Assessing Explosibility Characteristics of Combustible Dusts

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Presentation at The Fire Protection Research Foundation Symposium
on
Dust Explosion Hazard Assessment and Risk Control: New Strategies
September 20th – 21st, 2011, Detroit, MI

Assessing Explosibility Characteristics of Combustible Dusts

Presentation Outline

- **Conditions for a Dust Cloud Explosion -** Overview
- **Management of Dust Cloud Explosion Hazards -** Overview
- **Explosion Characteristics of Dust Clouds**
  - Combustibility/Explosibility
  - Ignition Sensitivity
  - Explosion Severity
- **OSHA Salt Lake City Technical Center Testing Practices**

Conditions Required for Dust Cloud Explosions to Occur

A number of conditions must exist simultaneously for a dust flash fire or explosion to occur:

- Dust must be combustible
- Dust must be dispersed forming a cloud in air
- Dust concentration must be above the Minimum Explosible Concentration
- Sufficient oxidant must be present to support combustion of the dust cloud
- An ignition source with sufficient energy to initiate flame propagation must be present

Management of Dust Cloud Explosion Hazards

- **Control of the spread of combustible dust atmospheres:**
  - Proper plant design
  - Use of local exhaust ventilation
  - Management of dust deposits

- **Elimination/control of potential ignition sources including:**
  - Mechanical friction and sparks
  - Hot surfaces and equipment
  - Hot work
  - Thermal decomposition
  - Electrical arcs (sparks)
  - Electrostatic discharges

- **Application of explosion safeguards:**
  - Explosion protection (containment, relief venting, explosion suppression)
  - Explosion isolation
  - Inert Gas Blanketing

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Understanding Explosion Characteristics of Dusts

- **How easily will the dust cloud ignite?**
  - Explosibility Screening (Go / No Go)
  - Minimum Ignition Energy
  - Minimum Ignition Temperature
  - Thermal Instability
- **What will happen if the dust cloud does ignite?**
  - Maximum Explosion Pressure
  - Maximum Rate of Pressure Rise
- **Ensuring Safety by Avoiding/Controlling Flammable Atmospheres?**
  - Limiting Oxygen Concentration
  - Minimum Explosible Concentration
- **Electrostatic Properties**
  - Electrostatic Chargeability
  - Volume Resistivity

Explosibility Screening (ASTM E1226)

Use a Hartmann Bomb, 20L sphere, or 1m^3 sphere test vessel to determine whether the dust cloud is explosible at the dust handling/processing conditions

