Safety Data Sheets: Section 9, Physical & Chemical Properties

for

Process Safety Applications

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Presentation Outline

Safety Data Sheets: Section 9, Physical and Chemical Properties for Process Safety Applications

- **Introduction**
  - Definition
  - Conditions for flash fires and explosions
  - Management of Flash Fire & Explosion Hazards
- **Safety Data Sheet: Section 9**
  - Laboratory testing
  - Applicable codes and standards, including NFPA 652
- **Establishing a Basis of Safety**
  - Control of flammable atmospheres
  - Control of potential ignition sources
  - Explosion Protection & Isolation
- **Discussion**

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Process Safety - Definition

- Prevention and control of incidents with potential to release hazardous materials or energy.
- Management of the integrity of operating systems and processes handling hazardous substances by applying good design principles, engineering, and operating practices.

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Fire Triangle

- **Fuel** - A gas, liquid vapor, mist, or solid material capable of being oxidized
- **Oxidant** - A material that may cause or enhance the combustion of other materials, usually oxygen in air
- **Ignition source** - An energy source capable of initiating a combustion reaction

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Dust Cloud Flash Fire Conditions

- Explosible (combustible, flammable) dust
  - Small particle size to support flame spread
- Dust cloud formation
  - Concentration above Minimum Explosible Concentration (MEC)
- Oxidant
  - Typically, oxygen in air

Above conditions are usually expected during handling, transfer, processing, dust collection, and packaging operations

- Ignition source
  - Simultaneous existence of an energetic ignition source will result in a deflagration (flashfire)

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Dust Cloud Explosion Conditions

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  - Small particle size to support flame spread
- Dust cloud formation
  - Concentration above Minimum Explosible Concentration (MEC)
- Oxidant
  - Typically, oxygen in air
- Ignition source
  - Occurrence of an energetic ignition source will result in a deflagration
- **Confinement**
  - If the deflagration is confined and produces a pressure sufficient to rupture the confining enclosure, the event is an “explosion”

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Management of Flash Fire & Explosion Hazards

Effective evaluation and management of flash fire, and explosion hazards requires:

- **Assess flammability and explosion characteristics of fuel(s)**
- **Understand your processes and operations**
- **Flash fire and explosion hazards analysis**
  - Identify locations where flammable atmospheres (gas, vapor, dust) are or could be present - normal and abnormal conditions
  - Identify potential ignition sources - under normal and abnormal conditions
  - Effectiveness of existing measures for ensuring safety
- **Practical measures for ensuring safety**
  - Prevention, and/or
  - Protection and isolation
- **Written safety management programs**
- **Training of operating, engineering, and management staff**
- **Regular inspection and maintenance of programs, equipment, and facility**

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Flammability of Vapor Clouds

- Conditions for Combustion?
  - Flash Point - ASTM D93
  - Limits of Flammability - ASTM D681
- Ease of Ignition?
  - Minimum Ignition Energy - ASTM E582
  - Auto-Ignition Temperature - ASTM E659
- Explosion Effects?
  - Maximum Explosion Pressure - EN 13673-1
  - Maximum Rate of Pressure Rise - EN 13673-2
- Controlling Oxidant?
  - Limiting Oxygen for Combustion - ASTM E2079
- Electrostatic
  - Liquid Conductivity - ASTM D257

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Safety Data Sheet (SDS) - Toluene

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a) Appearance: Form: liquid, Color: colorless
b) Odor: no data available
c) Odor Threshold: no data available
d) pH: no data available
e) Melting point/freezing point: Melting point/range: -93°C (-135°F)
f) Initial boiling point and boiling range: 110 - 111°C (230 - 232°F)
g) Flash point: 4.0°C (39.2°F) – closed cup
h) Evaporation rate: no data available
i) Flammability (solid, gas): no data available
j) Upper/lower flammability or explosive limits: Upper explosion limit: 7%(V), Lower explosion limit: 1.2%(V)
k) Vapor pressure: 29.1hPa (21.8mmHg) at 20.0°C (68.0°F)
l) Vapor density: no data available
m) Relative density: 0.865g/mL at 25°C (77°F)
n) Water solubility: no data available
o) Partition coefficient: n-octanol/water: no data available
p) Auto-ignition temperature 535.0°C (995.0°F)
q) Decomposition temperature no data available
r) Viscosity no data available
s) Explosive properties no data available
t) Oxidizing properties no data available

