

Hazard Identification and Risk Assessment of Static Electricity in Chemical and Pharmaceutical Industries

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Abstract

Static electricity is a significant process-safety concern in chemical and pharmaceutical manufacturing, particularly during the handling, transfer, mixing, filtration, drying and processing of flammable liquids, powders and other materials capable of generating electrostatic charge. An electrostatic discharge can become an ignition source when a flammable vapor, gas or combustible dust atmosphere is present. IEC TS 60079-32-1 specifically provides guidance for assessing electrostatic hazards and controlling them through measures such as earthing, reducing charge generation and controlling chargeable insulating surfaces. IEC Webstore+1

This research proposes a systematic Hazard Identification and Risk Assessment (HIRA) of static-electricity hazards in chemical and pharmaceutical industries. The study focuses on identifying sources of electrostatic charge, evaluating the likelihood and consequences of electrostatic discharge, assessing existing controls, and developing risk-reduction measures. Particular attention is given to solvent transfer, powder handling, charging and discharging operations, mixing, filtration, drying and storage. The proposed methodology combines workplace observation, process review, interviews, document analysis and HIRA. The research can help organizations strengthen grounding and bonding systems, operating procedures, equipment selection, employee training and process-safety management.

Keywords: Static electricity, electrostatic discharge, HIRA, risk assessment, chemical industry, pharmaceutical industry, solvent handling, fire and explosion, grounding, bonding, process safety.

Introduction

Chemical and pharmaceutical manufacturing processes frequently involve materials and operations capable of generating electrostatic charges. Movement of liquids through pipes, transfer between containers, mixing, pumping, filtration, powder handling and movement of personnel or equipment can produce electrostatic charge.

The hazard becomes particularly important when an electrostatic discharge occurs in the presence of an ignitable atmosphere. OSHA identifies static sparks among potential ignition sources in flammable-liquid operations and requires appropriate precautions against ignition. OSHA

Static electricity can be generated when dissimilar materials move relative to one another. OSHA notes that factors such as transfer speed, humidity and container characteristics can influence the magnitude of charge that develops. OSHA

In chemical and pharmaceutical plants, potential consequences include:

- Fire.
- Flash fire.

- Explosion.
- Dust explosion.
- Solvent-vapor ignition.
- Equipment damage.
- Worker injury.
- Production interruption.
- Chemical release.

Therefore, static electricity should be considered as part of the overall process-safety and risk-assessment program.

Background

Static electricity is an accumulation of electrical charge on an object or material. When the electrical potential difference becomes sufficiently high, the accumulated charge may discharge.

A simplified sequence is:

Charge generation → Charge accumulation → Electrostatic discharge → Ignitable atmosphere → Fire/explosion

IEC TS 60079-32-1 provides guidance for avoiding ignition and electrostatic-shock hazards and specifically identifies earthing, reduction of charging and control of chargeable areas as important measures. IEC Webstore

IEC 60079-32-2 provides test methods relevant to electrostatic hazards, including measurements related to surface resistance, earth-leakage resistance, powder resistivity, liquid conductivity, capacitance and discharge incendivity. IEC Webstore

Objectives

The objectives are:

1. To identify sources of static-electricity generation in chemical and pharmaceutical operations.
2. To identify activities with potential electrostatic-discharge hazards.
3. To assess the risks associated with electrostatic ignition.
4. To evaluate existing grounding and bonding practices.
5. To examine static-electricity risks during solvent handling and transfer.

Literature and Technical Framework

Electrostatic charge generation

Charge can be generated through processes such as:

- Liquid flow.
- Pumping.
- Spraying.
- Mixing.
- Filtration.
- Powder transfer.
- Pneumatic conveying.

- Sliding or rubbing of materials.
- Movement of workers and equipment.

OSHA recognizes that movement of liquids through pipes and movement between containers can generate static charge. OSHA

Electrostatic discharge

A discharge may occur when sufficient potential difference develops between charged and uncharged objects.