- **Explosible Dust Cloud**

  Capable of causing a flash fire or explosion

Modified Hartmann Apparatus

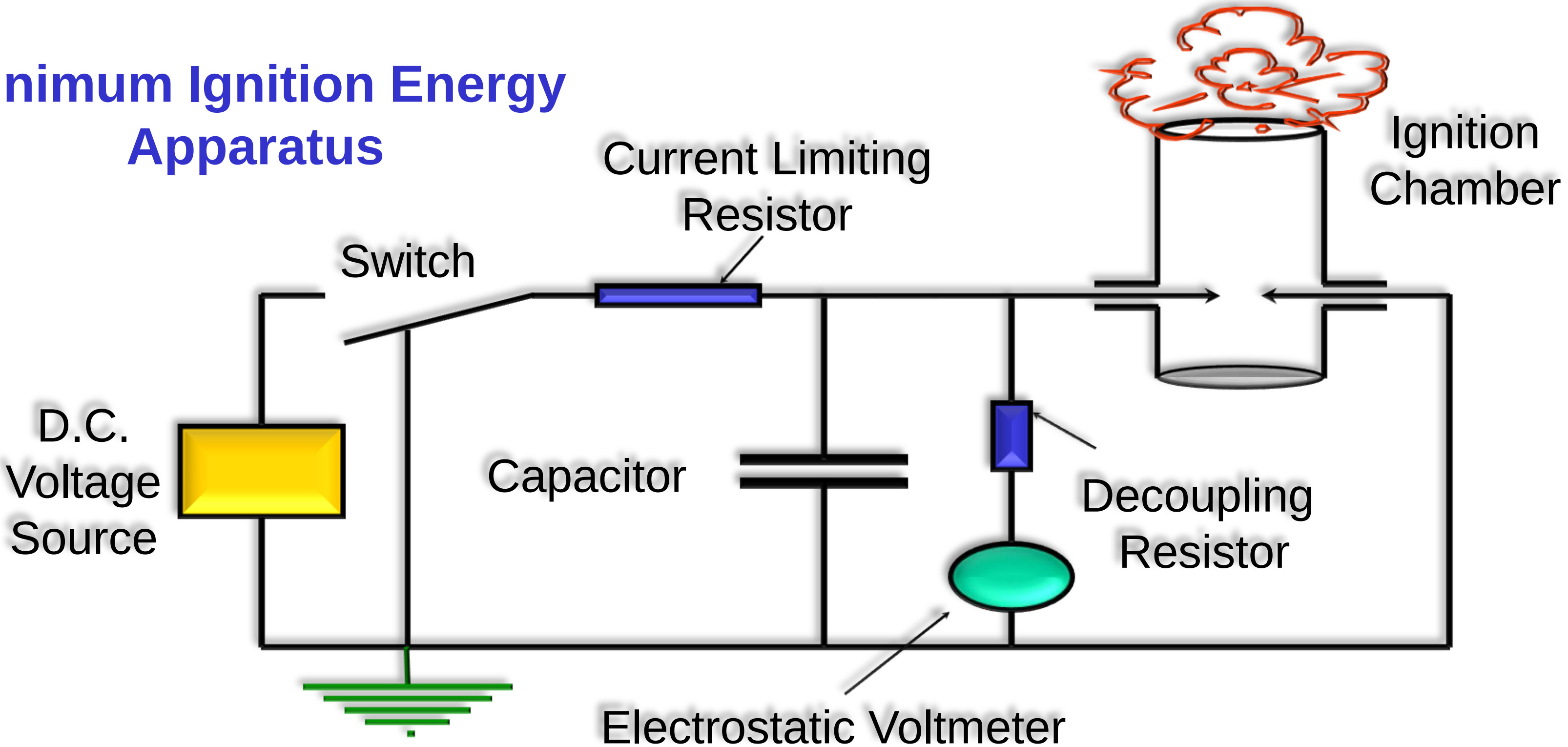
Chilworth 1m^3 Vessel

20L Sphere

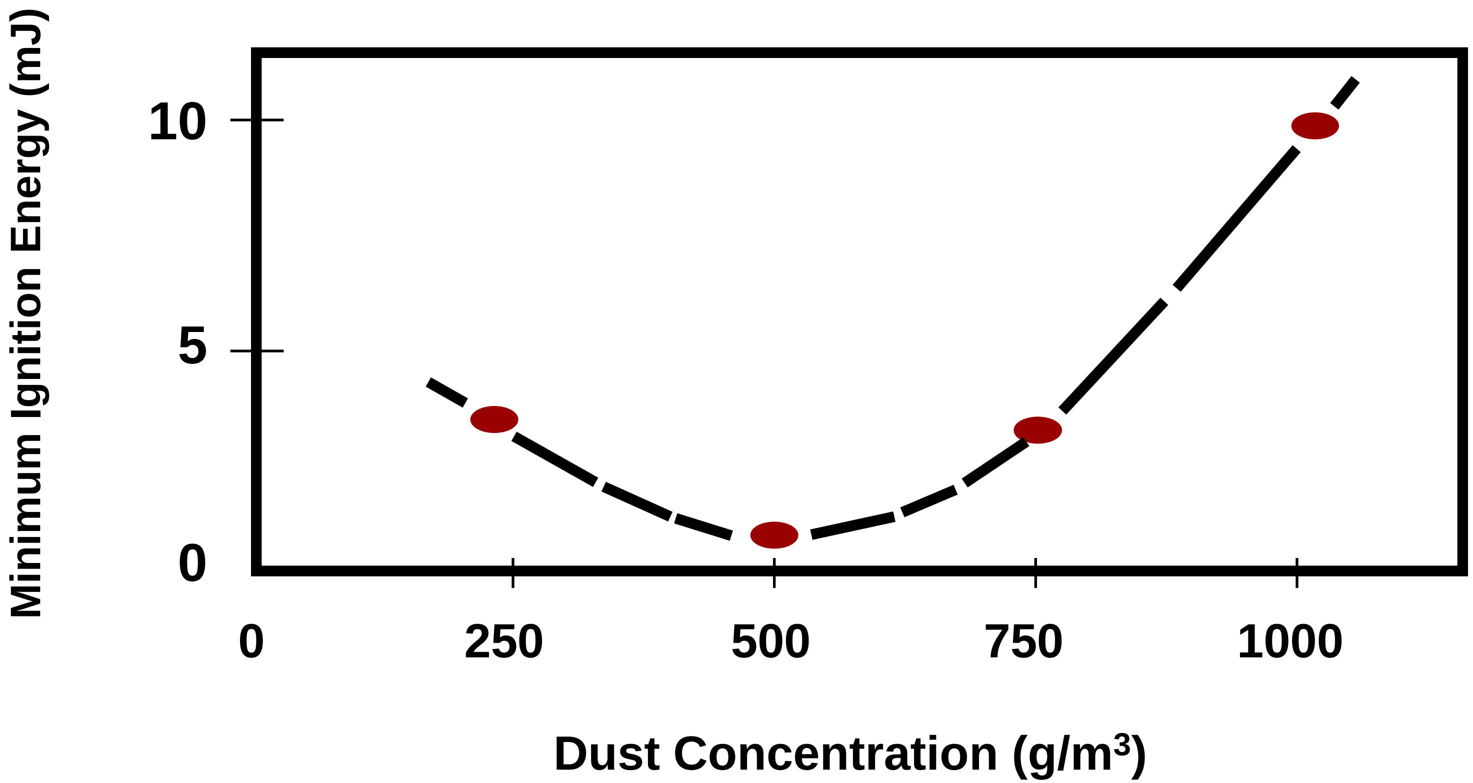
Minimum Ignition Energy (MIE) (ASTM E 2019)

MIE of a flammable material is the smallest electrostatic spark energy needed to ignite an optimum concentration of the material using a capacitive spark

Minimum Ignition Energy Apparatus



MIE and the effect of Dust Cloud Concentration



Factors Affecting Minimum Ignition Energy

Some Influencing Factors	Effect
Increasing Particle Size	↑
Increasing Moisture Content	↑
Inductance of Discharge Circuit	↓
Presence of Flammable Vapor (even if below LFL)	↓
Increase in Ambient Temperature	↓

Types of Electrostatic Discharges

Several types of electrostatic discharges are distinguished depending on resistivity and the geometric arrangement of the charged object and the geometry of the discharge initiating electrode:

- ***Spark Discharge -*** *Spark from ungrounded conductor*

  Stored (Spark) Energy = ½ C V^2

  - Resistance to ground should be checked. If R > 10 ohm, direct ground connection is required

