Understanding Flammable Liquid Ignition Risks from Static Sources Involving Plastics

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DEKRA Process Safety

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Michigan Safety Conference

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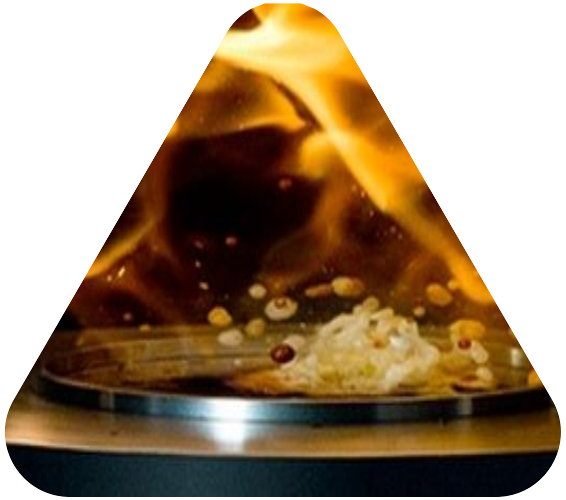


Consulting

Engineering

- Dust Flash Fire & Explosion Hazards
- Gas & Vapor Flammability Hazards
- Electrostatic Hazards
- Chemical Reaction Hazards

Process Safety Management

- Program Implementation & Improvement
- Dust & Process Hazard Analysis
- Incident Investigations
- Consequence Modeling

Laboratory Testing

- Combustible Dust Fire & Explosion
- Gas & Vapor Flammability
- Thermal Instability
- Chemical Reactivity
- Static Electricity
- DOT & UN Transportation of Hazardous Materials
- Explosivity/Energetic Materials

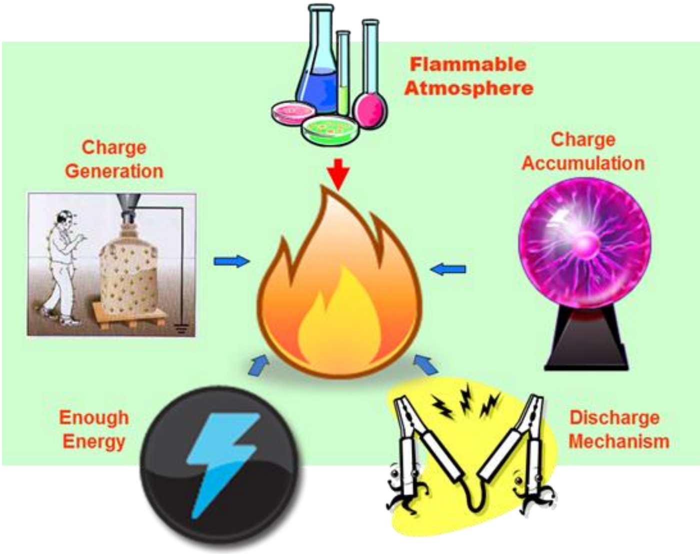
Training & Competency

- Courses Cover Practical Applications & Case Studies
- Standard Topics and Customized Options Available
- On-site and Publicly Held Options

More Info:

Outline for Today's Conversation

- Ignition Risks Viewed through the Fire Triangle
- Electrostatic Hazards Evaluation and Control
- Global Information Sources for Conducting Electrostatics Evaluation
  - NPFA 77 (2024), Recommended Practice on Static Electricity
- Unique Electrostatic & Ignition Hazards of Plastic Containers
  - NFPA 30 (2024), Flammable and Combustible Liquids Code
  - Interior Container Surfaces
  - Exterior Container Surfaces
- Discussion & Conclusion
- Introduce Table of References



Plastics & Flammable Liquids

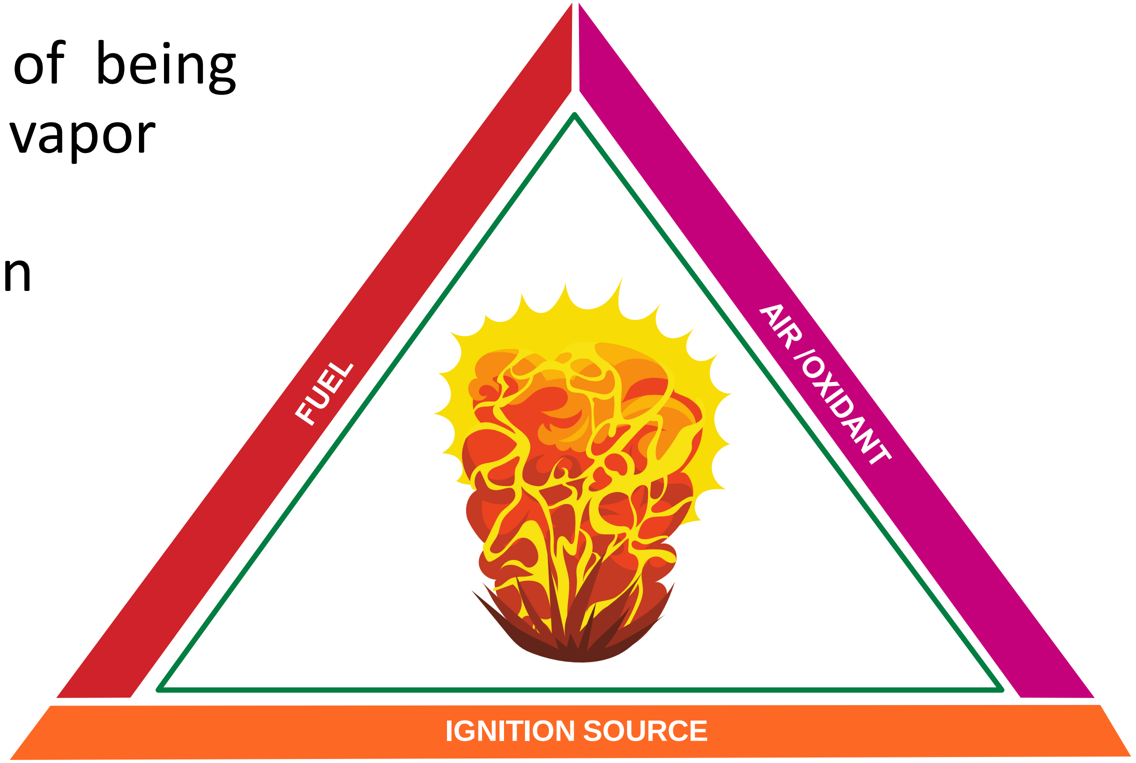
New Emerging Risks over the Past 50 Years

- **NFPA 30 (1969) had limited recognition of plastic containers for flammable & combustible liquids.**
  - Plastic Containers present ignition hazards both Inside & Outside the container.
  - Basis for OSHA 1910.106
- **Users have demanded purer solvents & reagents.**
  - Less Contaminants = Lower Conductivity
  - Concerns about contamination from Dip Pipes.
- **Emerging "Comfort" with Gasoline in Plastic Containers.**
  - The vapor space of most Gasoline Containers is typically Above the Upper Flammable Limit (UFL).
  - Many solvents (particularly alcohols and weathered gasoline) have vapor spaces between LFL & UFL

