IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Assessment of Electrostatic Ignition Hazards in Chemical Industries Using Discharge Energy Analysis

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Abstract: *Electrostatic discharge (ESD) remains one of the most elusive and critical ignition sources in chemical plants, where the sudden release of accumulated static electricity can lead to catastrophic fires and explosions. To implement robust safety protocols, this study moves beyond qualitative observations by employing a rigorous, systematic methodology that encompasses hazard identification, the analysis of static charge generation and accumulation, and the precise mathematical calculation of electrostatic discharge energies. The research comprehensively evaluates various high-risk operational domains within a large-scale chemical manufacturing facility, focusing on the processing and transfer of highly flammable solvents such as Methanol, Acetone, and Toluene. By utilizing electrical parameters like streaming current, surface resistance, and capacitance, the study quantitatively calculates the maximum discharge energy across multiple potential generation sources, including plant personnel, plant flooring, process pipelines, and storage materials. These calculated discharge energies are then directly compared against the Minimum Ignition Energy (MIE) of the respective chemicals, such as Methanol's highly sensitive MIE of 0.14 mJ. The findings of this analytical approach highlight specific, critical vulnerabilities within the plant's daily operations. While properly earthed plant personnel and conductive flooring generally dissipated static charges safely, the analysis revealed extreme hazards associated with non-conductive materials. Specifically, ordinary polythene bags (5kg and 50kg capacities) and certain Personal Protective Equipment (PPE), such as non-antistatic hand gloves, exhibited surface resistances exceeding 100 GΩ. This resulted in calculated discharge energies of 10 mJ, which far exceeds the ignition threshold of the handled solvents and poses a severe explosion risk. Ultimately, this research provides a vital, calculation-based framework for safety experts and plant operators. It establishes targeted, practical mitigation strategies—such as the mandatory use of electrostatic dissipative (ESD) footwear, the replacement of insulative packaging with antistatic materials, and strict pipeline velocity controls—thereby significantly reducing the risk of electrostatic disasters in chemical facilities.*

Keywords: Electrostatic Hazard Assessment, Chemical Industry, Discharge Energy Calculation, Minimum Ignition Energy (MIE), Hazardous Flammable Solvents, Quantitative Risk Mitigation, Static Electricity, Electrostatic Discharge (ESD) etc

I. INTRODUCTION

1.1 Background of the Research

The chemical industry in India form a critical base for chemical manufacturing, utilizing cutting-edge fermentation technology and fine synthetic chemistry. These advanced facilities are responsible for producing a wide range of Steroid-Hormone Base APIs and derivatives, such as Hydrocortisones, Prednisolones, and Dexamethasone. During these complex manufacturing processes, the plants handle, store, and process large volumes of highly flammable

DOI: 10.48175/IJARSCT-37815

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liquids (e.g., Methanol, Acetone, and Toluene) and combustible dusts. The extensive use of these hazardous chemicals inherently presents a severe and constant risk of fire and explosion.

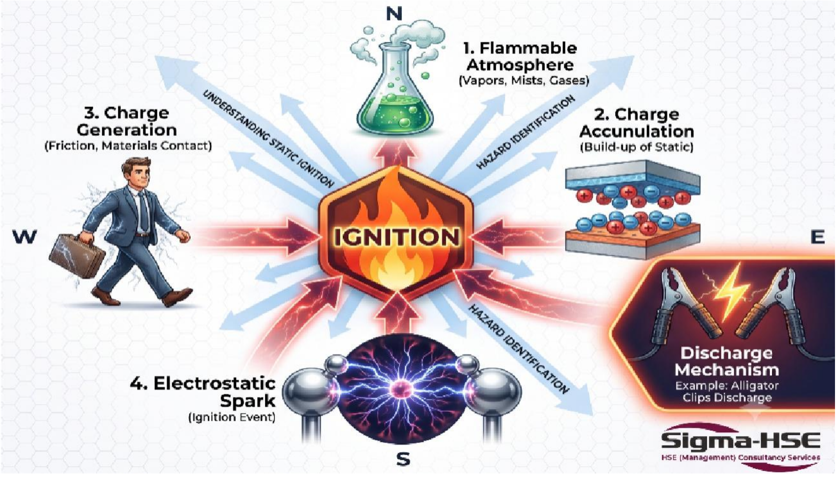

Figure 1.Electrostatic Hazard Assessment

1.2 Problem Statement

One of the most elusive and dangerous ignition sources in chemical processing plants is static electricity. Electrostatic charges are generated through friction, material contact, and separation, particularly when transferring low-conductivity liquids or powders through pipes and hoses, or through the movement of ungrounded plant personnel and equipment. If this accumulated static charge is suddenly discharged within a flammable atmosphere, the resulting spark energy is often sufficient to ignite the chemical vapors or dust clouds, posing a catastrophic threat to personnel, property, and the environment.

1.3 Objectives of the Research

• The primary objective of this research is to conduct a comprehensive Electrostatic Hazard Assessment (ESH) for a chemical manufacturing facility. The specific goals include:
• Understanding and evaluating the flammability and electrostatic properties (such as Minimum Ignition Energy - MIE) of the gases, liquids, and dusts handled on-site.
• Identifying specific operations and locations where flammable atmospheres exist and electrostatic charge generation or accumulation could occur under both normal and abnormal operating conditions.
• Quantifying potential electrostatic discharge energies associated with personnel, equipment, Personal Protective Equipment (PPE), and flooring.
• Reviewing existing control measures and recommending practical, evidence-based solutions (e.g., proper grounding, bonding, and the use of antistatic materials) to eliminate or mitigate the risk of static-caused fires and explosions.