Types of Electrostatic Discharges

Several types of electrostatic discharges are distinguished depending on resistivity and the geometric arrangement of the charged object and the geometry of the discharge initiating electrode:

- ***Propagating brush Discharge -*** *Discharge from the surface of an insulator backed by a conductor (e.g. plastic or glass-lined metal pipes and vessels) and from the surfaces of plastic pipes and hoses used for pneumatic conveying of powders*

  Maximum discharge energy of 1,000mJ to 2,000mJ

  - Avoid the use of plastic pipes and hoses for pneumatic conveying of powders
  - Avoid plastic containers/liners for powders with high charge densities

Types of Electrostatic Discharges

Several types of electrostatic discharges are distinguished depending on resistivity and the geometric arrangement of the charged object and the geometry of the discharge initiating electrode:

- ***Discharges from Human Body***

  Maximum energy of about 25mJ to 30mJ

  - Personnel should be grounded so that their resistance-to-ground $<1 \times 10^8$ ohm
  - Static dissipative footwear may be used
  - Resistance of the floor/surface on which the operator is standing should also be $<1 \times 10^8$ ohm

Types of Electrostatic Discharges

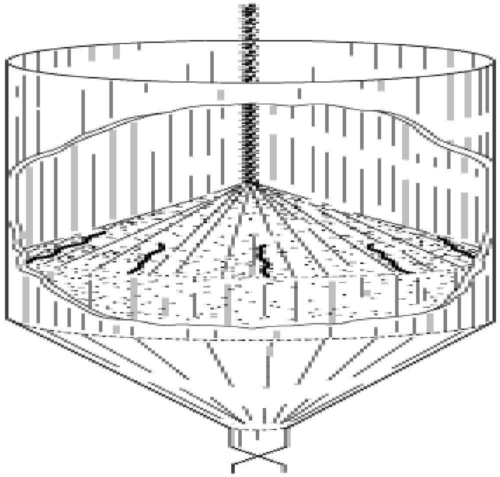
Several types of electrostatic discharges are distinguished depending on resistivity and the geometric arrangement of the charged object and the geometry of the discharge initiating electrode:

- ***"Bulk"/"Cone" Discharge -*** *Discharges on the surface of the powder during filling of vessels/bins/containers*

  Maximum discharge energy about 25mJ (depending on powder Volume Resistivity, Electrostatic Chargeability, particle size, and vessel dimensions)

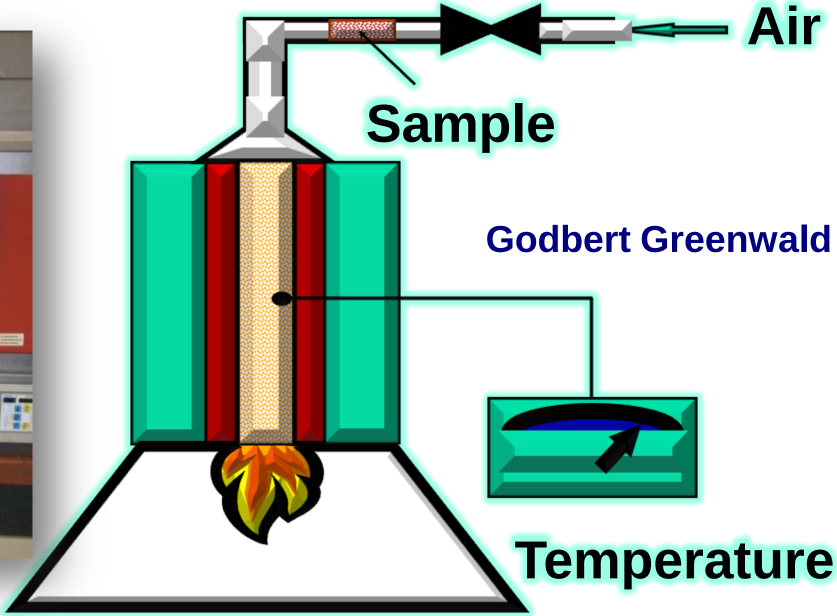
  - If the Chargeability and Volume Resistivity test results show that the quantity of electrostatic charge on the particles is sufficient to cause discharges from the surface of the bulking powder consider:

    - Installation of inert gas blanketing, or
    - Installation of explosion protection



Minimum Ignition Temperature - Dust Cloud, (ASTM E 1491)

- Minimum Ignition Temperature of a dust cloud is a measure of its sensitivity to ignition by heated environments
- Minimum Ignition temperature is NOT a fundamental property of the dust. Factors affecting MIT include particle size, moisture content, and test apparatus



Minimum Ignition Temperature - Dust Layer, (ASTM E 2021)

- MIT of dust layer is the lowest temperature of a heated free-standing surface capable of igniting a dust layer (12.7mm thick)
- With thicker layers, smoldering / glowing may start at a lower temperature
- Test applicable only for materials which will not melt or evaporate before reaching the ignition temperature

Minimum Ignition Temperature

- Minimum Ignition Temperature tests provide information on:
  - Sensitivity to ignition by:
    - hot environments and surfaces of some processing equipment and plant
    - hot surfaces caused by overheating of bearings and other mechanical parts due to mechanical failure
    - frictional sparks
  - Maximum exposure temperature (Temperature Rating) for electrical equipment