Ignition Risks: The Fire Triangle

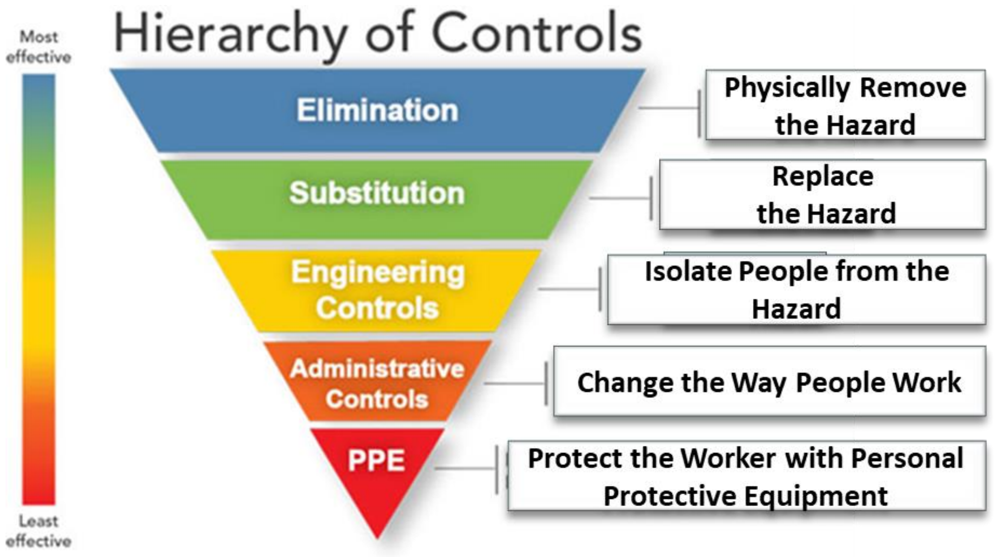
The Foundational "Recipe for Fire" in NFPA 30 and NFPA 660

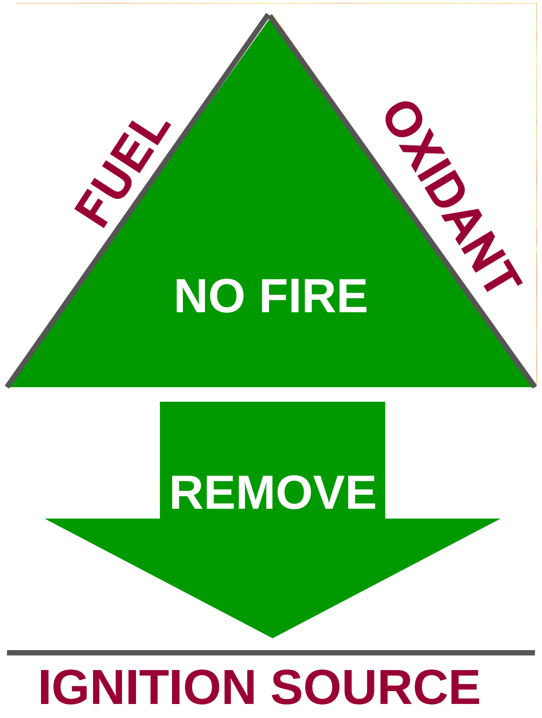
- **FUEL**
  - Liquid (vapor or mist), gas, or solid capable of being oxidized. Combustion always occurs in the vapor phase; liquids are volatized, and solids are decomposed into vapor prior to combustion
- **OXIDANT**
  - A substance which supports combustion.
  - Usually oxygen in air
- **IGNITION SOURCE**
  - An energy source capable of initiating a combustion reaction



Explosion Prevention & Protection

Our Goal is to Establish A Basis of Safety





- Avoidance of flammable atmosphere
- Elimination of (Competent) ignition sources
- Control oxygen concentration
- Provision against consequences of ignition

Fundamental Principles of Static Electricity

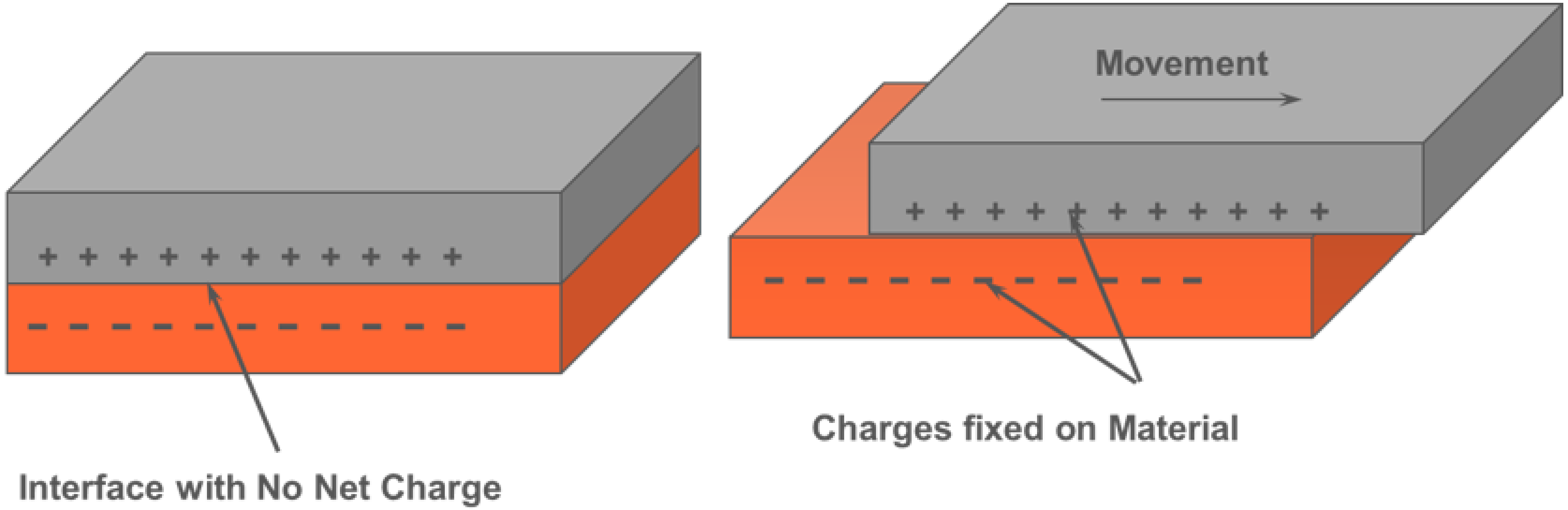
- **Static is Accumulation of electrical charge** on surfaces due to friction or separation of materials.
- **Can produce "sparks"** capable of igniting flammable atmospheres, vapors, gases, or dust.
- **Commonly occurs** with non-conductive (insulating) materials like plastics or synthetic fabrics.
- **Control methods** include grounding, bonding, humidity control, and antistatic treatments.

Electrostatic Charge Generation

Tribocharging

- Electrostatic charges are usually generated when any two materials make and then break contact, with one becoming negative and the other positive.