1.4 Scope of the Research

The scope of this assessment is strictly limited to plant operations and locations where flammable materials are actively handled, specifically the Underground/Above Ground Solvent Tank Farms and Manufacturing Units (Unit-01 and Unit-06). The evaluation is based on information provided by Material Safety Data Sheets (MSDS) and on-site electrostatic measurements (including grounding, bonding, and electrical resistance checks) to formulate effective risk control measures

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II. LITERATURE REVIEW

2.1 Introduction to Related Work

The assessment of electrostatic hazards in chemical and pharmaceutical plants has been a critical area of research due to the severe risks of fires and explosions associated with flammable substances. This chapter reviews prominent existing literature on electrostatic risk assessment, prevention strategies, and hazard quantification, while identifying the limitations and research gaps that this current study aims to address.

2.2 Review of Electrostatic Risk Assessment Methodologies

Recent studies have highlighted the importance of systematically identifying static ignition sources in hazardous environments. Sumitomo Kagaku (2024) detailed an electrostatic risk assessment framework for chemical and pharmaceutical plants, emphasizing the need for robust induction programs and safety measures to prevent fires and explosions. However, this study relied primarily on a qualitative and quantitative hazard categorization approach without providing detailed mechanisms of discharge or exact charge calculations, rendering its proposed preventive measures somewhat inadequate.

Sumitomo Kagakuc (2023) focused on the evaluation and prevention of electrostatic hazards through consultation with safety experts and the implementation of basic theoretical countermeasures. While it successfully introduced discharge phenomena, the research only provided simplified examples of charge calculation, lacking advanced mathematical models necessary for complex or unfamiliar industrial processes.

Dr. VahidEbadat (2020) outlined a systematic methodology based on National Fire Protection Association (NFPA) standards to identify hazards related to gas, vapor flammability, and dust explosions. Although it provided a strong foundational approach for conducting hazard assessment surveys under actual operating conditions, it failed to incorporate specific examples with proper mathematical calculations to predict the actual severity of the hazards.

2.3 Electrostatic Properties of Materials and Equipment

Research has also heavily focused on the electrostatic behavior of specific industrial materials.

MarcinJachowicz (2023) studied the electrostatic properties of Personal Protective Equipment (PPE), such as helmets and visors, in explosive atmospheres. The study confirmed that even small PPE items can accumulate hazardous electric charges, though it concluded that further research is required to improve the evaluation and selection methods for PPE in explosion-prone zones.

D Bennett (2021) analyzed the electrostatic risks associated with various plastic containers and Intermediate Bulk Containers (IBCs) used for flammable liquids. The study highlighted the ignition hazards posed by highly insulating plastics; however, the findings are limited as they do not apply to modern IBC designs and completely excluded the critical aspect of electrostatic hazard assessment for plant personnel.

Figure2. Incident due to Electrostatic Charge

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M. Glor (2022) reviewed electrostatic ignition hazards associated with flammable gases, vapors, mists, and dusts across common industrial operations. While current knowledge is sufficient for standard processes, Glor noted that the constant evolution of new chemical processes and increasingly hazardous operating conditions continually introduce unresolved challenges for future electrostatic hazard assessments.

2.4 Identified Research Gaps

Based on the extensive review of the existing literature, several critical research gaps have been identified, which form the rationale for the current study:

Sr.No	Author & Year	Primary Focus of the Study	Identified Research Gap / Key Issue
1	Sumitomo Kagaku (2024)	Electrostatic risk assessment for chemical and pharmaceutical plants to prevent fire and explosion.	Relies on a purely qualitative and quantitative approach to identify hazards but does not explain how the discharge occurs or calculate the exact amount of charge generated. Proposed preventive measures are inadequate.
2	Sumitomo Kagakuc (2023)	Evaluation and prevention of electrostatic hazards, focusing on practical and theoretical control measures.	Provides only brief knowledge about static discharge and charge calculations using oversimplified examples. It lacks advanced calculation models for complex or unfamiliar processes.
3	Dr. VahidEbadat (2020)	Systematic approach and methodology for identifying electrostatic hazards (gas/vapor flammability, dust explosions).	Only describes the basic conducting methodology for hazard assessment surveys. It fails to provide specific examples with proper mathematical calculations to predict the actual seriousness of the hazards.
4	MarcinJachowicz (2023)	Electrostatic hazard properties of Personal Protective Equipment (PPE) like helmets and visors in explosive atmospheres.	While it confirms PPE accumulates charge, there is a need for further research to improve the methods for evaluating and selecting PPE specifically for explosion-prone zones.
5	M. Glor (2022)	Electrostatic ignition hazards associated with flammable substances (gases, vapors, mists, dusts).	Although current knowledge covers common processes, the constant development of new processes and more hazardous conditions leaves open questions and unresolved challenges for future electrostatic hazard assessments.
7	D Bennett (2021)	Electrostatic risks associated with various plastic containers and IBCs (Intermediate Bulk Containers) for flammable liquids.	The tests do not apply to current IBC models due to design changes. Most importantly, electrostatic hazard assessment for plant personnel was completely excluded from this study.

Table 1 Research gap based on literatures

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Lack of Precise Calculations: Previous studies (Sumitomo Kagaku, 2024; Sumitomo Kagakuc, 2023; Ebadat, 2020) heavily rely on theoretical guidelines or basic qualitative assessments, failing to provide exact mathematical calculations (such as real-time discharge energy in millijoules) to quantify the precise severity of static hazards.

Incomplete Scope: Studies focusing on specific equipment, such as Bennett (2021), completely neglected the electrostatic hazard assessment of plant personnel, which is a major source of charge generation.

Need for Advanced Mitigation: There is a distinct need for comprehensive studies that not only identify hazards but also bridge the gap between theoretical standards and practical, calculated safety interventions for modern, complex chemical operations (Glor, 2022; Jachowicz, 2023).

