Minimum Ignition Energy (MIE)

Assessment of Dust Explosion Hazards – Practical Facts to Consider

Presented by:

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- Safety Consulting Engineers, Inc. 2001-2007
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- Memberships – AIChE, ASTM, NFPA
- Editorial Advisory Board of Powder/Bulk Solids and Journal of Loss Prevention in the Process Industries
- Chairperson of the ASTM E27 Committee
- NFPA Technical Committee 654, 655, 91, 61, 664, & 484

Fundamentals of Dust Explosions

Dust Fires & Explosions

Like all fires, a dust fire occurs when fuel (the combustible dust) is exposed to heat (an ignition source) in the presence of oxygen (air)

Removing **any one** of these elements of the classic fire triangle eliminates the possibility of a fire

Dust Fires & Explosions (continued)

Dust explosions require the presence of two additional elements – *dust dispersion and confinement*

Suspended dust burns more rapidly and confinement allows for pressure buildup; removal of either the suspension or the confinement elements prevents an explosion, although a fire may still occur

Hazard Identification

Screening Tests
Is My Material Combustible?

- Two main tests
  - Determination of Combustibility
    - UN Test N.1 (4.1) – Test Method for Readily Combustible Solids
    - Identifies if the material presents a fire hazard
  - Determination of Explosibility
    - ASTM E1226 – Go/No Go Methodology
    - ASTM E1515 – Minimum Explosible Concentration

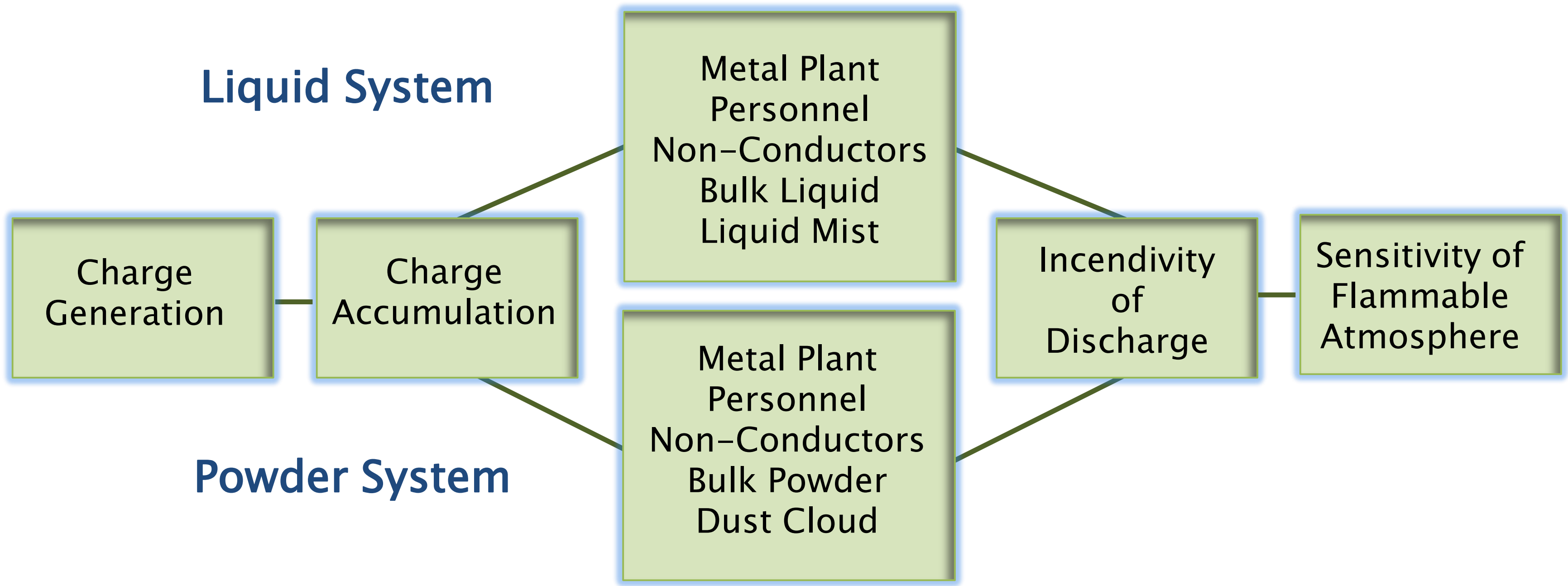
Characterize the Explosion Potential of a "Material"