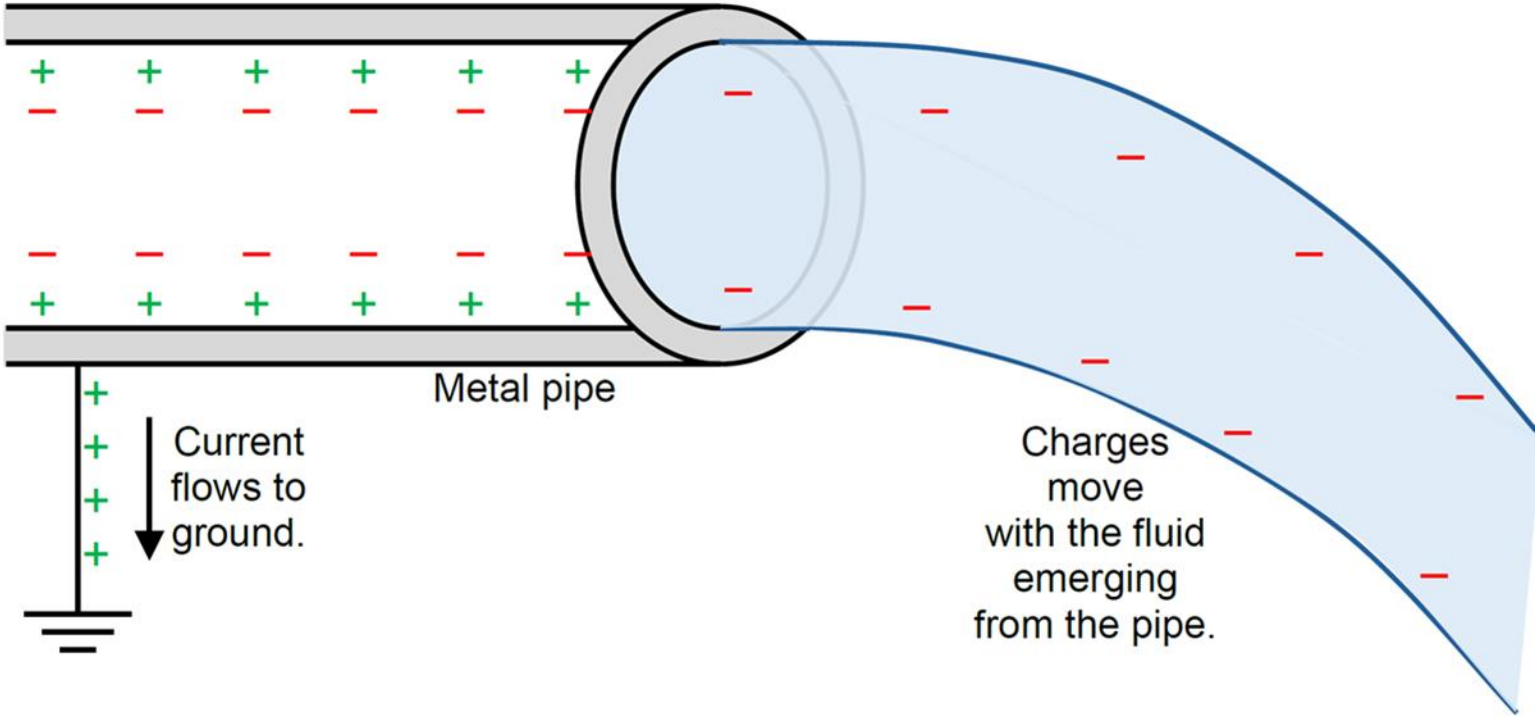
- The build up of the charge on electrically isolated conductors and/or on insulating materials, can give rise to electrostatic discharges.



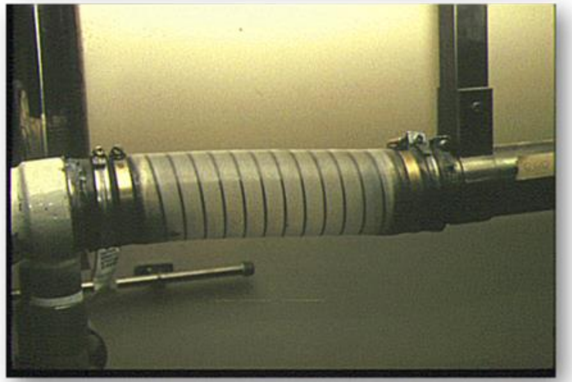
Electrostatic Charge Generation

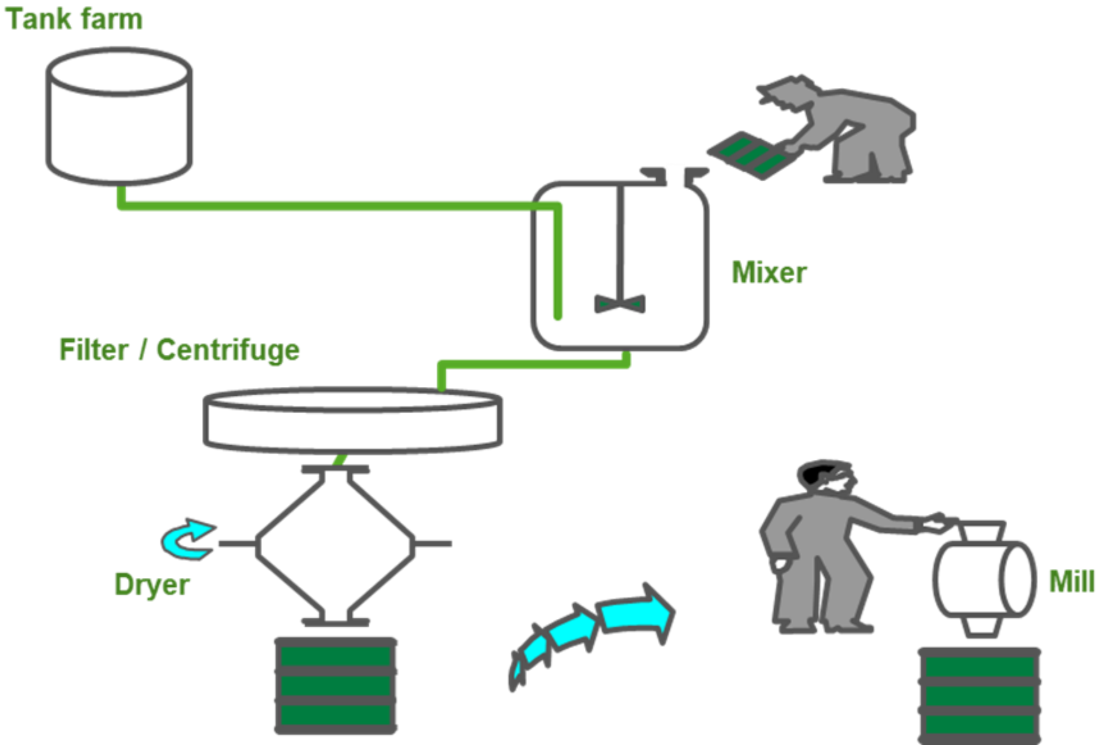
Flow Electrification

- Ions occur naturally in fluids.
- More ions of one polarity stick to the wall.
- Their counter ions move with the liquid flow.