Control of Heat Sources and Frictional Sparks

- Prevent overloading of processing plant (grinders, conveyors, etc.)
- Isolate/shield hot surfaces
- Prevent/remove dust accumulations on hot surfaces
- Use approved electrical equipment (correct temperature rating)
- Prevent overheating due to misalignment, loose objects, belt-slip/rubbing etc. by regular inspection and maintenance of plant
- Prevent foreign material from entering the system when such foreign material presents an ignition hazard. Consider use of screens, electromagnets, pneumatic separators, etc.
- Hot work operations should be controlled by a hot work permit system in accordance with NFPA 51B, Standard for Fire Prevention During Welding, Cutting and Other Hot Work

Self-Heating

Prevention of Fires and Explosions in Dryers, 2nd Edition, IChem E, 1990

- Ignition of bulk powders can occur by a process of self-heating
- Ignition occurs when the temperature of the powder is raised to a level at which the heat liberated by the exothermic reaction is sufficient to exceed the heat losses and to produce runaway increase in temperature
- The minimum ambient temperature for self-ignition of a powder depends mainly on the nature of the powder and on its dimensions

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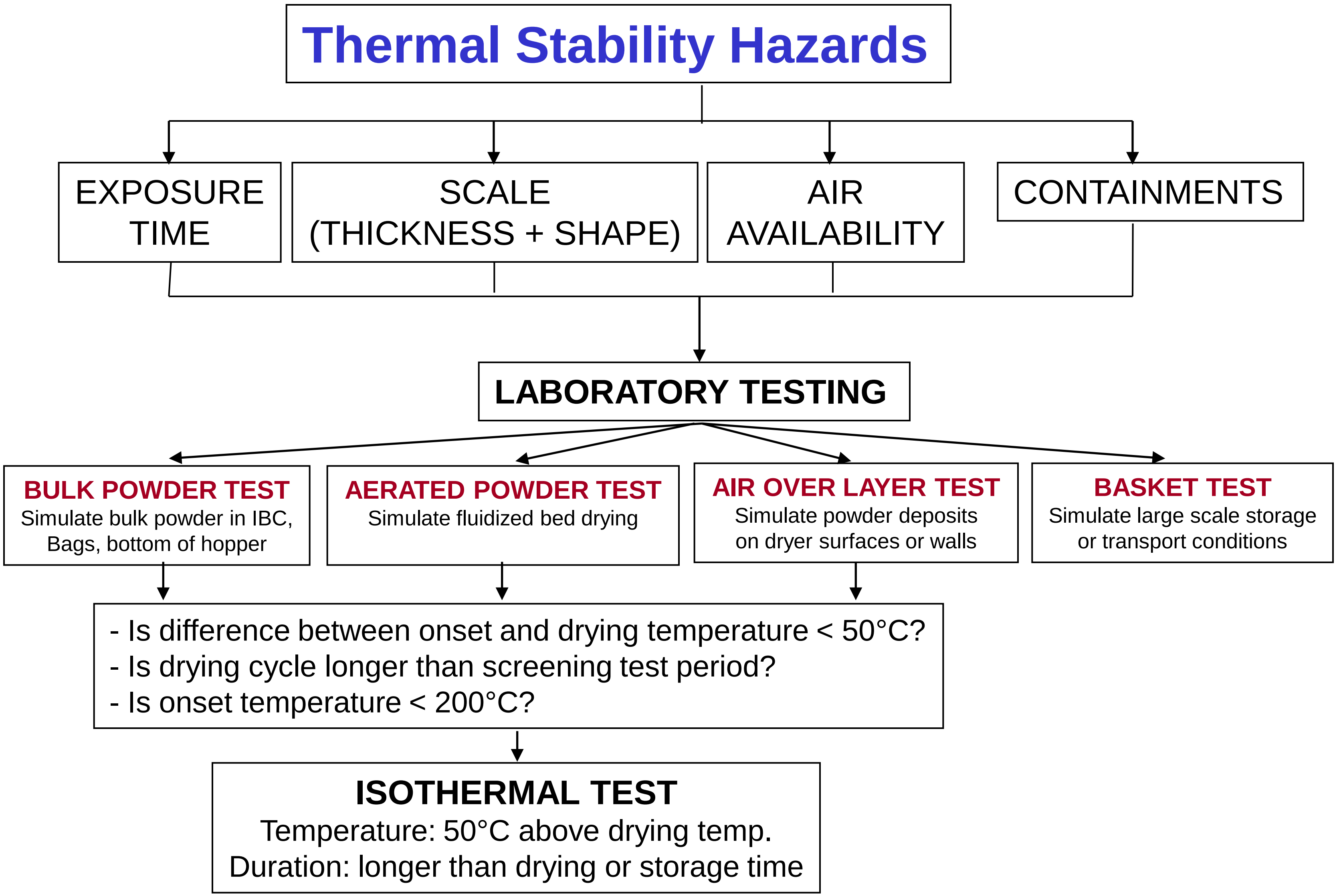
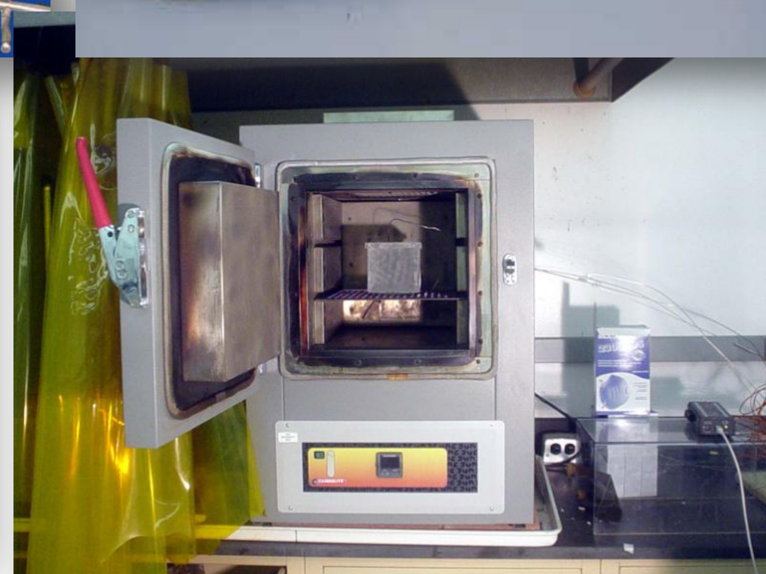
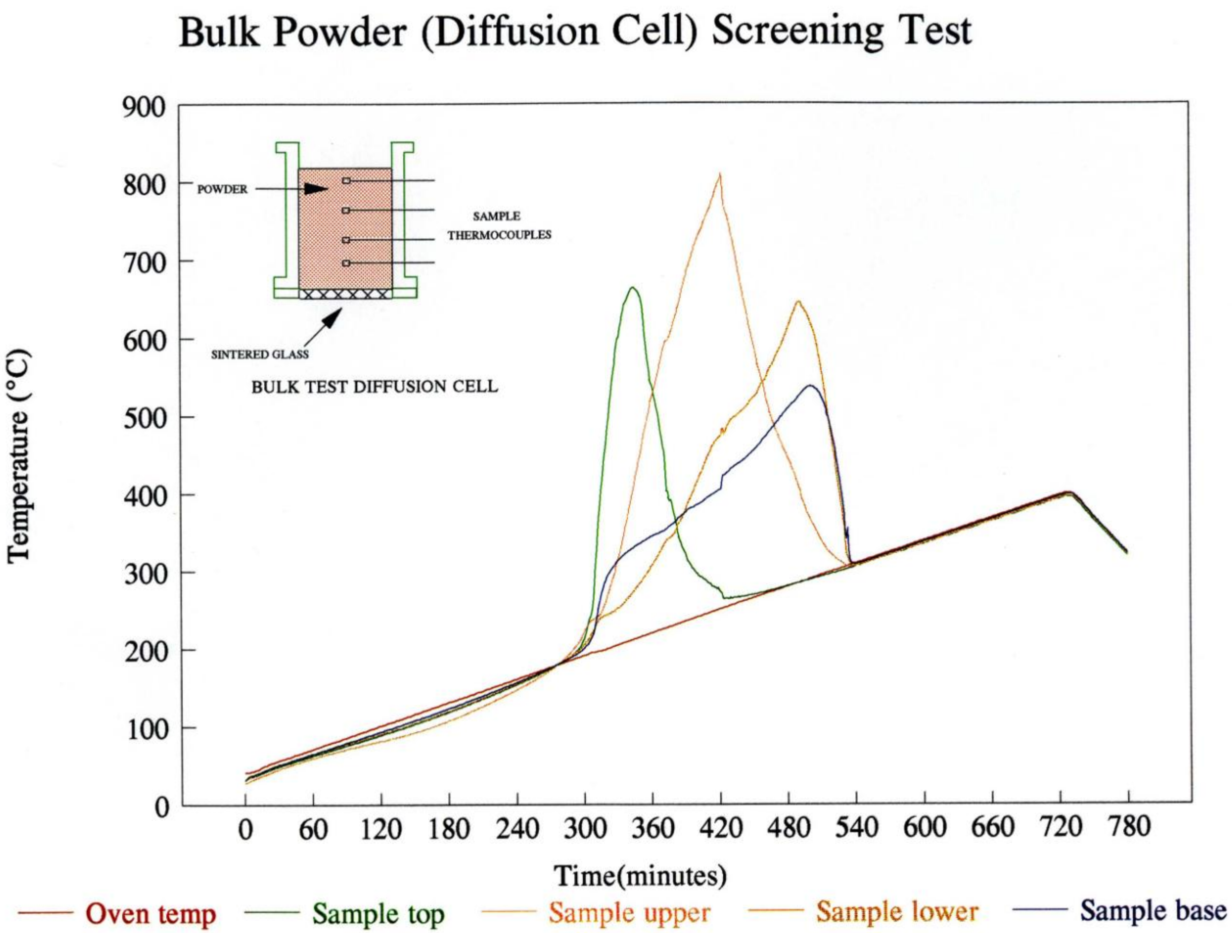