- Explosion severity – violence of the explosion
  - K_{St} – Dust deflagration index
  - P_{max} – Maximum explosion overpressure
  - $(dP/dt)_{max}$ – Maximum rate of pressure rise
- Ignition sensitivity – ease of ignition
  - **MIE – Minimum ignition energy**
  - MEC – Minimum explosible concentration
  - MIT – Minimum Ignition Temperature
  - LIT – Layer Ignition Temperature
  - LOC – Limiting Oxygen Concentration

Minimum Ignition Energy

Identification of Electrostatic Hazards

Systematic Approach to Electrostatic Hazard Assessment



Minimum Ignition Energy (MIE) ASTM E2019

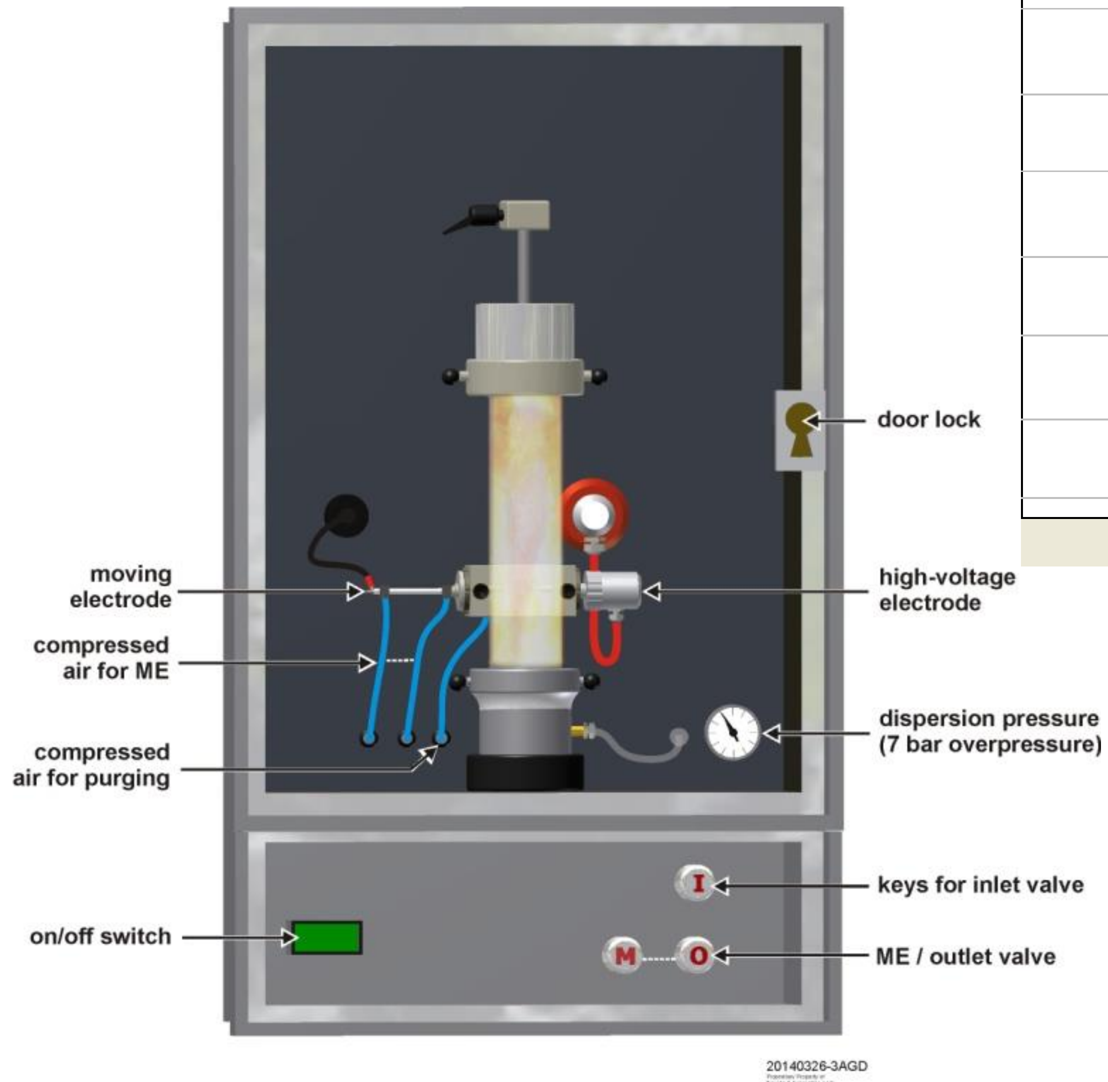
- Predicts the ease and likelihood of ignition of a dispersed dust cloud
- MIE of a flammable dust is the minimum spark energy needed to ignite an ideal concentration under lab conditions
  - A capacitive discharge spark is used for this test
  - Test can be run with or without inductance
  - Compared to typical ES ignition sources