III. AREA OF STUDY

3.1 Overview of the Facility

The study was conducted at a prominent steroid chemistry manufacturing facility located in Central India. The plant operates with a complete backward integration to the basic soy sterol molecule, utilizing cutting-edge fermentation technology and fine synthetic chemistry. The facility specializes in manufacturing a wide range of Steroid-Hormone Base APIs and their derivatives, including Hydrocortisones, Prednisolones, Dexamethasone, Betamethasones, Estrogens, and Testosterones. To ensure a high standard of fire and explosion safety, the Electrostatic Hazard Assessment (ESH) was carried out across various departments involving the storage, handling, manufacturing, and packaging of highly flammable liquids and combustible dusts.

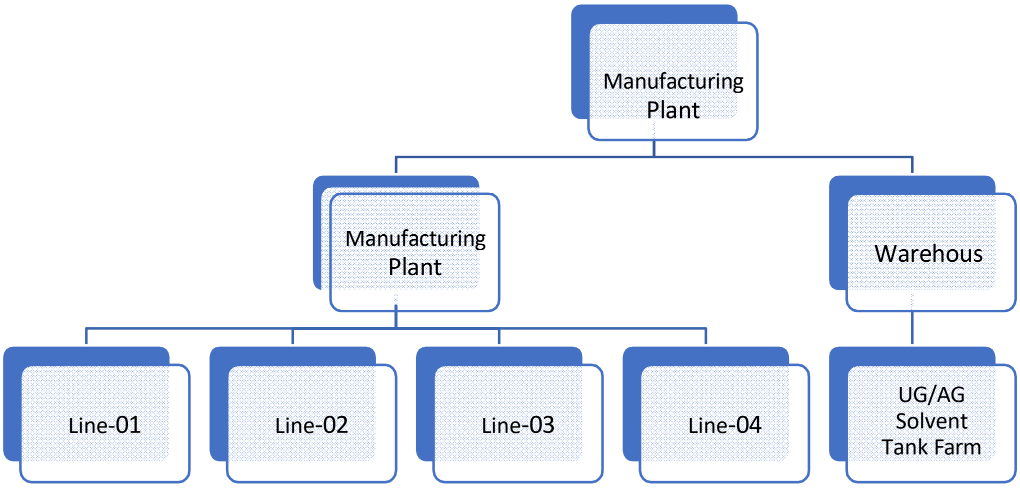

Figure3.System for ESH Assessment

3.2 Targeted Locations for Assessment

The assessment was systematically divided into specific operational zones where hazardous materials are handled. The primary areas assessed include:

Underground/Above Ground Solvent Tank Farm

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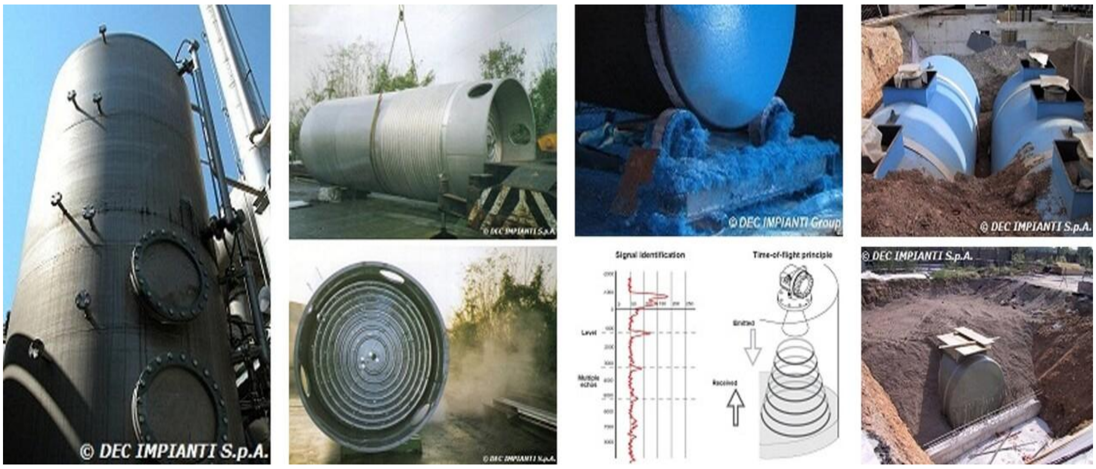

Figure 4.Underground/Above Ground Solvent Tank Farm

Unit-01 Manufacturing Plant
Unit-06 Line-01, Line-02, and Line-03 Manufacturing Plants
Unit-06 Line-04 Manufacturing Plant

3.3 Key Sources of Electrostatic Generation

During the study, several critical sources of static electricity were identified and measured across the targeted locations. These sources include:

Plant Personnel: Movement and involvement of employees handling flammable and combustible chemicals.
Plant Flooring: Floors and surrounding areas of equipment during API processing.
Plant Equipment: Reactors, receivers, flanges, dryers, and centrifuges utilized during processing.
Personal Protective Equipment (PPE): Safety gear, such as hand gloves, aprons, and protective suits worn by employees.
Poly Bags: Containers (5 kg and 50 kg polythene bags) used for storing intermediates and finished goods.

Sr.No.	Source of Generation	Activity
1.	Plant Personnel	Movement of employee and their involvement for handling of flammable andCombustible chemicals.
2.	Floor of Plant and Surrounding area of PlantEquipment.	Processing of API by using several of flammable and combustible chemicals.
3.	Plant Equipment.	Processing of API by using several of Flammable and combustible chemicals.
4.	Personnel ProtectiveEquipment.	PPE worn by Employees
5.	Poly Bags.	Storing of Intermediates and Finished Goods

Table 2 Source of Static Electricity

3.4 Operational Hazard Analysis by Area

3.4.1 Underground/Above Ground Solvent Tank Farm:

This area stores highly flammable liquids with low flash points and low electrical conductivity. The major electrostatic ignition hazards occur during the unloading of road tankers and sampling procedures. The study focused on evaluating the grounding/bonding of tanks and associated pipework, the use of electrostatic dissipative (ESD) footwear by unearthed operators, and controlling pipeline flow speeds for non-conductive liquids like Methanol to prevent dangerous charge accumulation.