Self-Heating

Various Test Cells for Thermal Stability Testing



Self-Heating



Self-Heating

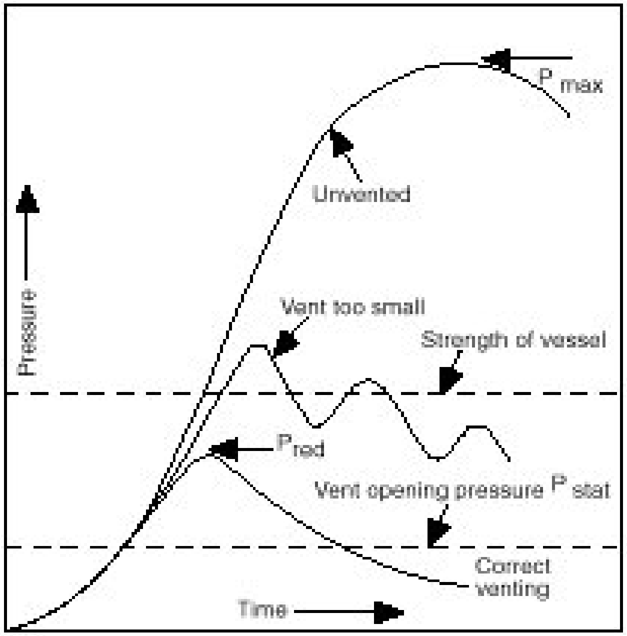
- If the material is subjected to heat as part of the normal process (e.g. during drying), the temperature should be maintained below the self heating temperature (for solids)