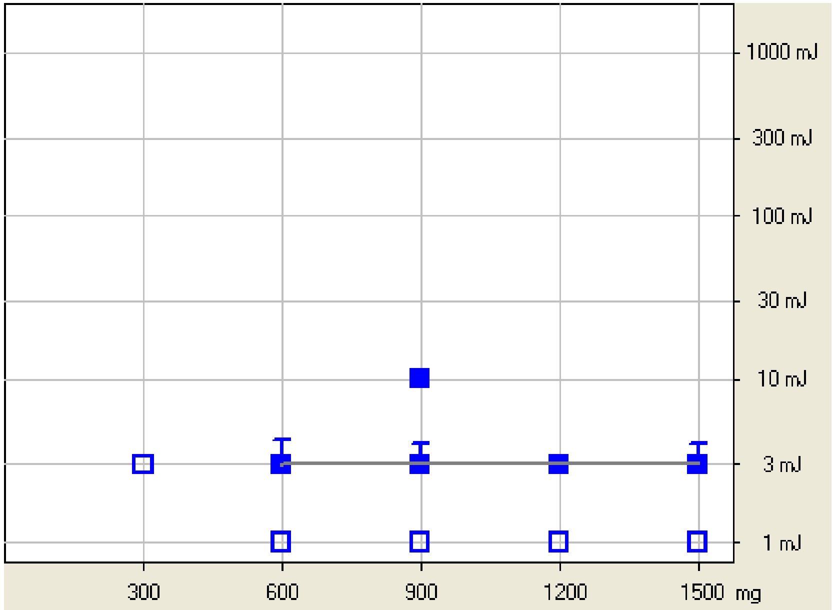
Spark Discharge from a Capacitor

$$W_{Stored} = \frac{1}{2} C (V_1^2 - V_2^2)$$

Where:	W_{STORED}	=	capacitor stored ignition energy, Joules
	C	=	capacitance of the discharge circuit capacitor, Farads
	V_1	=	voltage to which the capacitor is charged, Volts
	V_2	=	voltage on the capacitor after discharge, Volts