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3.4.2 Unit-01 Manufacturing Plant:

Unit-01 conducts critical operations including charging via Powder Transfer Systems (PTS), main reactions, distillation, filtration (centrifugation), drying via Rotary Vacuum Dryers (RVD), and packing. Major static generation occurs due to high rotational speeds in RVDs and the pneumatic transfer of powders. Because Methanol's conductivity is critically low, the presence of flammable atmospheres is mitigated using inert gas blanketing (Nitrogen or Argon) to keep the oxygen concentration below explosive limits.

3.4.3 Unit-06 Manufacturing Plant (Lines 01, 02, 03, & 04):

Similar to Unit-01, these lines handle significant volumes of highly flammable solvents (Methanol, Toluene, Methylene Dichloride, and SBP) to manufacture Steroid APIs and intermediates. The electrostatic hazards are associated with manual charging through manholes, the pneumatic transfer of combustible powders, and liquid accumulation inside reactors. The assessment emphasizes maintaining solvent conductivity pathways to the earth and strictly avoiding splash filling or adding powders during high-speed agitation to minimize spark risks.

IV. PROBLEM IDENTIFICATION AND FORMULATION

4.1 Problem Identification:

The fundamental problem identified in this study revolves around the severe fire and explosion risks introduced by static electricity in chemical manufacturing environments. The specific issues identified within the facility include:

Handling of Highly Combustible Materials: The plant extensively processes highly flammable liquids (such as Methanol, Acetone, and Toluene) and combustible dusts that possess critically low Minimum Ignition Energies (MIE), making them highly susceptible to ignition.

Continuous Charge Generation: Routine manufacturing operations, including high-speed fluid pumping, pneumatic powder conveying, filtration, and drying in Rotary Vacuum Dryers (RVD), continuously generate significant electrostatic charges through friction and material contact.

Charge Accumulation on Insulators: The facility utilizes various non-conductive materials that act as capacitors and accumulate static charge. This includes the use of non-conductive plastic bags for storing intermediates, epoxy-coated flooring with high electrical resistance, and non-antistatic Personal Protective Equipment (PPE) worn by operators.

Hazardous Discharge Potential: When isolated conductors or ungrounded personnel carrying accumulated static charge come into contact with grounded objects, a rapid and energetic electrostatic discharge (such as a spark or brush discharge) occurs. The core problem is that this discharge energy often exceeds the MIE of the surrounding flammable atmosphere, creating an imminent risk of a catastrophic event.

4.2 Problem Formulation

To systematically address the identified hazards, the research problem is formulated around quantifying the electrostatic risks and designing appropriate mitigation strategies. The core challenge is to mathematically and practically evaluate whether the generated static charge in various plant zones translates into a viable ignition source. The problem can be formulated into the following specific research questions and parameters:

Hazard Quantification: How can the facility accurately measure and calculate the maximum electrostatic discharge energy (Emax in millijoules) generated by plant personnel, flooring, and equipment (e.g., using parameters like resistance, capacitance, streaming current, and voltage drops)?

Comparative Risk Analysis: Does the calculated accumulated discharge energy from specific sources (such as a non-conductive poly bag with resistance exceeding 100 G-ohms) exceed the Minimum Ignition Energy (MIE) of the lowest consumable solvent (e.g., Methanol at 0.14 mJ)?

Infrastructure Evaluation: Are the existing grounding and bonding systems mathematically and physically adequate to safely dissipate static charges to the earth (maintaining resistance below the prescribed limit of 10 ohms for equipment)?

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Mitigation Strategy Development: What specific engineering controls, material substitutions (such as electrostatic dissipative bags and antistatic PPE), and operational changes (such as controlling fluid velocity below 5 m/s) must be implemented to ensure the discharge energy remains well below the hazardous threshold?

V. METHODOLOGY ADOPTED

A common ignition source within Chemical plants is sparks resulting from static charge build up and sudden discharge. Static electricity is perhaps the most elusive of ignition sources. Despite considerable efforts, serious explosions and fires caused by static ignition continue to plague the chemical process industry. Electrostatic Charge Assessment shall be followed as

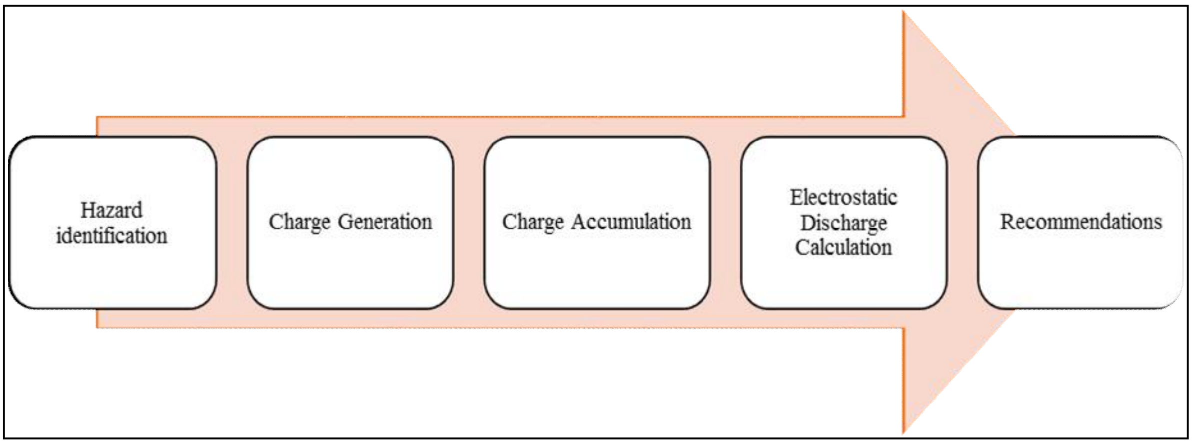

Figure 5. Process for ESH Assessment

Step No-1 Hazard Identification:

The first step for electrostatic hazard assessment is to identify the hazard. Which type of chemicals is being used in the facility, flammability properties of the particular chemicals?