Static Charge Generation Example

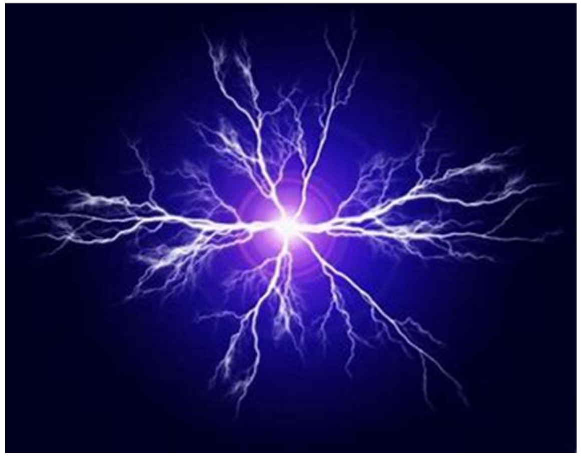




Typical Ignition Sources

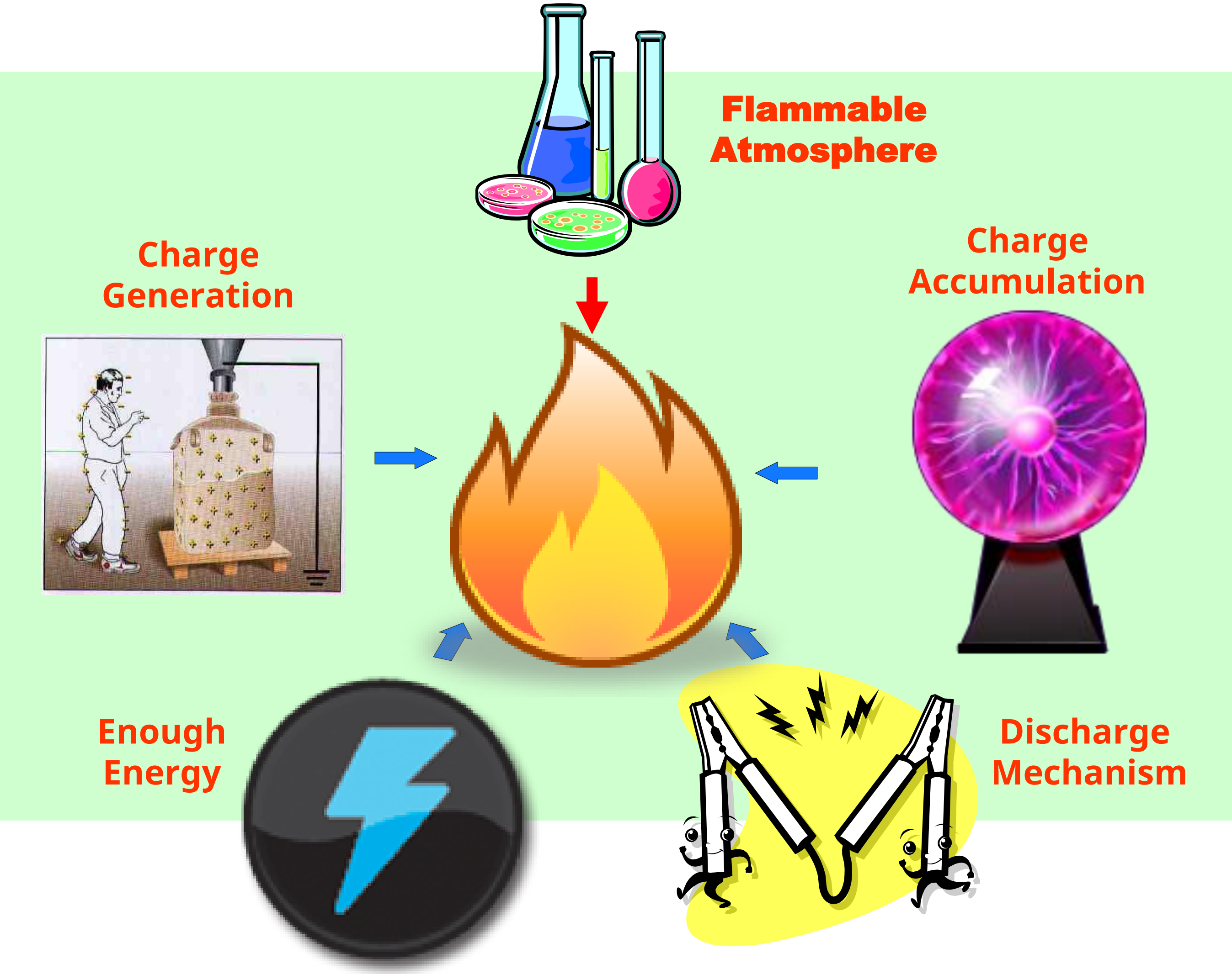
BS EN 1127-1 (2019)

- Personal smoking materials
- Hot work & Open flames
- Mechanical friction and sparks
- Impact sparks
- Hot surfaces and equipment
- Thermal decomposition
- Electrical equipment
- **Electrostatic discharges**



An Overview of Ignition Sources: Electrostatic Considerations

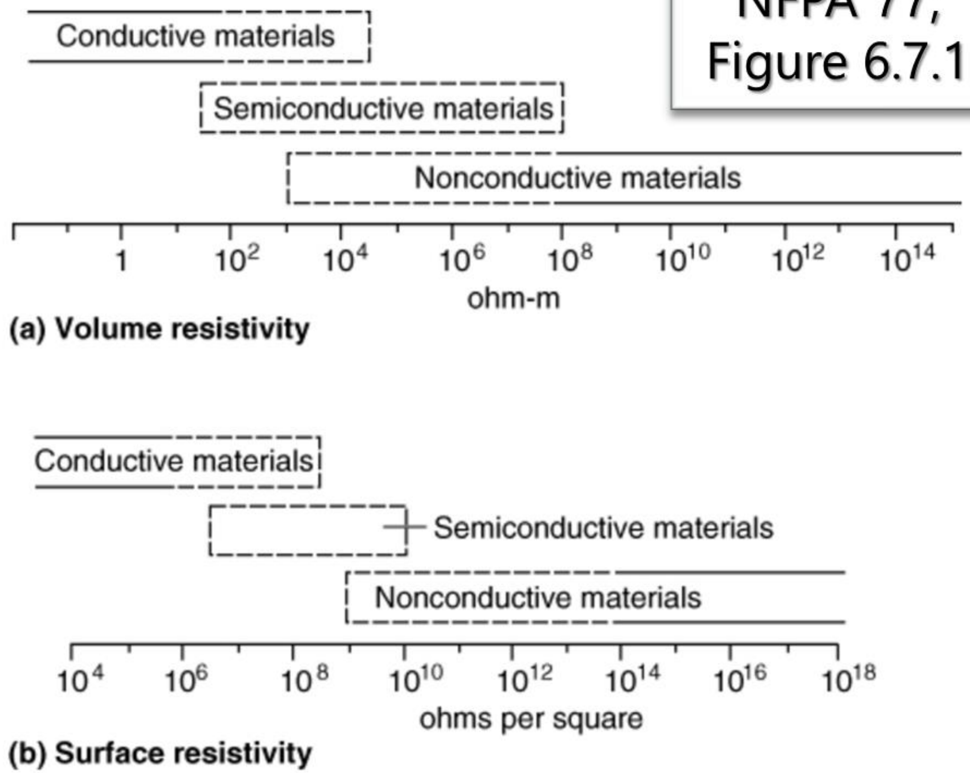
Evaluating a Static Ignition Source



Important Electrostatics Definitions

- **Conductive**
  - The ability to allow electric charges to move.
- **Nonconductive (Insulating)**
  - The ability to resist the motion of an electric charge.
  - Charge generation rate <u>greater than</u> charge relaxation rate.
- **Static Dissipative (Semiconductive)**
  - Capable of dissipating a static electric charge at an acceptable rate
  - Charge dissipation rate <u>greater than</u> charge generation rate.