Explosion Severity of Dust Cloud, K_{st} (ASTM E 1226)

- An indication of the severity of dust cloud explosion
- Data produced:
  - *Maximum developed pressure, P_{max}*
  - *Maximum rate of pressure rise, $(dP/dt)_{max}$*
- Deflagration index (explosion severity) K_{st}

$$K_{st} = (dP/dt_{max}) \cdot V^{1/3} \quad [bar.m/s]$$

Where V is the volume of the test vessel (m^3)



- Used for the design of deflagration protection (venting, suppression, Containment)

Explosion Severity - Dust Explosion Hazard Classification

Based on test data using $1m^3$ and 20L Vessels and 10KJ Ignition Source		
Dust Explosion Class	K_{st} (bar.m/s)	Characterization
St 0	0	Non-explosible
St 1	$0 < K_{st} < 200$	Weak to moderately explosible
St 2	$200 < K_{st} < 300$	Strongly explosible
St 3	$K_{st} > 300$	Very strongly explosible

Note:

- **Any explosion can cause burn injuries**
- **Any explosion can cause structural damage if the structure is not strong enough**

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Comparison of Dust Properties Measured in $1m^3$ and 20L Vessels

Material	Kst $1m^3$ (bar-m/sec)	Kst 20L (bar-m/sec)	P_{max} $1m^3$ (bar-m/sec)	P_{max} 20L (bar)
Calcium Stearate	140	197	9.1	6.6
Lignite	138	113	7.3	6.2
Maltodextrine	205	147	9.5	6.8
Grinding Dust	36	59	4.2	2.9
Sodium Momochloroacetate	0	62	0	7.4
Lixivalt Dust	0	9	0	3.3
Metco Dust	0	13	0	1.3
Solid Sewing Residues	0	65	0	1.3
PVC Dust	64	113	8.7	7.8

Ref. **Proust, CH., et al, Journal of Loss Prevention in the Process Industries, Vol. 20, 2007**
Rodgers, S. A., et al, 6th Global Congress on Process Safety, San Antonio, TX, March 2010

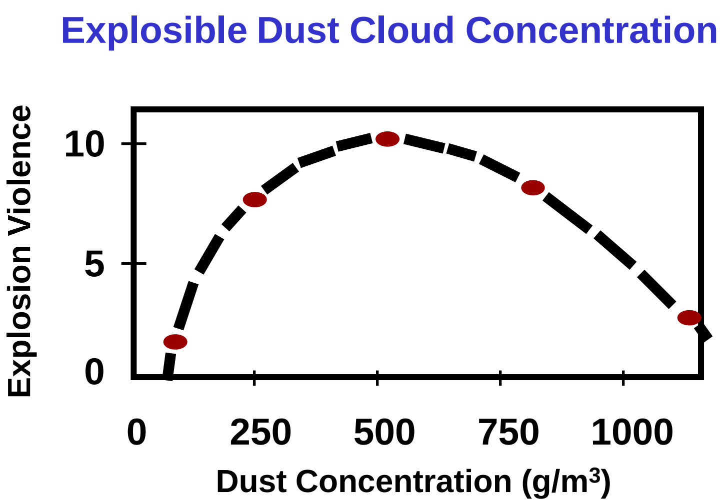
Explosion Severity of Dust Cloud, K_{st} (ASTM E 1226)

Chilworth 1m³ Vessel

Minimum Explosible Concentration (ASTM E 1515)

- When concentration of dispersed dust cloud in air is below the **Minimum Explosible Concentration**, an explosion can not propagate

- Explosion violence of the cloud increases as the dust concentration increases until an optimum concentration is reached giving the highest explosion violence



Limiting Oxidant Concentration (ISO 6184/1)

- The concentration of oxidant below which a deflagration cannot occur is referred to as the **Limiting Oxidant Concentration (LOC)**

- Limiting Oxidant Concentration (LOC) for combustion is dependent on the material and type of inert gas used

- Nitrogen gas is the most commonly used inert gas. Carbon dioxide and argon are also used

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Inert Gas Blanketing Techniques - NFPA 69

- **Pressure Purging**
  Vessel is pressurized with an inert gas, then relieved to the outside. This procedure is repeated until the desired oxygen concentration is reached.