Potential discharge mechanisms include:

- Spark discharge.
- Brush discharge.
- Propagating brush discharge.
- Corona discharge.

The hazard depends on factors including the properties of the material, accumulated charge, geometry, environment and characteristics of the surrounding atmosphere.

For a practical plant-level study, the focus should be on whether the discharge could provide an effective ignition source under the actual process conditions.

Static Electricity Hazards in Chemical Industries

Chemical plants frequently handle:

- Flammable solvents.
- Hydrocarbon liquids.
- Volatile organic compounds.
- Combustible powders.
- Reactive chemicals.

Potential high-risk activities include:

Solvent transfer

Pumping or pouring solvent can generate electrostatic charge. OSHA's flammable-liquid requirements specifically address static protection and electrical interconnection during dispensing operations. OSHA

Tank filling

Rapid or poorly controlled filling can contribute to static-charge generation. OSHA requirements for certain flammable liquids include design provisions intended to minimize static generation during tank filling. OSHA

Mixing

Agitation of liquids or suspensions can produce charge.

Filtration

Movement through filters can produce electrostatic charging.

Powder transfer

Movement of powders can produce charge accumulation and, depending on material properties and concentration, potentially contribute to combustible-dust hazards.

Static Electricity Hazards in Pharmaceutical Industries

Pharmaceutical manufacturing may involve:

- Organic solvents.
- Fine powders.
- Active pharmaceutical ingredients.
- Excipients.
- Granulation.
- Milling.
- Blending.
- Drying.
- Fluid-bed processing.
- Powder transfer.

Particular attention should be given to:

Powder transfer → charge generation → charge accumulation → discharge → combustible atmosphere → ignition

The assessment should consider the specific material properties and process conditions rather than assuming that every pharmaceutical powder presents the same level of electrostatic risk.

IEC guidance explicitly covers electrostatic hazards associated with solids, liquids, gases and powders. BSI Knowledge

HIRA Methodology

A five-step HIRA process can be used:

Step 1: Identify the hazard

Example:

Electrostatic charge during solvent transfer.

Step 2: Identify the cause

Possible causes:

- High transfer velocity.
- Poor grounding.

- Inadequate bonding.
- Insulating container.
- Poor equipment maintenance.

Step 3: Determine consequences

Possible consequences:

- Spark.
- Vapor ignition.
- Flash fire.
- Explosion.

Step 4: Assess risk

A simple approach is:

$$\text{Risk} = \text{Likelihood} \times \text{Severity}$$

Step 5: Establish controls

Controls may include:

- Bonding.
- Grounding.
- Controlled transfer.
- Appropriate conductive equipment.
- Inerting where justified by the process.
- Elimination/control of ignition sources.
- Appropriate hazardous-area equipment.
- Procedures and training.

Sample Risk-Assessment Matrix

Severity	Score
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Minor	1
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Moderate	2
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Serious	3
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Major	4
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Catastrophic	5
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Likelihood	Score
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Rare	1
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Unlikely	2
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Severity Score

Possible 3

Likely 4

Almost certain 5

Risk score = Likelihood × Severity

The actual risk categories and acceptance criteria should be defined by the organization and applicable regulatory framework.

Grounding and Bonding

Grounding and bonding are fundamental controls for conductive equipment and transfer operations.

Bonding

1. Grounding and bonding.
2. Static-dissipative equipment where appropriate.
3. Conductive containers where suitable.
4. Controlled liquid-transfer velocity.
5. Closed transfer systems.
6. Appropriate ventilation.
7. Inerting where technically justified.
8. Hazardous-area electrical equipment.
9. Appropriate process instrumentation.
10. Explosion-protection systems where required by the process risk assessment.