NFPA 77; Figure 6.7.1



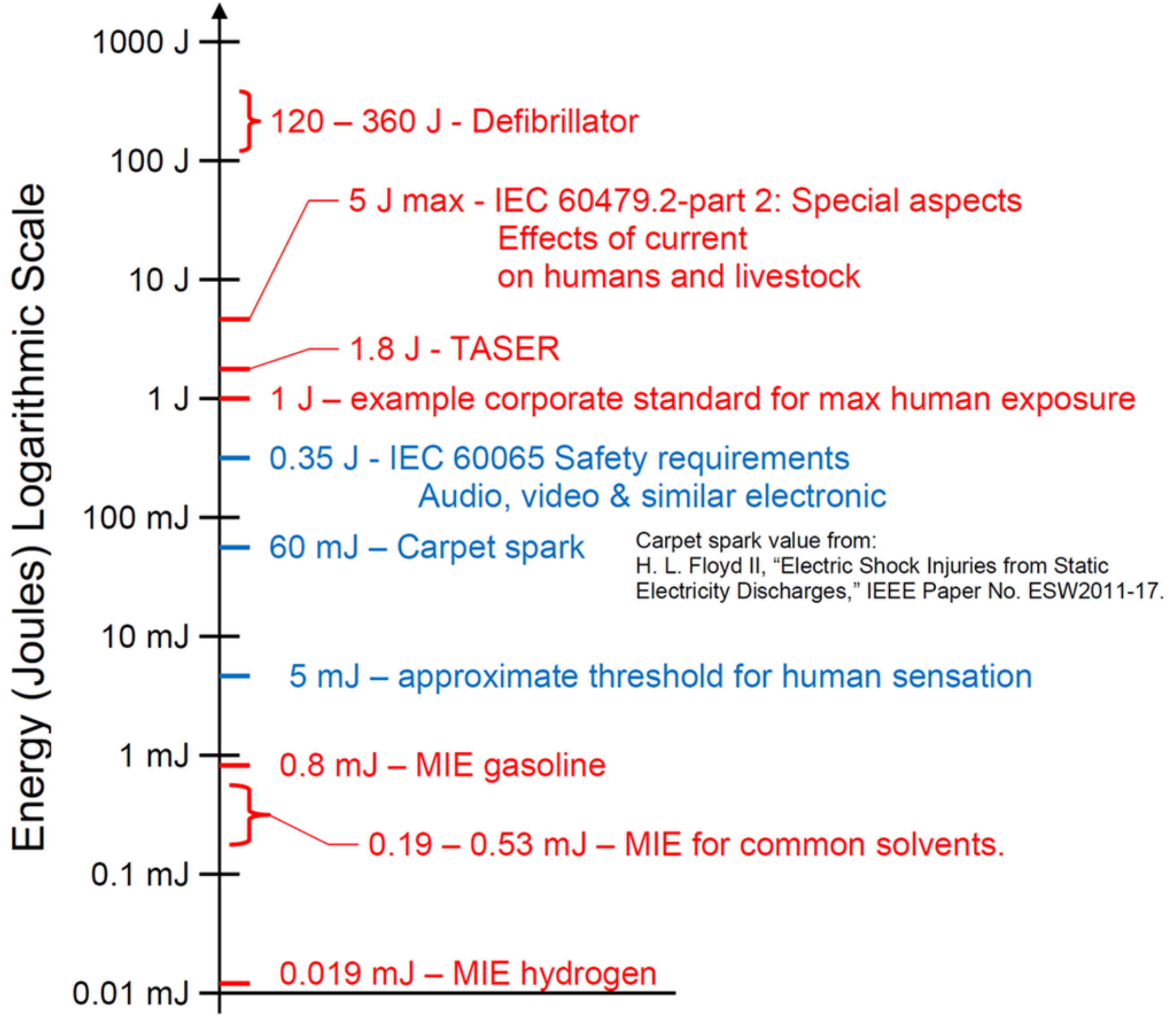
Practical Views of Static Discharge

Energies of interest range widely
from 0.01 mJ to 1000 J
… 8 factors of 10!