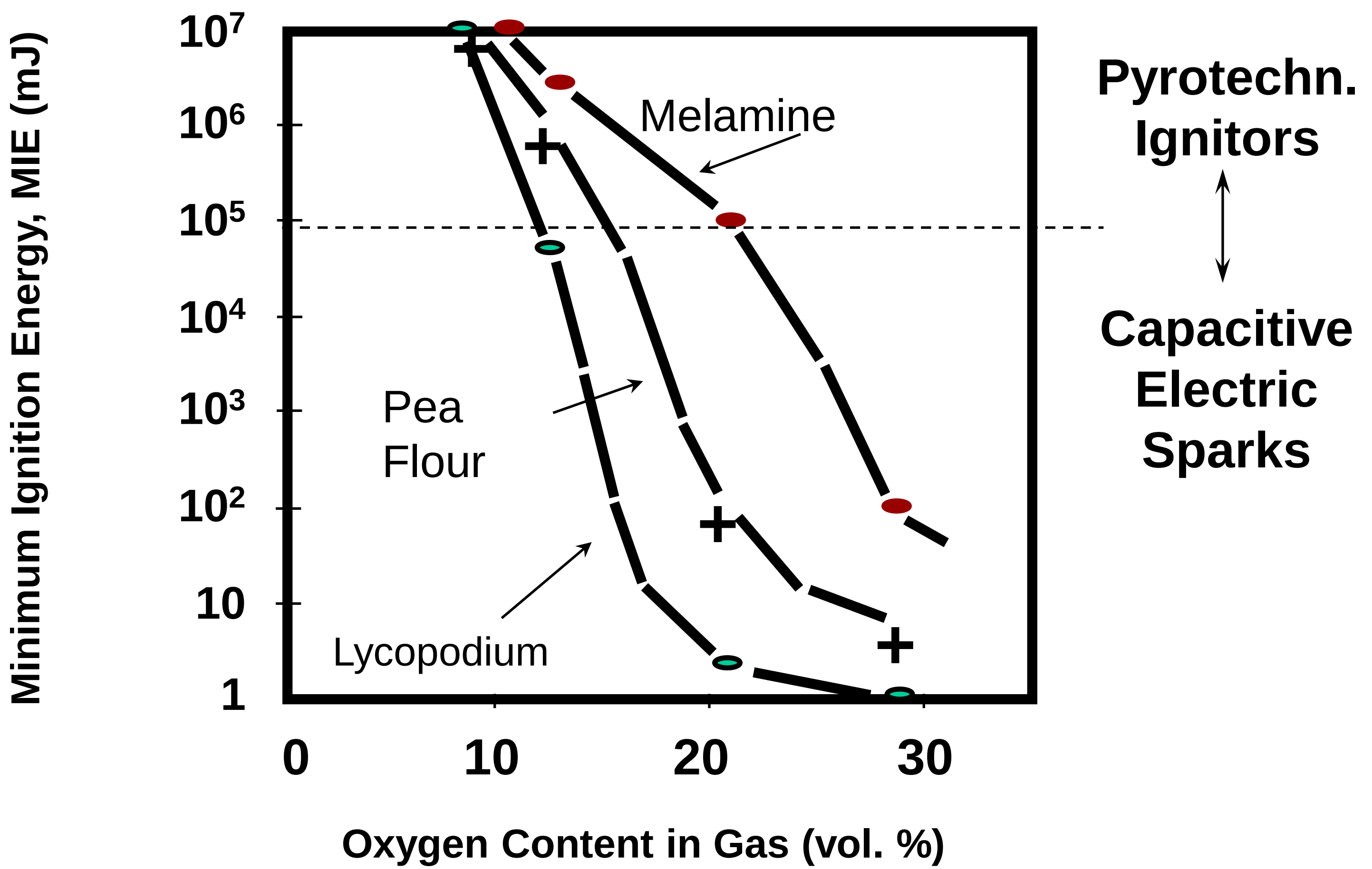
- **Vacuum Purging**
  Vessel is evacuated and then pressure is increased to atmospheric using an inert gas.

- **Flow-Through Purging**
  Vessel is purged with a continuous flow of inert gas.

Partial Inerting

- Partial inerting is considered where:
  - It is impossible or impractical to reduce the oxidant concentration below the LOC
  - Explosion protection measures alone cannot satisfactorily provide a Basis of Safety
- Reduces the ignition sensitivity and explosion severity of the atmosphere
- Does not completely eliminate the fire or explosion hazard and must be used in conjunction with another Basis of Safety

Influence of Oxygen Content in Gas on MIE *(Eckhoff)*



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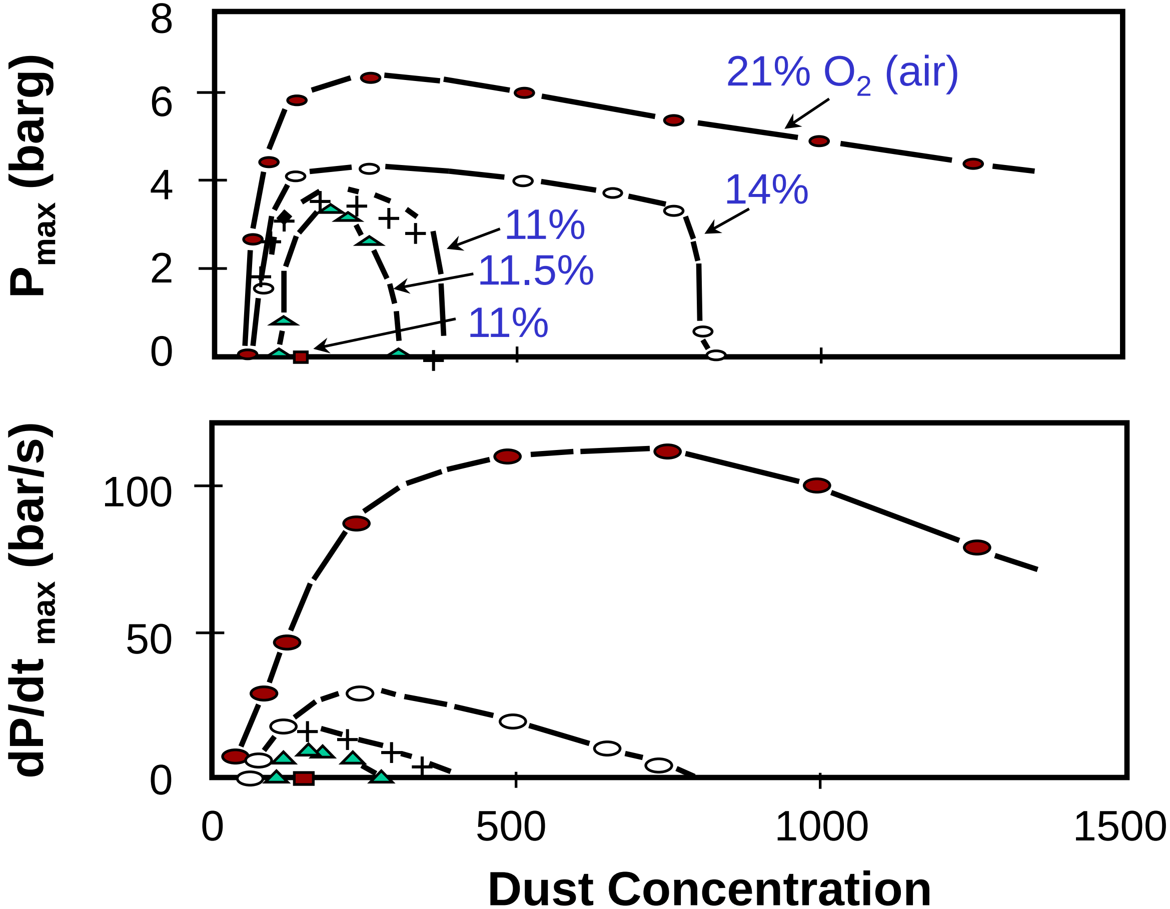
Influence of oxygen content in the gas on the maximum explosion pressure and maximum rate of pressure rise of brown coal dust for various dust concentrations. Nitrogen as inert gas. *(R. K.Eckhoff, 1997)*