Kühner MIKE 3 – now TÜV





Minimum Ignition Energy Test

Statistically Interpolated MIE – Es

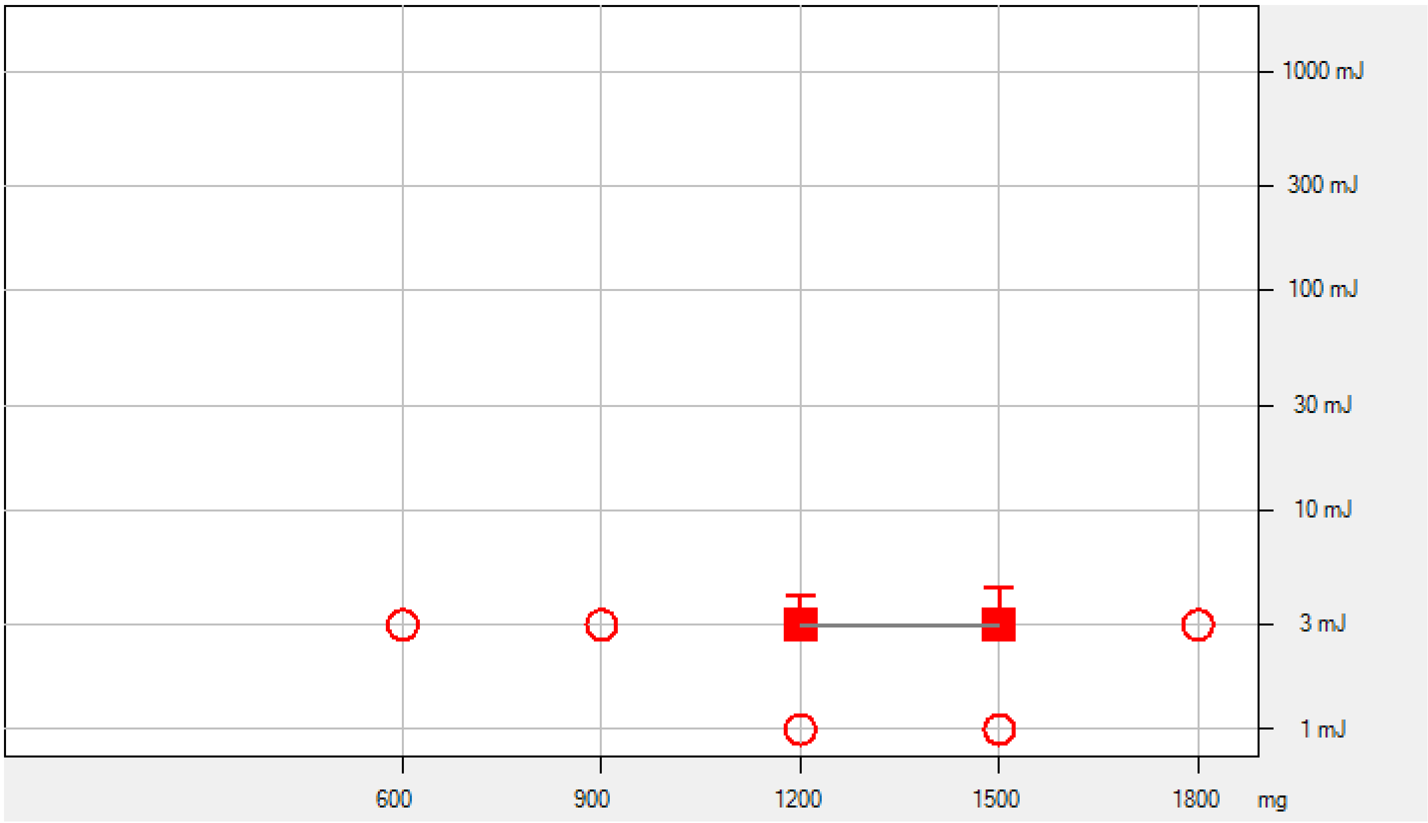
$$E_s = 10^{\left(logE_2 - \left(\frac{I[E_2](logE_2 - logE_1)}{(NI+I)[E_2]+1}\right)\right)}$$

I[E2] = number of tests with ignition at the energy E2.
(NI+I)[E2] = total number of tests at the energy E2.