Energies > 1 J threaten human health

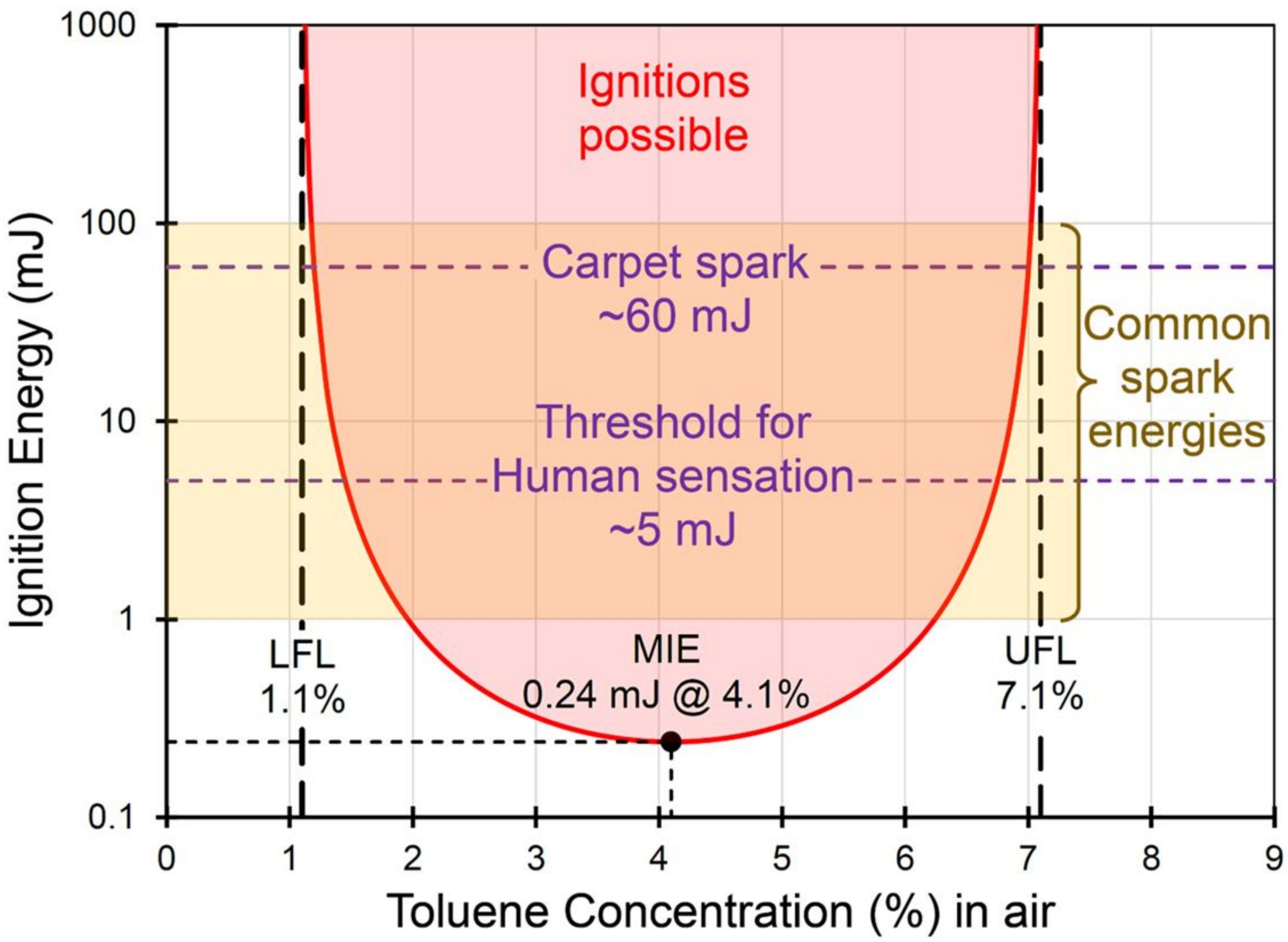
Humans commonly experience sparks
with energies in the range 1 – 100 mJ

Ignitions can occur with spark energies
in the range 0.01 – 1 mJ.



A Deeper Look at Minimum Ignition Energy

- Ignition energy depends on concentration
- Minimum Ignition Energy (MIE) occurs at a specific concentration.
- The energy of common electrostatic discharges greatly exceeds the MIE of common solvents



Typical Minimum Ignition Energies

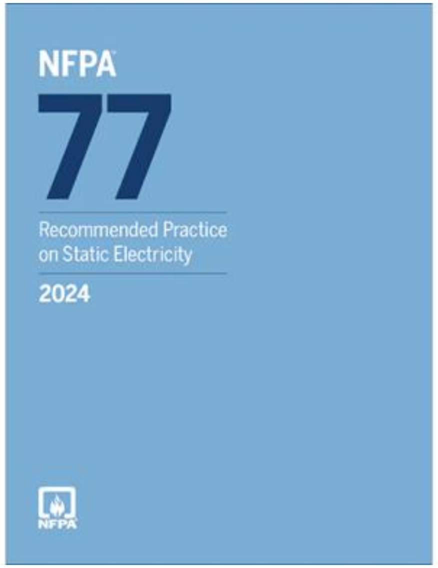
Reference: NFPA 77 (Annex B) and NFPA 660 (Annex Y)

Atmosphere	Material	Minimum Ignition Energy (mJ)
Vapor / Gas	ETHYLE ACETATE	0.460
	METHANE	0.280
	PROPANE	0.250
	ETHANE	0.240
	METHANOL	0.140
	ACETYLENE	0.017
	HYDROGEN	0.016
	CARBON DISULPHIDE	0.009
Dust Cloud **Note:** Values will depend on moisture content and particle size	PVC	1,500
	ZINC	200
	WHEAT FLOUR	50
	POLYETHYLENE	30
	SUGAR	30
	MAGNESIUM	20
	SULPHUR	15
	ALUMINIUM	10
	EPOXY RESIN	9
	ZIRCONIUM	5

The US View: Static Electricity

Fundamental Considerations through NFPA 77

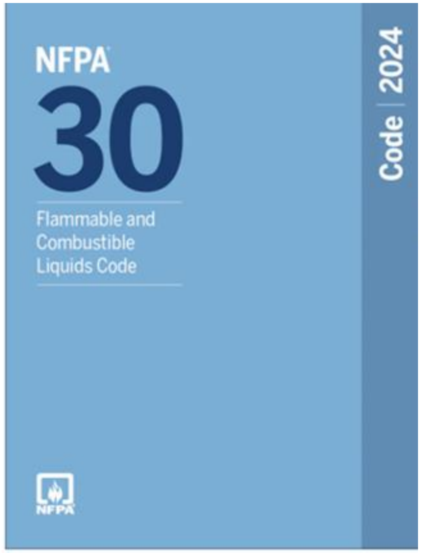
- **NFPA 77 (2024),** Recommended Practice on Static Electricity
- **The purpose of NFPA 77 is to provide assistance in controlling the hazards associated with the generation, accumulation, and discharge of static electricity by providing:**
  - A basic understanding of the nature of static electricity
  - Guidelines for identifying and assessing hazards of static electricity
  - Techniques for controlling the hazards of static electricity
  - Guidelines for controlling static electricity in selected applications
  - Chapter 11 – Static Electricity Hazards in Non-Bulk Containers
  - Several useful reference Appendices
- Generally considered a Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) for Static Electricity



The US View: Static Electricity

Expanded views through NFPA 30

- **NFPA 30 (2024),** Flammable and Combustible Liquids Code
- Historically**,** Static not formally documented in Hazardous Area Classification studies.
- Practices are beginning to evolve:
  - NFPA 30 (2024), Section 6.5.4 – Static Electricity
  - Class I Liquids and Class II/III Liquids Heated above Flashpoint
- Some gaps exist, for example related to use of insulating plastic materials in electrically classified areas.
- All nonmetallic containers, equipment, and piping shall be designed and operated to prevent electrostatic ignition where the potential for an ignitable mixture exists.

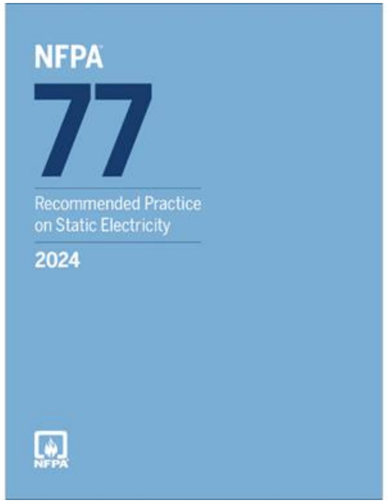


Evaluation & Control of Static Hazards

Characterization of Materials & Equipment

The first step in assessing electrostatic hazards is to determine the relevant properties of the materials being processed, handled, and/or used in the plant.

- Minimum Ignition Energy of flammable atmospheres.
- Resistance-to-Ground of conductive (metal) objects.
- Surface and Volume Resistivity of plastic containers and liners.
- Electrostatic Chargeability of powders and liquids.
  - Volume Resistivity of powders
  - Conductivity of liquids
- Electrical Resistance of operators' footwear and floors.