u) 9.2 Other safety information
v) no data available

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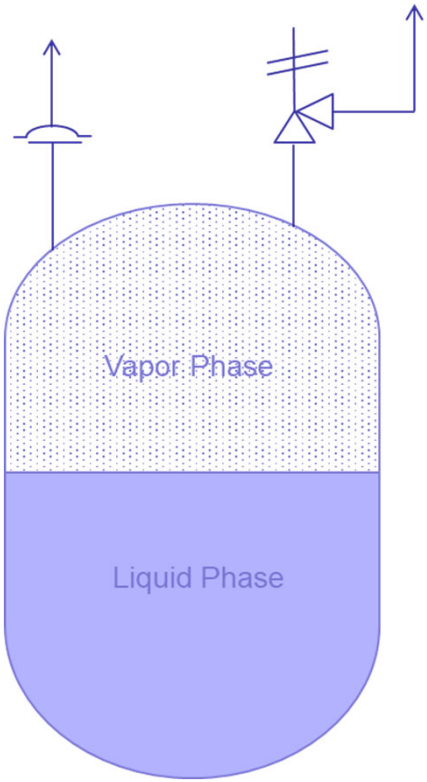
Flash Point Temperature

- Minimum temperature at which a volatile material gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid
- The minimum temperature at which combustion can be sustained is referred to as Fire Point (higher than Flash Point)



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Flash Point Temperature - Typical Values

Liquid	Closed Cup (°F / °C)	Open Cup (°F / °C)
Acetone	**0** / -18	**16** / -9
Toluene	**39** / 4	**45** / 7
Methanol	**54** / 12	**61** / 16
Xylene	**63** / 17	**75** / 24
N-Butanol	**84** / 29	**109** / 43

Ref: Industrial Ventilation, 12th edition, American Conference of Industrial Hygienists

Addition of small amount of volatile can have a significant effect on flash point. For example:

- Flash Point Temperature of Ethylene Glycol = 232°F (111°C);

However,

- Flash Point Temperature of Ethylene Glycol + 2% Acetaldehyde* = 84°F (29°C)

  * FP -39°C, -38.2°F

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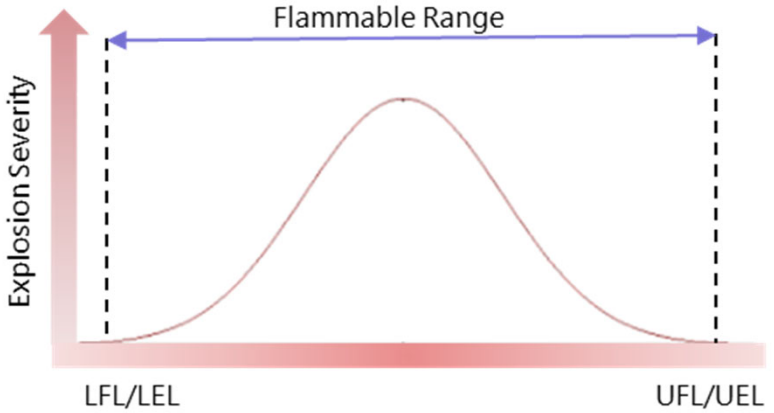
Limits of Flammability

- **Lower Flammable Limit (LFL)**
  - Minimum concentration of vapor/gas in air below which propagation of flame does not occur on contact with an ignition source
- **Upper Flammable Limit (UFL)**
  - Maximum concentration of vapor or gas in air above which propagation of flame does not occur on contact with an ignition source
- **Expressed as %v/v in air at atmospheric pressure**



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Limits of Flammability - Typical Values

Ref: Fire Protection Guide to Hazardous Materials, NFPA, 11th Edition

	LFL (%v/v)	UFL (%v/v)
LIQUIDS		
Acetone	2.5	12.8
1-Butanol	1.4	11.2
Toluene	1.1	7.1
Carbon Disulfide	1.3	50
Methyl Alcohol	6	36
GASES		
Hydrogen	4	75
Butane	1.9	8.5
Methane	5	15
Ethylene	2.7	36

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Effect of Process Conditions on Flammability

	Flash Point	Lower Flammable Limit	Upper Flammable Limit
Pressure ▲	▲	Little effect ▼	Significant increase ▲
Pressure ▼	▼	Little effect ▲	Significant decrease ▼
Temperature ▲	N/A	▼	▲
Temperature ▼	N/A	▲	▼
Oxygen ▲	No change	No change	Significant increase ▲
Oxygen ▼	No change until nose of the curve (LOC) - then minimal ▲	No change until nose of the curve (LOC) - then minimal ▲	Significant decrease ▼