IEC TS 60079-32-1 specifically identifies earthing and reduction of charge generation among the methods for controlling electrostatic hazards. IEC Webstore

Administrative Controls

Engineering controls should be supported by:

- SOPs.
- Work permits.
- Pre-job risk assessments.
- Grounding/bonding checklists.
- Employee training.
- Inspection programs.
- Preventive maintenance.
- Incident reporting.
- Near-miss reporting.
- Management of change.
- Periodic HIRA review.

Training should ensure that workers understand **why** grounding and bonding are required, rather than simply instructing them to attach a grounding cable.

Research Methodology

Research design

A **mixed qualitative and quantitative HIRA methodology** is appropriate.

Qualitative component

- Plant observations.
- Operator interviews.
- Safety-professional interviews.
- SOP review.
- Incident investigation.
- HAZOP review.
- Maintenance-record review.

Quantitative component

Where data are available:

- Risk scores.
- Grounding-continuity measurements.
- Number of identified hazards.
- Corrective-action closure rates.
- Incident/near-miss frequency.
- Training completion.
- Inspection compliance.

Data Collection

Primary data

Primary information can be collected through:

- Interviews.
- Questionnaires.
- Site observations.
- Process walkthroughs.
- HIRA workshops.
- Equipment inspections.

Secondary data

Relevant documents include:

- HAZOP studies.
- HIRA records.
- SOPs.

- Incident reports.
- Near-miss reports.
- Grounding-test records.
- Equipment-maintenance records.
- Training records.
- Electrical-area classification documents.
- Emergency procedures.

Data Analysis

The study can use:

Descriptive analysis

- Frequency.
- Percentage.
- Mean.
- Standard deviation.

Risk analysis

- Initial risk.
- Existing safeguards.
- Residual risk.
- Recommended controls.

Qualitative analysis

Interview responses can be coded into themes such as:

- Grounding deficiencies.
- Inadequate training.
- Equipment issues.
- Poor procedures.
- Maintenance problems.
- Management-of-change gaps.
- Solvent-handling risks.
- Powder-handling risks.

Incident-Causation Model

A useful conceptual model is:

Electrostatic charge generation

↓

Charge accumulation

↓

Inadequate dissipation**Potential discharge****Flammable/combustible atmosphere****Ignition****Fire/explosion**

The research should also investigate why the controls failed:

Technical failure + Human factors + Maintenance + Procedures + Management system

This converts the study from simply identifying static electricity as a hazard into a true **risk-management investigation**.

Risk-Control Hierarchy

Controls should preferably follow a hierarchy rather than relying solely on PPE.

Elimination

Remove the operation or material that generates an unacceptable electrostatic hazard where technically feasible.

Substitution

Use a less hazardous material or process where feasible.

Engineering controls

- Grounding.
- Bonding.
- Closed transfer.
- Process control.
- Ventilation.
- Inerting where appropriate.
- Appropriate hazardous-area equipment.

Administrative controls

- SOPs.
- Training.

- Inspections.
- HIRA.
- Permit systems.
- Maintenance.

PPE

PPE should supplement—not replace—effective engineering and process controls.

Conclusion

Static electricity represents an important hazard in chemical and pharmaceutical manufacturing, particularly where flammable liquids, vapors, gases or combustible powders are present. The generation and accumulation of electrostatic charge do not necessarily result in an incident; the risk depends on the possibility of a hazardous discharge occurring under conditions capable of ignition.

A systematic HIRA approach can identify where electrostatic charge is generated, how it accumulates, where discharge could occur and what consequences could result. IEC TS 60079-32-1 provides specific guidance for electrostatic-risk assessment and control, including earthing, reduction of charge generation and management of chargeable materials. IEC Webstore+1

For chemical and pharmaceutical facilities, the most useful approach is to integrate electrostatic-risk assessment into the wider **process safety management system**, rather than treating static electricity as an isolated electrical issue.

The proposed study therefore combines **HIRA + process review + workplace observation + interviews + grounding/bonding assessment + incident analysis** to develop a comprehensive electrostatic-hazard management framework.

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