Ignition Energy (mJ)	Dust Loading in 1.2-L chamber (mg)					Probability
	300	600	900	1200	1500	
30	NI	I	I	I	NI	**3 of 5**
10		**NI**	**NI**	**NI**		**0 of 3**

$$E_s = 10^{\left(log30 - \left(\frac{3(log30 - log10)}{5+1}\right)\right)} = 17\ mJ$$

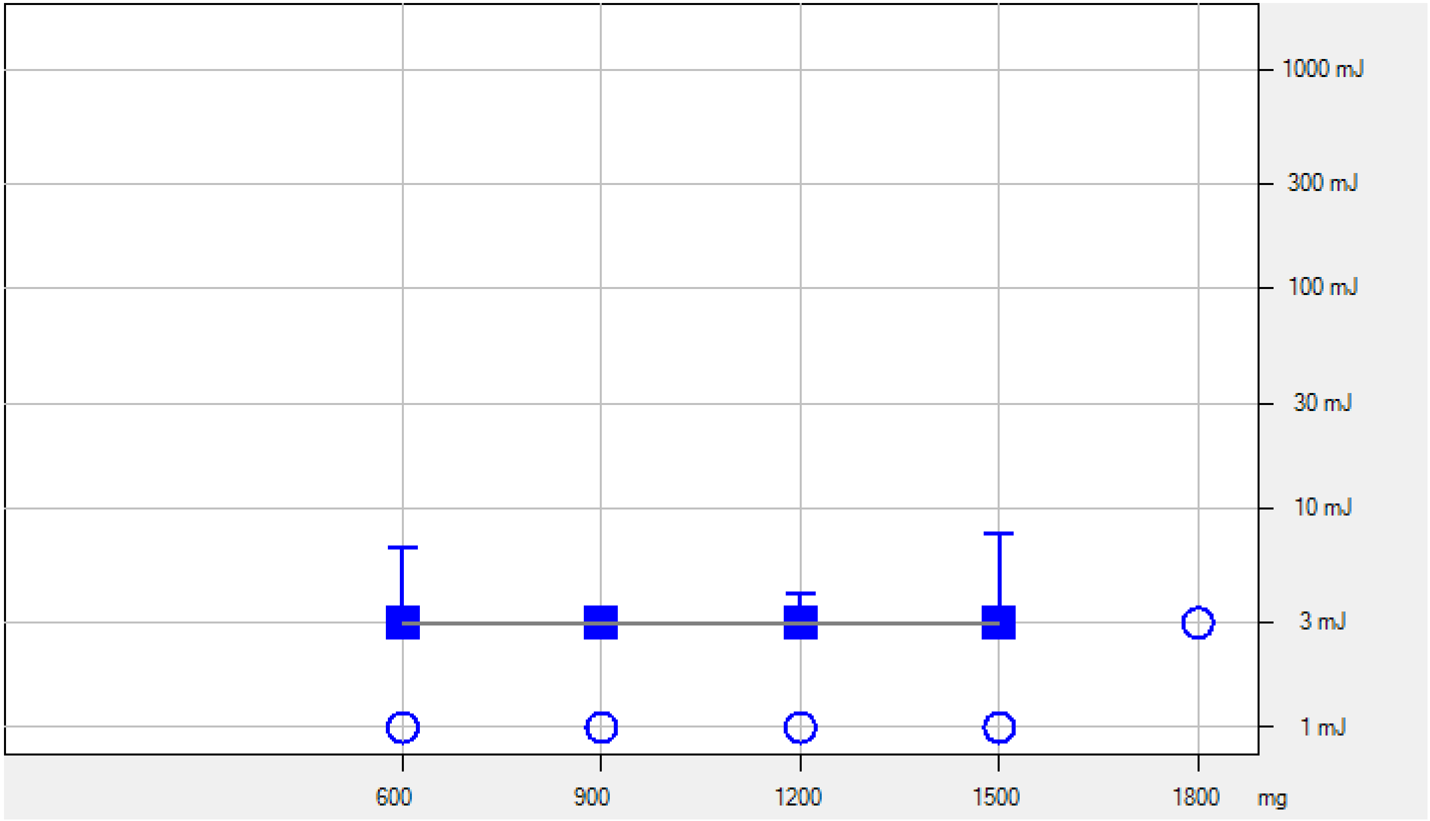
90 ms Delay Time