Following below tentative information needs to be furnished before assessment.

Sr.No.	Gases, Liquid &Vapours	Powder &Dusts
1)	Flash Point	Particle Size
2)	LFL&UFL	MIE
3)	MIE	MIT
4)	Electrical Conductivity	Resistivity
5)	AIT	Charge Relaxation Time
6)	VapourDensity	LOC

Table3 Hazard Identification

Step-2-Charge Generation:

The second step is to identify the source of generation from where it can be generated.

a) Most common charging mechanism is contact charging.

b) At least one of the materials must be non-conducting (insulating).

c) Other mechanisms-charge sharing, induction charging (only for conductors).

Step No-3 Charge Accumulation:

1. There are four charge accumulation processes that are relevant to dangerous electrostatic discharges in a Pharmaceutical plants:

2. Contact and frictional charging:

3. Double-layer charging:

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4. Induction charging:
5. Charging by transport:

Step No-4 Electrostatic Discharge Calculation
Five types of industrial electrostatic discharges, as follows:
1) Spark Discharge -Occurrence
Charged isolated conductor
Energy = 0.5 x C x V2 can be up to 100 mJ
2) Brush Discharge-Occurrence
If charges of one polarity are distributed on the surface of an insulator, brush discharges can occur as soon as the surface of an earthed electrode nears the surface.
Energy Associated is 3-4mJ
3) Propagating Brush Discharge -Occurrence
High charging situations on high resistivity materials. Insulator with metal close by.
Energy Associated is >1000 mJ
4) Corona Discharge- Occurrence
Highly charged conductor or insulator away from earth points
Usually with a sharp point or edge
Energy
Not established
Very low, << 0.1 mJ
5) Cone Discharge - Occurrence
These discharges are observed in connection with charged and highly insulating bulk solids filled into silos and containers;
Cone discharges aren't usually observed in dust volumes below 1 m3.
Luminous discharges may propagate along the surface of the powder heap
Energy
Up to ~25 mJ for fine powder
6) LightningType Discharge – Occurrence
Lightning is a massive electrostatic discharge between electrically charged regions within clouds, or between a cloud and the Earth's surface;
Occur in atmosphere with very large clouds compared to industrial plant.
7) Electrostatic Discharge Calculation:
$Vmax = IR$
$Vmax = Voltageinkilovolts.$
$I = CurrentinampereA$
$R = Resistanceinkilovolts$
$Emax = \frac{1}{2}$ CV2
$Emax{=}DischargeEnergyinmillijoule$
$C{=}Capacitanceofojectinpicofarad$
$v{=}Voltageinkilovolts$

Step No-5 Recommendation
The availability of ventilation has an influence on the Recommendations will be based on good engineering practices like earthing bonding, ionizing and inclusion of basis of safety like inerting system etc

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VI. ELECTROSTATIC HAZARD ASSESSMENT

Step-1- Hazard Identification: - The first step for electrostatic hazard assessment is to identify the hazard. Following below chemicals are handled and used in Manufacturing Plant Unit-06 Line-01, 02, 03 & 04.

Sr.No.	Material	Flash Point (^oC)	Flammable Limits (%)	Minimum Ignition Energy in MJ
1)	Methanol	11	6-36	0.14
2)	Acetone	-20	2.5-12.8	1.15
3)	Toluene	4	1.1-7.1	0.24

Table4.Hazard Identification for Unit-06

Step-2- Charge Generation:-

Following below sources of static electricity shall be measured in above mentioned area so that effective preventive measures can be recommended accordingly.

Sr. No.	Source of Generation	Activity
1	Plant Personnel	Movement of employee and their involvement forhandling of flammable and combustible chemicals.
2	Floor of Plant andSurrounding area of Plant equipment.	Processing of API by usingseveral of flammable andcombustible chemicals.
3	Personnel Protective Equipment.	PPE worn by Employees
4	Poly Bags.	Storing of Intermediates andFinished Goods
5	Plant Equipment.	Processing of API by using several of flammable andcombustible chemicals.

Table 5.ElectrostaticChargeGenerationfor Unit 06

Step-3- Charge Accumulation:

Following below example for accumulation of Electrostatic charge

Sr. No.	Source of Generation	Activity	Charge Accumulation
1	Plant Personnel	Movement of employee and their involvement for handling of flammable and combustible chemicals.	Footwear
2	Floor of Plant and Surrounding area of Plant equipment.	Processing of API by using several of flammable and combustible chemicals.	Plant Flooring
3	Personnel Protective Equipment.	PPE worn by Employees	Hand Gloves, Protective Suit, Apron,
4	Poly Bags.	Storing of Intermediates and Finished Goods	Poly Bag Capacity 5 Kg & 50 Kg
5	Plant Equipment.	Processing of API by using several of flammable and combustible chemicals.	Reactor, Receiver, Flanges, Dryer & Centrifuge

Table6.ElectrostaticChargeAccumulationforPlant

Step-4- Electrostatic Discharge Calculation:

