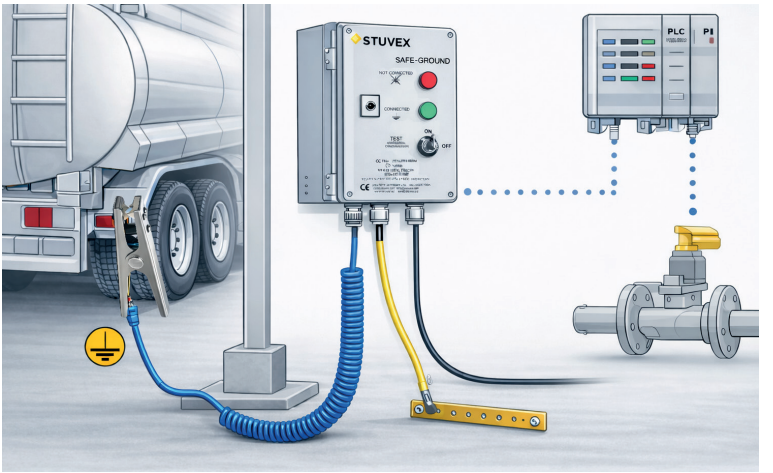


Figure A1

The drawing shows a grounding controller that monitors the tanker-to-earth connection and sends a status signal to the PLC; CONNECTED means the grounding is valid (relay closed), while NOT CONNECTED means grounding is missing or lost (relay open), and the PLC uses this signal as a safety interlock to allow or block the transfer.

A.6.2. Drums, IBCs and multi-position stations

In multi-position installations, the system monitors all earthing circuits in parallel. Failure of any single circuit results in interlocking of the entire process.



A.7. Functional requirements for earthing monitoring systems

Parameter	Requirement	Typical implementation
Earthing resistance	R ≤ 10 Ω	Continuous measurement
Object identification	Required for tankers	Capacitive methods
Continuous supervision	Required	Real-time monitoring
PLC integration	Required	NO/NC outputs
Operation in hazardous areas	Required	ATEX / IECEx certification

Table A.2. Minimum functional requirements

These functional requirements are met by modern industrial-grade earthing monitoring systems designed for use in hazardous areas.

A.8. Selection of systems depending on the process

Process	Risk level	Functional requirements	Example solution class
Tanker loading/ unloading	Very high	Resistance + identification + interlock	Single-object systems (e.g. Safe-Ground TES01)
Drum / IBC filling	High	Parallel monitoring	Multi-channel systems (e.g. MGS01)
Semi-technical operations	Medium	Monitoring and signalling	Point monitoring systems
System validation	–	Resistance and capacitance testing	Test devices (e.g. ReConno1)

Table A.3. Selection of earthing monitoring systems by process

A.9. Periodic inspection and maintenance

Each earthing monitoring system should be subject to:

- functional testing (recommended every 6-12 months);
- inspection of earthing circuits;
- inspection of cables and clamps;
- documentation of results in accordance with explosion protection documentation requirements.

A systematic validation approach significantly facilitates maintenance of normative compliance and preparation for audits.

Annex A – Summary

Earthing monitoring systems constitute a key element of protection against electrostatic hazards in industrial installations. Although commercially available solutions may comply with the same basic normative requirements, differences become evident at the level of system integration, automation and operational risk management.

Industrial-grade systems such as Safe-Ground (Stuvex NV) represent a system-oriented approach in which ESH control is an integral part of process safety. In applications requiring high reliability, advanced integration and engineering support, cooperation with an experienced system solution provider enables selection of a solution tailored to the specific process and risk level.



Figure A2

The drawing shows the TES01 grounding system by StuvEx, connected to the road tanker prior to unloading, before connection of the unloading hose to the tanker outlet nozzle, ensuring proper grounding and electrostatic safety.

Electrostatic Hazard Control – Reliability & Decision Checklist

(for use in Ex areas after identification of electrostatic ignition risk)

Purpose

This checklist supports the evaluation of the reliability of electrostatic hazard control measures and provides decision-oriented guidance where loss of control over earthing may lead to ignition risk.

A. Electrostatic hazard context (risk existence)

Mark YES / NO

☐ 1. Does the process involve mechanisms known to generate electrostatic charge
(e.g. liquid flow, powder transfer, friction, pneumatic conveying)?

☐ 2. Is a potentially explosive atmosphere present or reasonably foreseeable
(e.g. zones 0, 1, 2, 20, 21, 22, including abnormal but foreseeable conditions)?

☐ 3. Is the minimum ignition energy (MIE) of the handled substances low
(flammable gases, vapours, fine combustible dusts)?

B. Earthing and bonding reliability (loss of control)

☐ 4. Are objects requiring earthing mobile or temporarily connected
(e.g. road tankers, drums, IBCs, big bags, trolleys, temporary structures)?

☐ 5. Can continuity of earthing or bonding be lost during normal operation
(e.g. movement, vibration, handling, wear of clamps or cables)?

☐ 6. Is the establishment or verification of effective earthing dependent on manual operator actions
(e.g. manual connection, manual start approval)?

C. Process safeguards (consequence control)

☐ 7. Does loss or absence of effective earthing not result in automatic process interruption
(e.g. no technical interlock, no permissive condition)?

☐ 8. Can process conditions influencing electrostatic risk change over time
(e.g. different products, batch variability, flow rates, environmental conditions)?

D. Operational feedback (evidence)

☐ 9. Have electrostatic-related incidents, alarms or near-miss events been recorded
(e.g. loss of earthing, unexpected discharges without ignition)?

☐ 10. Is the effectiveness of earthing verified only periodically or by visual inspection
(i.e. no continuous verification during operation)?

Interpretation & decision guidance

0–1 × YES
Electrostatic hazard control measures may be considered robust, provided they are correctly designed, implemented and maintained.

2–3 × YES
The reliability of electrostatic risk control measures should be reviewed as part of a detailed electrostatic risk assessment.

4 or more × YES
Loss of control over earthing cannot be excluded. Additional technical and/or organisational measures are strongly recommended to reduce the risk of electrostatic ignition.

Important note

This checklist:

- does not replace an electrostatic risk assessment;
- does not mandate any specific technical solution;
- supports both engineering evaluation and operational decision-making under real conditions.

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