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Test Data Requirements for Some Unit Operations

Unit Operation	Explosion Screening[1]	MIE (mJ)	MIT – Cloud (°C)	MIT – Layer (°C)	Explosion Severity – Kst (bar.m/s)	LOC[2] (%)	MEC (g/m^3)	Volume Resistivity[3] (Ω.m)	Chargeability[4] (C/Kg)	Self-Heating Onset Temp. (°C)
Manual Handling / Pouring	X	X						X	X	
Sieving / Screening	X	X						X	X	
Tumble / Double Cone Blending	X	X			X	X		X	X	
Ribbon Blending	X	X	X	X				X	X	
Milling	X	X	X	X	X	X		X	X	X
Jet Milling	X	X			X	X		X	X	
Drying (Fluidized Bed, Spray, Tumble)	X	X			X			X	X	X
Tray Drying	X	X			X					X
Pneumatic Conveying	X	X					X	X	X	
Screw Conveying	X	X	X					X	X	
Transfer to Hopper / Bin / Tote / Container	X	X			X			X	X	
Dust Collector and Exhaust Ventilation	X	X			X		X	X	X	

Test Data Requirements for Some Unit Operations

1. Explosibility Screening test is only conducted if the combustibility of the powder/dust (present in the process/facility) is not yet established. If the dust is found to be non-combustible, other tests in the table may not be required
2. LOC is determined if the basis of safety is inert gas blanketing
3. Volume Resistivity should be considered if the Minimum Ignition Energy is less than 25mJ
4. Chargeability should be considered if the Minimum Ignition Energy is less than 25mJ

About Chilworth Global

Chilworth Global

Our History

- **Chilworth Global was first established in the UK in 1986**
- **Since then we have expanded and are now providing process safety and flammability services through our facilities in:**
  - **United Kingdom – Chilworth Technology Ltd**
  - **United States of America:**
    - Chilworth Technology, Inc – New Jersey
    - Safety Consulting Engineers - Chicago
    - Chilworth Pacific Fire Laboratories – Kelso, Washington
  - **Italy – Chilworth Vassallo Srl**
  - **France – Chilworth SARL**
  - **India – Chilworth Safety and Risk Management Ltd**
  - **Spain – Chilworth Amalthea SL**

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Our Business

We provide services to business and industry to help **identify**, **characterize**, **prevent**, and **mitigate** potential fire, explosion, and thermal instability (runaway reaction) hazards in their processes

We achieve this by providing the following services:

- Process safety consulting and Incident Investigation
- Laboratory testing
- Training courses

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Our Services

- **Consulting**
  - Hazard Assessment
  - Incident Investigation
  - Process Safety Engineering

- **In-Company Training Courses**
  - Gas/Vapor Explosion Hazards
  - Dust Explosion Prevention & Protection
  - Understanding & Controlling Static Electricity
  - Understanding Thermal Instability Hazards

- **Laboratory Testing (ISO 17025 Certified Tests)**
  - Gas/Vapor Flammability
  - Dust Fire/Explosion
  - Electrostatic Characteristics
  - Reaction hazards and Thermal Runaway

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Our Expertise

- Gas & Vapor Flammability
- Dust Explosion Hazards
- Chemical Reaction Hazards
- Chemical Process Optimization
- Spontaneous Combustion and Thermal Instability
- Electrostatic Hazards, Problems, & Applications
- Hazardous (Electrical) Area Classification
- Transportation of Dangerous Goods
- Process Safety Management
- Flammability of Materials

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Our Clients

Chilworth Global serves clients in a wide variety of industries, including:

- Basic and Specialty Chemicals
- Pharmaceuticals
- Paints and Coatings
- Petrochemicals
- Agrochemicals
- Agricultural and Food Products
- Oil and Gas
- Metals
- Soaps and Detergents
- Fragrance and Flavors
- Plastics and Resins
- Pulp and Paper