1) Electrostatic Discharge Calculation for Plant Personnel-

Personnel working in the plant can generate electrostatic charges on their body by walking, participating in various manufacturing operation or working near highly charge items. If the person is not connected to earth, during normal activity the charge could develop to hazardous level. For this reason many companies that handle flammable have a policy to all those operator who may be exposed to flammable atmosphere. A Random sample of footwear was checked using insulation tester and special hand electrode assembly to establish operator’s resistance to earth. Electrostatic

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discharge shall be measured in milli joule if itis found less than the MIE of lowest consumable solvent then there will not be any issue but if it is higher than the MIE then effective control measures needs to be taken immediately. Calculation for electrostatic discharge shall be calculated:

$Vmax = IR$

$Vmax = Voltage\ in\ kilo\ volts.$

$I = Current\ in\ ampere\ A$

$R = Resistance\ in\ kilo\ volts.$

During measure resistance was found R = 4.75 MΩ= 4.75 x 106 Ω

Based on ohm law we can find out Vmax

In industrial operation I does not exceeds 10-6A then

$Vmax = 10-6 \times 4.75 \times 106$

$\boldsymbol{Vmax = 4.75 Volts}$

After that

$Emax$ = ½ CV2

$Emax = Discharge\ Energy\ in\ milli\ joule$

$C = Capacitance\ of\ object\ in\ picofarad$

$v = Voltage\ in\ kilovolts$

$C = The\ Capacitance\ of human\ body\ genrally\ considered\ 200x10-12$

Then

$Emax$ = ½ CV2 After calculation $\boldsymbol{Emax} = 2.256 \times 10-6mj$

This is significantly lower than the energy required to ignite a flammable liquid (Methanol MIE- 0.14 mj); therefore there is no hazard.

Sr. No.	Name of Employee	Department	Result- Avg. Resistance to Earth	Remark s	Recommended Limit
1	XYZ	Plant	4.65 MΩ	Properly Earthed	105Ω- 108Ω

Table7 Electrostatic Discharge Calculation for Plant Personnel

2) Electrostatic Discharge Calculation for Floor of Plant and Surrounding area of Plant equipment

$\boldsymbol{Emax} = 968 \times 10-6mj$

This is significantly lower than the energy required to ignite a flammable liquid (Methanol MIE- 0.14 mj); therefore there is no hazard.

Sr. No.	Name of Equipment	Department	Result- Avg. Resistance to Earth	Remarks	Recommended Limit
1	CF-02 area (Epoxy Coated)	Unit-01	10 GΩ	Floor resistance is found to be greater than range	106Ω- 108Ω

Table 8 Electrostatic Discharge Calculation for Floor of Plant

3) Electrostatic Discharge Calculation for Personnel Protective Equipment-

$\boldsymbol{Emax} = 10mj$

This exceeds the energy required to ignite a flammable liquid (Methanol MIE- 0.14mj); therefore there is extreme hazard and Material for hand gloves was not in antistaticin nature.

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4) Electrostatic Discharge Calculation for Poly Bags-

$\boldsymbol{Emax}=10mj$

This exceeds the energy required to ignite a flammable liquid (Methanol MIE- 0.14mj); therefore there is extreme hazard and Material for Poly Bag was not in antistatic in nature.

Sr. No.	Name of PPE or Material	Department	Result- Avg. Resistance to Earth	Remarks	Limit
1	Orange Hand Gloves	Unit-01	>100 GΩ	Orange Hand Gloves is not antistatic /static dissipative type.	<1011Ω
2	50 kg Polythene Bag	Warehouse	>100 GΩ	50 kg Polythene Bag is not antistatic /static dissipative type.	011Ω

Table9. Electrostatic Hazard Result for PPE and Poly Bags

5) Electrostatic Discharge Calculation for Plant Equipment-Through the pipeline-

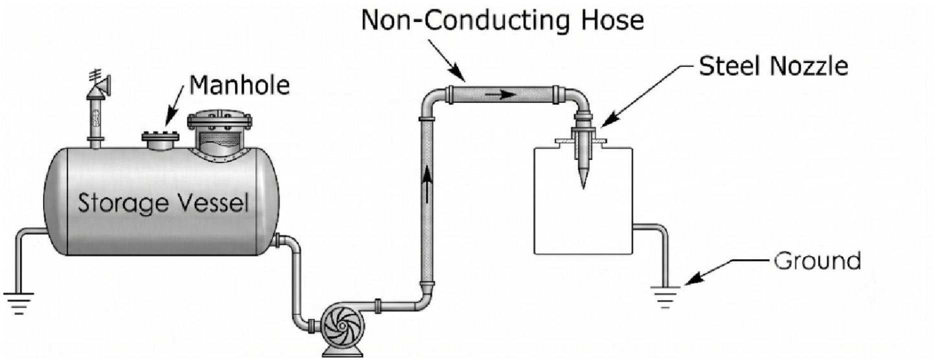

Figure5.1; Electrostatic Hazard for Process Pipe Line

Sr. No.	Name of Equipment	Department	Result-Avg. Resistance to Earth	Remarks	Limit
1	SSR-01	Unit-01	0MΩ	Properly Earthed	10 Ω

Table10. Electrostatic Hazard Result for Plant Equipment

VII. RESULT

Results for electrostatic charge have been analyzed for all the departments and its recommended limits were also verified

7.1 Electrostatic Hazard Result for Plant Personnel (Note: - 1 MΩ=106 Ω , 1 GΩ=109 Ω)

Sr. No.	Name of Employee	Department	Result- Avg. Resistance to Earth	Remarks	Limit
a)	P1	Unit-01	4.65MΩ	Properly Earthed	105Ω-108Ω
b)	P2	Unit-06	4.5MΩ	Properly Earthed	105Ω-108Ω
c)	P3	Unit-06	4.4MΩ	Properly Earthed	105Ω-108Ω
d)	P4	Unit-06	4.75MΩ	Properly Earthed	105Ω-108Ω