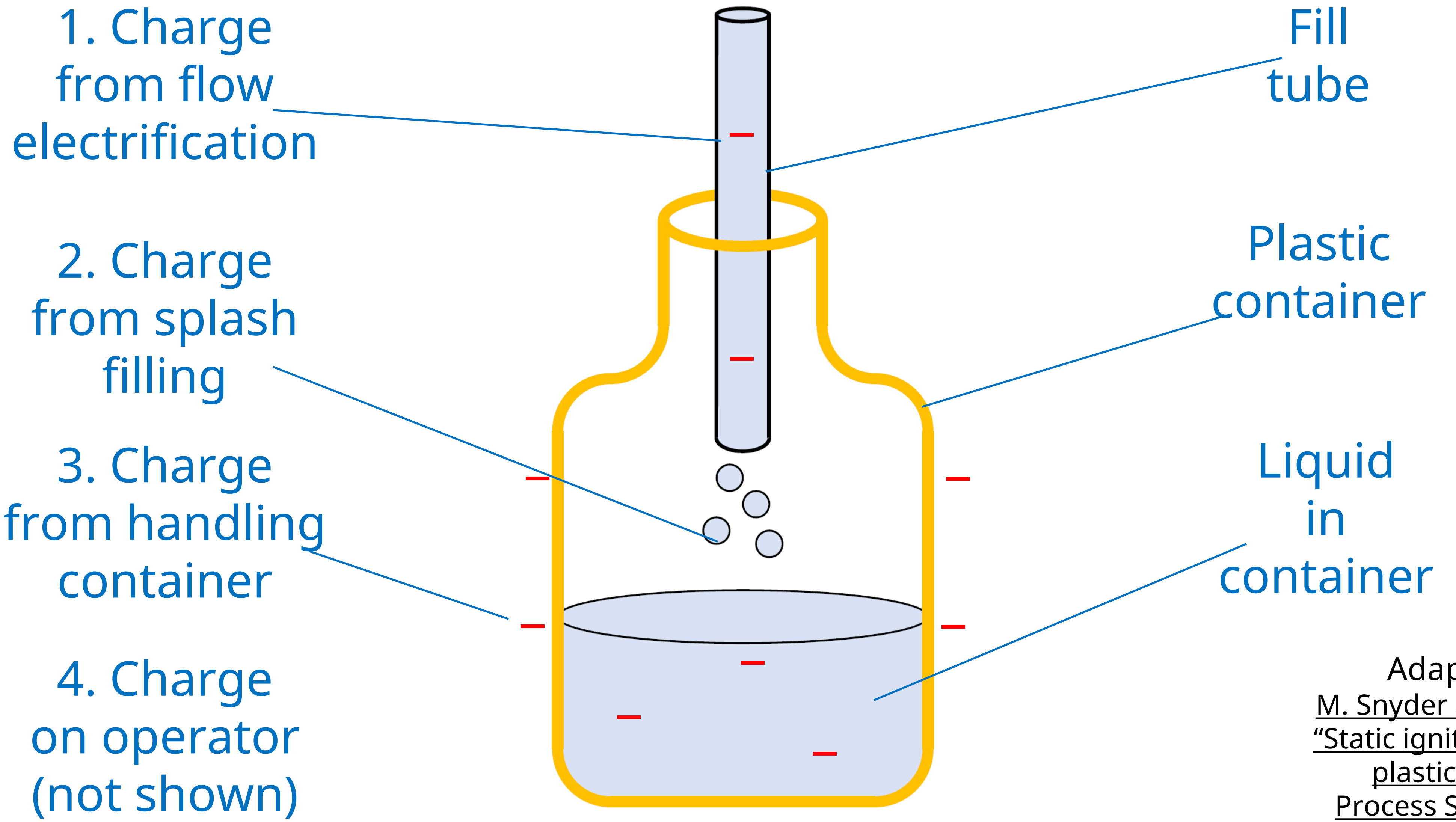
Considerations for Plastic Containers

- Inside the Container
- Outside Surfaces

Static Risks Inside Plastic Containers

- **Main Hazard:**
  - Igniting Flammable Vapors that accumulate inside the container.
  - Dangerous when the vapor space is between LFL and UEL (e.g. alcohols)
- **Controlling Ignition Risks:**
  - Difficult to Bond/Ground Systems involving Plastic Containers.
  - Consider Inerting containers when Vapor Space is in flammable range.
- **Impact of Liquid Conductivity:**
  - Low Conductivity Liquids more Easily Generate Static
- **Importance of Proper Filling Methods (Next Slide):**

Plastic Containers in Flammable Liquid Service



Adapted from:
M. Snyder and K. Robinson, "Static ignition hazards with plastic containers," Process Safety Progress, Vol. 43, 2024, pg. 231-232.

Static Risks: Outside Surfaces of Plastic Containers

- **Main Hazard:**
  - Igniting Flammable Vapors that accumulate outside the container of from other external sources in the area.
- **External Surface Charging:**
  - Surface Handling and Tribocharging.
- **Static Discharges:**
  - Discharge between the Plastic Container and Grounded Objects, including personnel.
- **Environmental Factors:**
  - Dry Conditions and Low Humidity Increase External Static Build-up.
- **Control Measures:**
  - Consider alternative Container Materials.
  - Wipe External Surface with Wet Cloth Before bringing into environment with flammable vapors.

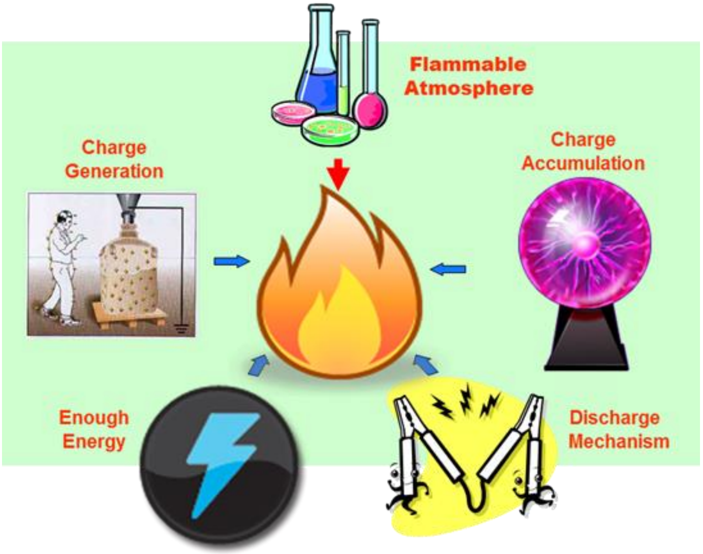
Flammable Liquid Static Case Study

A Case Study: Plastic Pail Liners

Looking at the Impact of a Small Change

- **Use of 10 – 20 mil Pail Liners for steel pails is increasing**
  - Viewed as a Waste Minimization Project
  - Often used for equipment draining & waste transfers
- **Most Pail Liners are made from High Density Polyethylene**
  - Volume Resistivity: 10^{17} to 10^{18} ohm-cm
  - Surface Resistivity: 10^{11} Ω/sq. typical
- **Often Advertised as 'Anti-Static'**
  - Use caution if reference is made to NFPA 99
- **More Flammable Liquid & Electrostatic Risks:**
  - Many solvents with moderate vapor pressure (LFL – UFL)
  - Spray Filling without use of Dip Pipes

Concluding Thoughts



- Electrostatics present risks in most operations involving transferring and processing of liquid & solids.
- Static Electricity Ignition Scenarios Involve 4 Aspects:
  - Charge Generation
  - Charge Accumulation
  - Discharge Energy Level
  - Sensitivity of Atmosphere to Ignition
- Plastic (non-conductive) containers used in flammable liquid Sensitivité service present unique hazards.
  - Several methods available to identify risk factors.
- NFPA 77 (2024), Recommended Practice on Static Electricity, serves as a comprehensive source of information for conducting electrostatics evaluation.