1mJ < MIE < 3 mJ

Es = 2.1mJ

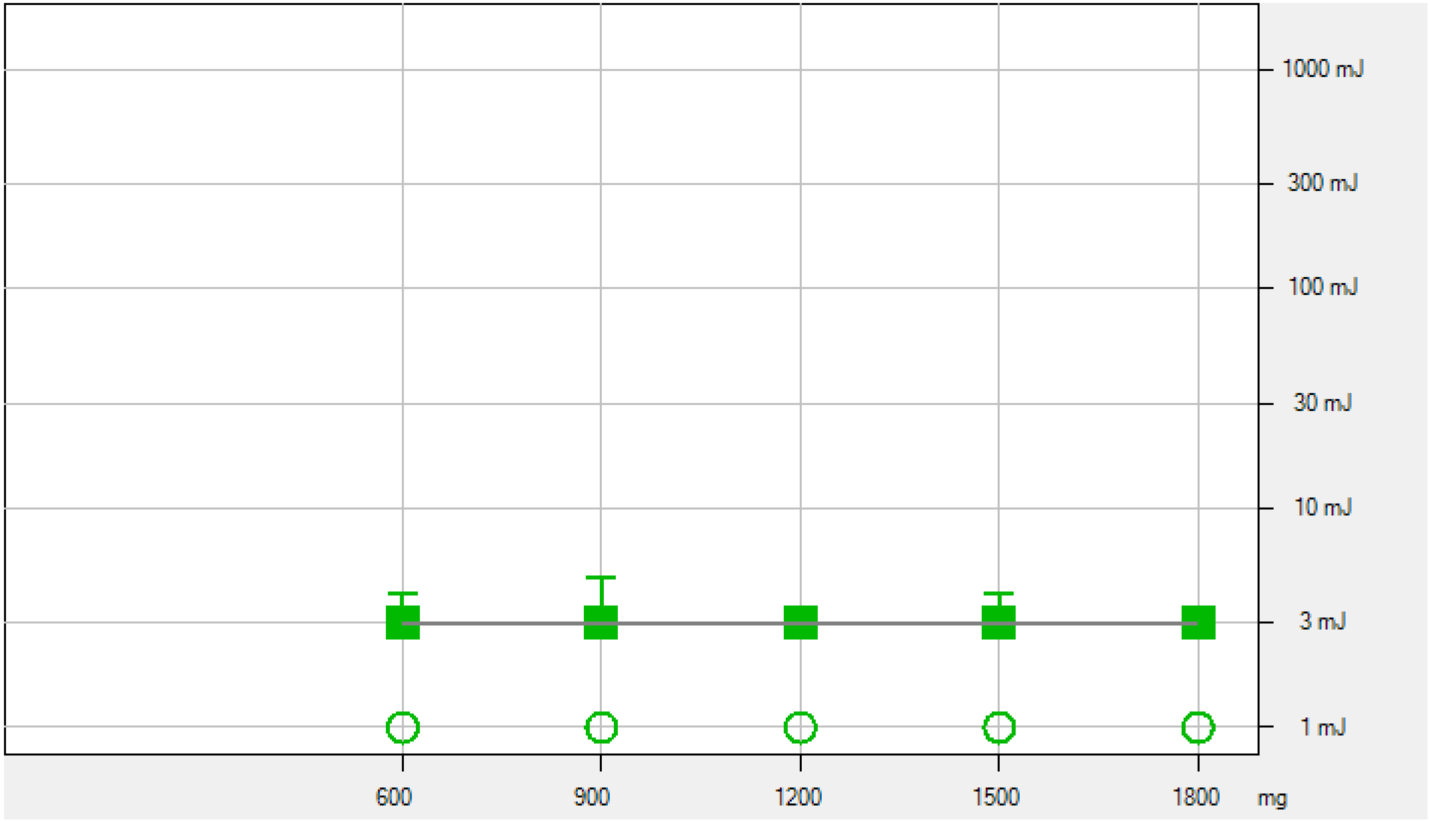
120 ms Delay Time



1mJ < MIE < 3 mJ

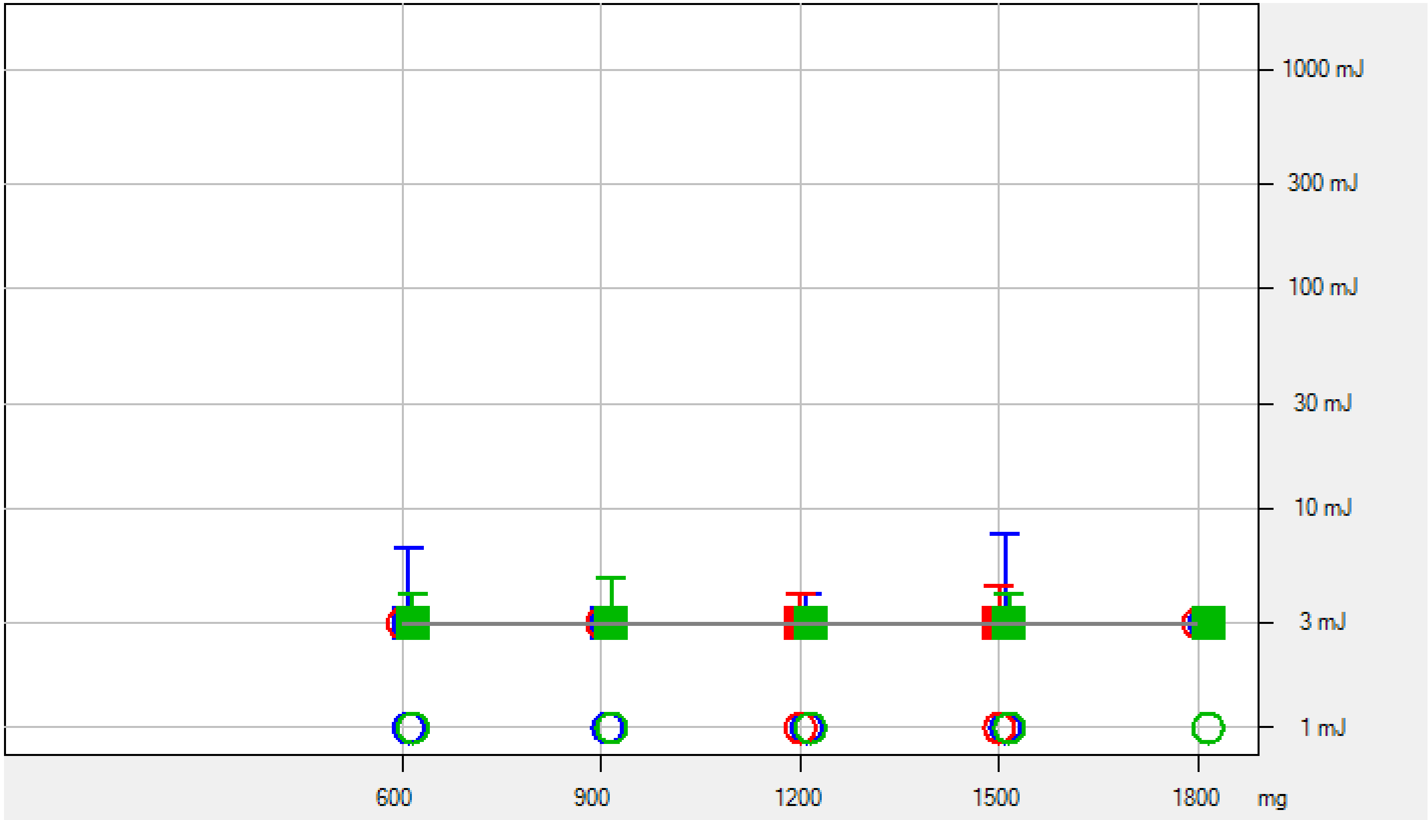
Es = 1.4 mJ

150 ms Delay Time



1mJ < MIE < 3 mJ Es = 1.2mJ

All Times Reported



1mJ < MIE < 3 mJ

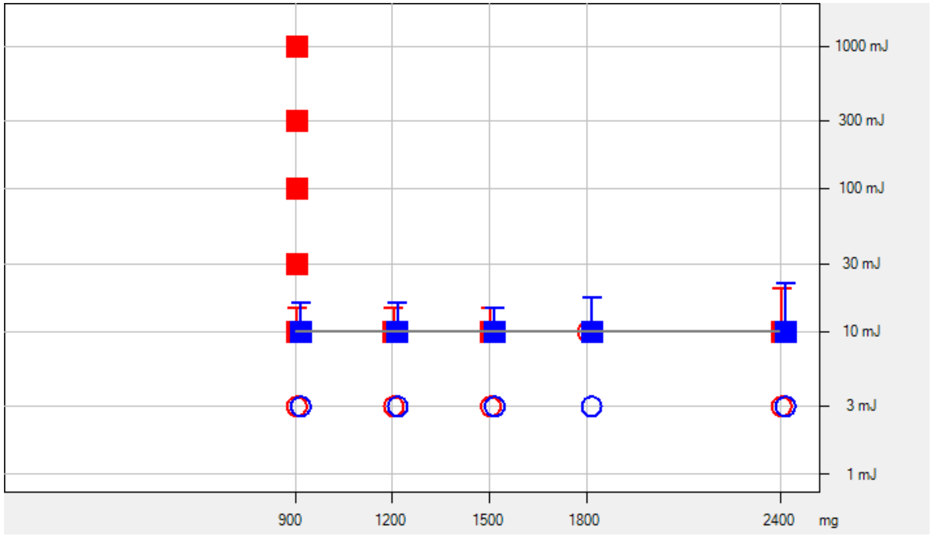