N/A Not Applicable

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Mist Cloud

- Mist clouds can be formed by:
  - Liquid droplets in air obtained by atomizing a liquid, **OR**
  - Flashing hot liquid and subsequently quenching the vapor with cold gas
- Mists can be flammable even if the liquid is at a temperature below its Flash Point

Explosibility of Dust Clouds

- Explosibility Screening (Go/No Go) - ASTM E1226

If Explosible (Go), then:

- Ease of Ignition?
  - Minimum Ignition Energy - Dust Cloud (MIE) - ASTM E2019
  - Minimum Auto-Ignition Temperature - Dust Cloud (MAIT) - ASTM E 1491
  - Layer Ignition Temperature - Dust Layer (LIT) - ASTM E2021
  - Thermal Instability/ Self-heating
- Explosion Effects?
  - Maximum Explosion Pressure (Pmax) - ASTM E1226
  - Maximum Rate of Pressure Rise (Kst) - ASTM E1226
- Controlling Flammable Concentrations?
  - Minimum Explosible Concentration (MEC) - ASTM E1515
  - Limiting Oxygen Concentration (LOC) - ASTM E2931

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Classification of Combustible Particulate Solid Mixtures

Ref. NFPA 652

- **Section 9 – Physical and Chemical Properties**
    a. Physical State: Powder
    b. Color: white to light yellow
    c. Odor: odorless
    d. pH: **Not available**
    e. Vapor Pressure: **Not available**
    f. Viscosity: **Not available**
    g. Boiling Point: **Not available**
    h. Freezing/Melting Point: **Not available**
    i. Auto ignition Temperature: 400˚C (752˚F)
    j. Flash Point: **Not available**
    k. Explosion Limits: Lower: **Not available**
    l. Explosion Limits: Upper: **Not available**
    m. Decomposition Temperature:
    n. Solubility in water: **Not available**
    o. Specific Gravity/Density:
    p. Molecular Formula: (C6H10O5)n
    q. Molecular Weight:

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Explosibility of Dust Clouds

- Several factors can affect explosibility of dust clouds, including:
  - **Particle size**
  - **Moisture content**

A reduction in **particle size** and **moisture content** results in an increase in Ignition Sensitivity & Explosion Severity

Mixture Composition	Consideration
Where a mixture containing both combustible and noncombustible materials do not remain homogeneously mixed	Combustible components shall be used as the basis for the mixture classification
Where components with different chemical compositions do not remain homogeneously mixed	Properties of the individual constituents shall be considered separately
Where the material with a range of particle sizes does not remain homogeneously mixed	A representative fine fraction shall be tested

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Hybrid Mixtures (Ref. NFPA 499)

- An explosible mixture, comprising gas with suspended solid or liquid particulates, in which
  - Total flammable gas concentration is ≥10% of LFL, **and**
  - Total suspended particulate concentration is ≥10% of minimum explosible concentration (MEC)
- Presence of even small amount of vapor increases ignition sensitivity of the dust cloud

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Hybrid Mixtures

- **Dust cloud**
  - MEC 70 - 80g/m3
  - MIE 300 - 500mJ
- **Dust cloud with ethanol vapor at 60% of LFL**
  - MEC 30 - 40g/m3
  - MIE 3 - 5mJ

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NFPA Codes & Standards - Flammable Liquids

(Ref. NFPA, 1 Batterymarch Park, Quincy, MA 02169)

- **NFPA 13,** Standard for the Installation of Sprinkler Systems
- **NFPA 30, Flammable and Combustible Liquids Code**
- **NFPA 33,** Standard for Spray Application Using Flammable or Combustible Materials
- **NFPA 34,** Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids
- **NFPA 35,** Standard for the Manufacture of Organic Coatings
- **NFPA 36,** Standard for Solvent Extraction Plants
- **NFPA 45,** Standard on Fire Protection for Laboratories Using Chemicals
- **NFPA 69,** Standard on Explosion Prevention Systems
- **NFPA 70,** National Electrical Code
- **NFPA 77,** Recommended Practice on Static Electricity
- **NFPA 91,** Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids
- **NFPA 101,** Life Safety Code
- **NFPA 497,** Recommended Practice `for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- **NFPA 704,** Standard System for the Identification of the Hazards of Materials for Emergency Response