Table 11. Electrostatic Hazard Result for Plant Personnel

7.2 Electrostatic Hazard Result for Flooring in Plant

Sr. No.	Name of Equipment	Department	Result-Avg. Resistance To Earth	Remarks	Limit
a)	HSA-01	Unit-01	44MΩ	Floor resistance is found to be	10^6Ω-

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

				Within range	$10^8\Omega$
b)	CF-01/03	Unit-01	4.15MΩ	Floor resistance is Found to beWithin range	$10^6\Omega$-$10^8\Omega$
c)	CF-02 area (Epoxy Coated)	Unit-01	10GΩ	Floor resistance is found to be greater than range	106Ω-108Ω
d)	ANFD-02	Unit-06	10.7MΩ	Floor resistance is found to be Within range	106Ω-108Ω
e)	GLR-02	Unit-06	1.17GΩ	Floor resistance is found to be greater than range	106Ω-108Ω
f)	HAS-01	Unit-06	47.5MΩ	Floor resistance is found to be Within range	106Ω-108Ω

Table 12. Electrostatic Hazard Result for Flooring in Plant

7.3 Electrostatic Hazard Result for Plant Equipment

Sr. No.	Name of Equipment	Department	Result- Avg. Resistance to Earth	Remarks	Limit
a)	SSR-01	Unit-01	0MΩ	ProperlyEarthed	10Ω
b)	Flange	Unit-01	0MΩ	ProperlyEarthed	10Ω
c)	REC-01	Unit-01	0.04MΩ	Earthingneeds to be check as it is More than limit	10Ω
d)	REC-03	Unit-01	0MΩ	ProperlyEarthed	10Ω
e)	GLR-01	Unit-01	0MΩ	Properly Earthed	10Ω
f)	CF-01	Unit-01	0MΩ	Properly Earthed	10Ω
g)	CF-03	Unit-01	0MΩ	Properly Earthed	10Ω
h)	ANFD-02	Unit-06	0MΩ	Properly Earthed	10Ω
i)	GLR-02	Unit-06	0MΩ	Properly Earthed	10Ω
j)	SSR-02	Unit-06	0MΩ	Properly Earthed	10Ω
k)	HAS-01	Unit-06	0MΩ	Properly Earthed	10Ω

Table 13. Electrostatic Hazard Result for Plant Equipment

7.4 Electrostatic Hazard Result for PPE and Poly Bags-

Sr. No.	Name of PPE or Material	Department	Result- Avg. Resistance to Earth	Remarks	Limit
a)	Orange Hand Gloves	Unit-01	>100GΩ	Orange Hand Gloves is not antistatic/static dissipative type.	$<10^{11}\Omega$
b)	Yellow Hand Gloves	Unit-01	97GΩ	Yellow Hand Gloves is antistatic/static dissipative type.	$<10^{11}\Omega$
c)	Green Hand Gloves	Unit-06	>100GΩ	Green Hand Gloves is not antistatic/static dissipative Type.	<1011Ω
d)	Antistatic Suit	Unit-06	26.2MΩ	Antistatic Suit is antistatic /staticdissipative type.	<1011Ω
e)	White Apron	Unit-06	4.4GΩ	White Apron is antistatic	1011Ω

IJARSCT

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International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 3, July 2026

Impact Factor: 8.2

				/static dissipativetype.	
f)	50kgPolythene Bag	Warehouse	>100GΩ	50 kg Polythene Bag is not antistatic/static Dissipative type.	011Ω
g)	5kgPolytheneBag	Warehouse	>100GΩ	5kgPolythene Bag is not antistatic/staticDissipative type.	011Ω

Table 14. Electrostatic Hazard Result for PPE and Poly Bags

VIII. CONCLUSION

This research presents useful information about Electrostatic Hazard Assessment. A single spark can easily destroy the entire plant. Chemical manufacture plant consumes lot of highly flammable liquid and has greater risk of fire and explosion. Static charge now has become the most favorable causes for occurring a fire or explosion in chemical industry. This dissertation systematically examined and quantitatively assessed electrostatic hazard for various process operation. In this dissertation is has been assessed that how electrostatic charged is generated, accumulated and how much energy is released during charge transfer and how could be its impact than after what effective control measures can help to minimize the risk of electrostatic charge. Field measurement and walk though survey also imparted to get the correct information about the static charge. This report will help to the organization to assess electrostatic hazard assessment and preventive measure to reduce its venerable risk.

IX. RECOMMENDATIONS

1. It is recommended to carry out lightening arrestor survey as per IS2309 in order to install lightening arrester.
2. Ensure that no vegetation is present around the chemical storage/tank farm area.
3. Ensure strip should not be painted to maintain proper connectivity.
4. Ensure that time delay of at least 10 minutes before opening manhole for sampling of road tanker to relax electrostatic charges, accumulated on sampling material, especially low conductivity materials. If liquid contains a second immiscible liquid phase (greaterthan0.5% by vol) or solid particulate (Greater than 10 mg/l), then 30 minutes of time delay is recommended. However, during this retention time, the road tanker should be earthed securely.
5. No transfer activities should take place in the tank farm are a when there is the possibility of lightning.
6. Ensure that personnel working in potentially flammable such as sampling of road tankers, unloading operation etc. are earthed with the resistance to earth of less than 1 x 108 ohms. Provide electrostatic dissipative (ESD) footwear to personnel working in the storage tank area.
7. Ensure the display of an installation board for earthing while unloading solvent from tanker.
8. It is essential that the maximum pipeline flow is limited to less than 7 m/sec for low conductive liquids to avoid turbulence in the pipeline as this could lead to the static charge generation in the pipe.
9. It is recommended to use hoses which are made from insulating material with an earthed metal spiral embedded in the wall to avoid occurrence of propagating brush discharges during the pneumatic transfer of powder through hoses
10. Linear flow velocity of methanol used in unit 1 should be checked. Thisshould be less 5 m/s to avoid turbulence inside the reactor /centrifuge.
11. Non-conductive plastic bags should not be used for charging of powders in PTS system of the reaction vessels (Unit-1). Replace it with electro static dissipative plastic bags or paper bags (i.e. Antistatic) and ensure that proper earthing is provided to static dissipative bags. Conductivity of existing plastic bags is mentioned in the above table.
12. As Uni-1 & 6 plant fall under zone 2 classification. Non FLP (Flame Proof) fittings should not be used.
13. Allen bolts were found missing from flame proof fittings. This defeats the purpose of providing flameproof fitting. It is recommended to provide the same.