References

- **NFPA 77 (2024), Recommended Practice on Static Electricity**
  - www.nfpa.org/77
- **NFPA 30 (2024), Flammable and Combustible Liquids Code**
  - www.nfpa.org/30
- **IEC 60079-32-1: Explosive Atmospheres – Part 32-1: Electrostatic Hazard – Guidance”**
  - https://webstore.iec.ch/publication/60166
- **API RP 2003, Protection Against Ignitions Arising Out of Static, Lightening, and Stray Currents**
  - https://www.api.org/~/media/files/publications/whats%20new/2003_e8%20pa.pdf
- **EN 1127-1:2011, Explosive Atmospheres. Explosion Prevention and Protection. Basic Concepts and Methodology**
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- **M. Glor, “Hazards Due to Electrostatic Charging of Powders”, Journal of Electrostatics, Vol 16, (1985), pg 175-191**
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  - https://ieeexplore.ieee.org/document/6164721
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  - https://doi.org/10.1002/prs.12608
- **DEKRA Practical Guide to Industrial Electrostatics: Hazards, Problems, and Applications**
  - https://www.dekra.us/en/process-safety-training/practical-guide-industrial-electrostatics/

Thank You!

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Details on Electrostatics: Appendix Slides

Common Electrostatic Discharges

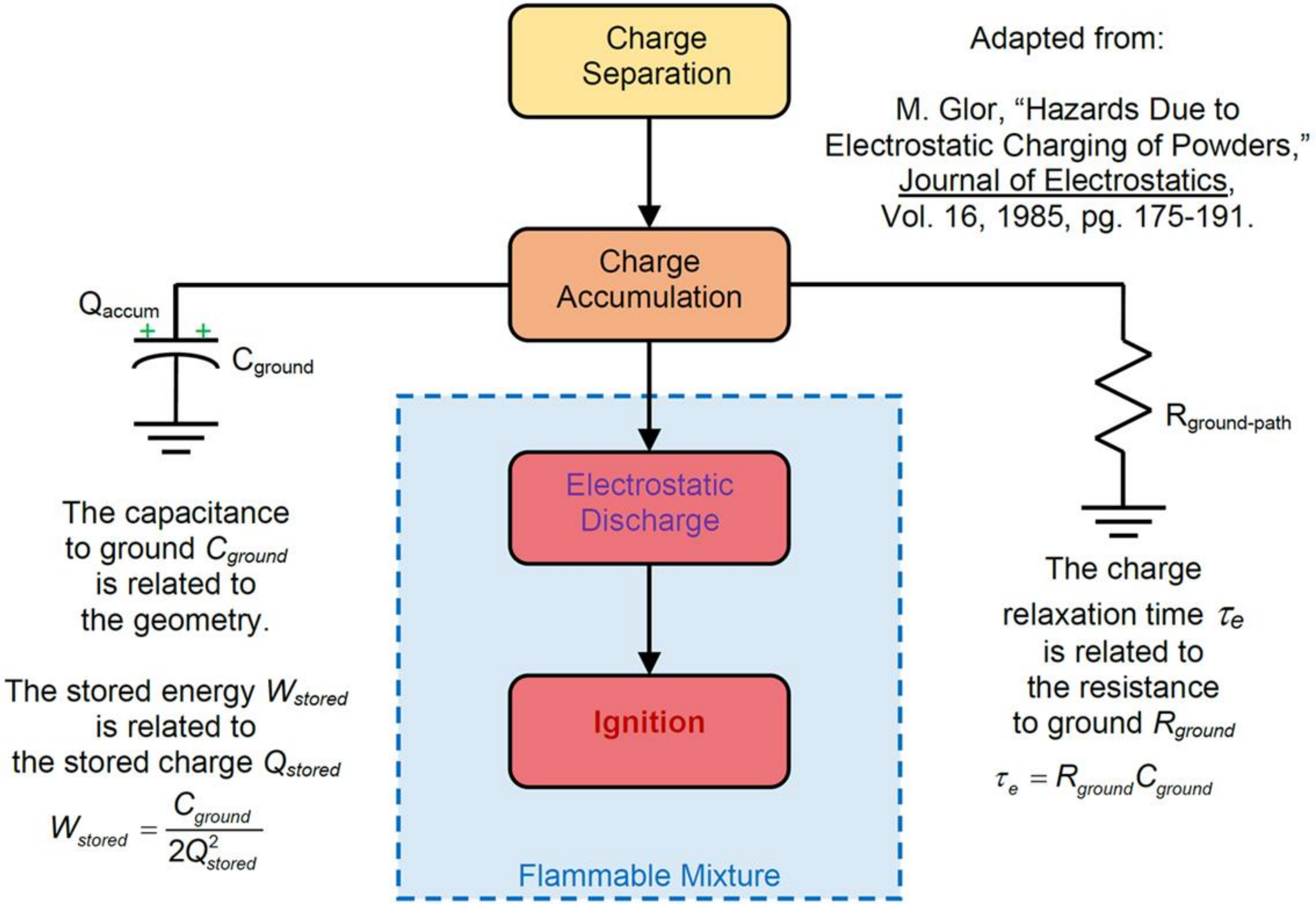
Discharge Types are based on resistivity and the geometric arrangement of the charged object and the geometry of the discharge initiating electrode

- ***Sparks* Between Conductors**
  - Stored (Spark) Energy = ½ CV^2.Energy can exceed 1000 mJ.
- ***Discharges Between Conductors and Insulators (Brush Discharge)***
  - Maximum discharge energy of 4mJ .
- ***Discharge on the Surface of an Insulator Backed by a Conductor (Propagating brush Discharge)***
  - A surface coated with a thin (< 8mm) layer of an insulating material will act as a capacitor to store charge. (note: 8 mm ~ 1/3 inch). Energy can exceed 1000 mJ.
- ***Discharges During Filling Operations (Bulk/Cone Discharge)***
  - Bulking discharges have a maximum effective energy of about 25mJ and occur during the filling of vessels with insulating powders.

Putting it All Together: Electrostatic Ignition

- Electrostatic ignitions of vapors and powders can occur when charge is separated and accumulates.

- Electrostatic discharges have provided competent ignition sources many fires & explosions.



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