NFPA Codes & Standards - Combustible Solids

(Ref. NFPA, 1 Batterymarch Park, Quincy, MA 02169)

- **NFPA 61**, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities
- **NFPA 68**, Guide for Venting of Deflagrations
- **NFPA 69**, Standard on Explosion Prevention Systems
- **NFPA 77**, Recommended Practice on Static Electricity
- **NFPA 484**, Standard for Combustible Metals, Metal Powders, and Metal Dusts
- **NFPA 499**, Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- **NFPA 652, Standard on the Fundamentals of Combustible Dust**
- **NFPA 654**, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids
- **NFPA 655**, Standard for Prevention of Sulfur Fires and Explosions
- **NFPA 664**, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

Hazard Management

Ensuring Safety Through Prevention & Protection

- Control of Fuel
- Control of Oxidant
- Control of Ignition Sources
- Explosion Protection

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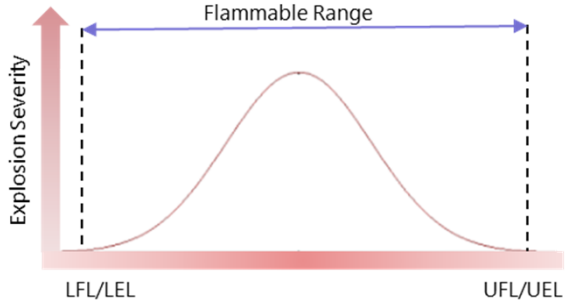
Control of Fuel

- Operate and maintain equipment in a way that minimizes escape of gas, vapor, dust
- If possible, operate below Flash Point temperature of the liquid
- Provide continuous local exhaust ventilation for processes where combustible dust, gas, and/or vapor is liberated in normal operation.
  - Maintain concentration below 25% of LFL / MEC
  - Dust should be conveyed to dust collectors



- For Dusty operations, establish regular cleaning frequencies for floors and horizontal surfaces to minimize fuel accumulations
  - Require Minimum Explosible Concentration Data

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Control of Oxidant (Inert Gas Blanketing/ Purging)

- Deflagration is prevented if the oxidant concentration is maintained below the Limiting Oxidant Concentration (LOC), by replacing the oxidant with an inert gas
- LOC is dependent on the nature of the fuel and the inert gas
- Commonly used inert gases are Nitrogen, Carbon dioxide, and argon

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Control of Ignition Sources

- **Static Electricity**
  - Bonding & grounding of conductive items of plant
  - Restricting the use of insulating (plastic) items (hoses, pipes, containers, etc.)
  - Grounding of operators
  - Controlling flow rates of non-conductive liquids
- **Mechanical Friction & Sparks**
  - Regular inspection and preventive maintenance
  - Hot-work permit
- **Electrical Arks & Sparks**
  - Perform Hazardous Area [Electrical] Classification
  - Select & use appropriately rated electrical equipment
- **Self-Heating (Auto-Ignition)**
  - Determine onset temperature for self-heating
  - Ensure process & storage temperature is at a safe margin below onset temperature for self-heating

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Explosion Protection

Ensuring Safety Through Prevention & Protection

- **Explosion Prevention**
  - Elimination of Fuel
  - Elimination of Oxidant
  - Elimination of Ignition Sources

- **Explosion Protection**
  - Protection measures must be considered when preventative measures on their own may not ensure acceptable level of safety
  - Explosion protection measures include:
    - Explosion venting to a safe place (NFPA 68)
    - Explosion suppression by injecting a suppressant (NFPA 69)
    - Containment by explosion resistant construction (Design based on ASME Boiler and Pressure Vessel Code, Section VIII, Division I)

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Summary

Effective evaluation and management of fire, flash fire, and explosion hazards requires:

- Assessment of flammability and explosion characteristics of fuel(s)
- Understanding your processes and operations
- Analysis of flash fire and explosion hazards:
  - Identify locations where flammable atmospheres (gas, vapor, dust) are or could be present - normal and abnormal conditions
  - Identify potential ignition sources - under normal and abnormal conditions
  - Effectiveness of existing measures for ensuring safety
- Practical measures for ensuring safety
  - Prevention, and/or
  - Protection and isolation
- Written safety management programs
- Training of operating, engineering, and management staff
- Regular inspection and maintenance of programs, equipment, and facility

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Thank You

We partner with our clients in the process industries to help them identify, assess, prevent, and control fire, explosion, and accidental loss of containment hazards in their operations.

We would like to hear from you. Please contact us!

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