14. Final product is stored in polythene bag & conductivity is >100 G ohms replace it with electrostatic dissipative plastic bags or paper bags (i.e Antistatic) and ensure that proper earthing is provided to static dissipative bags during unloading of the final products.
15. It is observed at site that earthing strips are mostly painted which will prevent appropriate dissipation of stored static charge. Consider removal of panting for proper dissipation.
16. Proper earthing should be given to all glass line reactors to avoid static charge generation.
17. Nuts and bolts earthing pits area found rusted which prevent proper dissipation of static charge to earth. Ensure proper maintenance of earthing pit for smooth dissipation of static charge.
18. It was indicated that the earth resistance is checked periodically. It is suggested that at each & every pit following information should be displayed as per electricity act which is mandatory.
19. Ensure that proper colour code of the pipeline as per IS 2379 is maintained throughout the plant.
20. In the plant area personnel were found using mobile phone in the process areas. It is suggested that the use of cell phones in flammable area should be banned. Instead of cell phones flameproof walkie talky can be used. Proper training about flammability hazard is required.
21. It was observed that weighing machine kept in Unit-1 & 6 process areas has electrical connection of non-flame proof type. It is recommended to provide flameproof electrical fittings as production area will fall under Zone-2
22. It is statutory requirement to provide guards for the various machines under various section of the factories act 1948. This is also one of the basic safety needs.
23. It is suggested that a detailed survey to be carried out to ascertain the adequacy of machine guarding and necessary corrective action taken.
24. Resistance of the floor near GLR-2 in line2 was exceeding the range. Reason behind this should be found out and its resistance should be maintained less than 108 ohms as per NFPA 77.
25. Ensure that operator don't remove line from the bag to shake out residual in the mixing vessel.
26. Don't use non-conductive plastic bag for charging of powders through manhole of the reaction vessel: replace it with electrostatic dissipative plastic bag or paper bag. Is is also necessary to provide proper earthing to the static dissipative bags.
27. Earth strips and jump over were found painted. Its shouldn't be painted.
28. Earth strips were not bolted properly near the re-boiler floor exit. It should be properly bolted.
29. Pipe line should be painted asperIS-2379.
30. Replace all non-conductive plastic bags with electrostatic dissipative plastic bags which are present inUni-1 &6. If a line is used inside bag then it should also be made of static dissipative plastic or paper. It is necessary that electrostatic dissipative plastic/ paper bags in conjunction with liner are earthed when being emptied.
31. Ensure that all the reactors and their associated pumps, strainers, pipe work and fittings are earthed properly with the resistance to earth less than10ohms. As methanol are highly nonconductive solvents it is necessary to take precautions against electrostatic sparks while transferring the solvent.
32. Earthing and bonding should be applied prior to filling of flammable product into the drums.
33. Ensure that proper colour code of the pipeline as per IS 2379 is maintained throughout the plant.
34. It is recommended to use static dissipative panel at the entrance of the production block in order to dissipate electrical charge.
35. Ensure that good ventilation is maintained inside the sample storage room and keep exhaust fan always switch on condition.
36. Ensure that socket of switch board are covered with plug to avoid short circuit.
37. Ensure that good ventilation is maintained inside the panel room. Provide proper exhaust system for maintaining the temperature.
38. Ensure that electrical panel doors of are always closed.

ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

39. Ensure proper housekeeping schedule, In order to keep the existing flooring free from the spilled isolative material and to ensure proper earthing of operator.
40. Water spillage was observed in unit 1 near solvent dispensing valves. In case of solvent leakage it can form vapour cloud. Proper draining/ Spill control arrangement has to be done for collection.
41. Ensure metal structural items, fixed equipment and all conducting process items are earthed properly with resistance to earth less than 10 ohms at all times.
42. Ensure that rubber gaskets and plastic sections shall not be lead to metal parts becoming isolated from earth.
43. Flanged joints on equipment or pipe work are normally adequately earthed by means of a bolted connection. Additional earthing straps across flanges can be used to maintain good continuity. It is necessary to remove paint flange surface to ensure adequate continuity.
44. Establish the procedure to check the effectiveness of the earthling of fixed items at regular interval, normally once in year and following every maintenance modification or repair.
45. Provide proper earthling to the weighing machine used in the bagging/packing area.
46. Ensure provide earthling is provided to the PTS system during charging operation.
47. It is suggested to replace non-conductive plastic bags with static dissipative bags with provision of proper earthling to the static dissipative bags.
48. It is suggested to use antistatic/static dissipative bags filter, to avoid static charge accumulation in the bag filter.
49. Provide electrostatic dissipative hand gloves to operators working with flammables as required.

X. FUTURE SCOPE

This dissertation will help us to predict the electrostatic hazard assessment in pharmaceutical industry which will not only prevent to fire and explosion etc. It is also beneficial to unnecessarily loss of product due to sticking with poly bag container and PPE due to static charge in production area. This dissertation is complete information pack to assess electrostatic hazard assessment in all the plant where flammable gas and chemicals are handled. This report will be utilized in chemical and other industries where such similar chemicals are used.

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