Es = 1.2mJ

Minimum Ignition Energy (MIE) ASTM E2019 (continued)

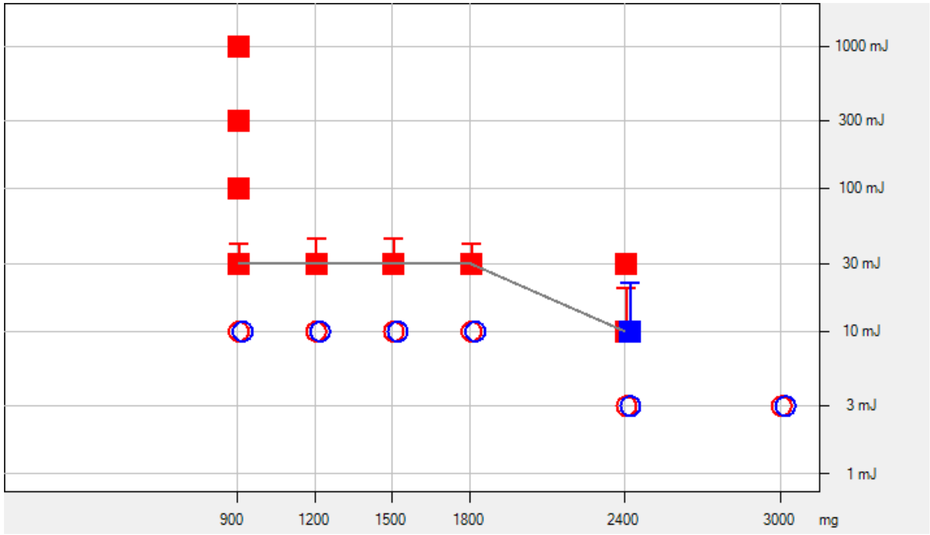
- Examples: sugar (powdered) 30 mJ, paper dust 20-60 mJ, aluminum 50 mJ, magnesium 40 mJ

MIE (mJ)	Recommended Precaution per BS 5958
500	Low sensitivity to ignition; ground plant below this level
100	Consider grounding personnel below this level
25	The majority of ignition incidents occur below this level
10	High sensitivity to ignition. Consider restrictions on the use of high resistivity non-conductors below this level
1	Extremely sensitive to ignition at this level. Handling operations should be such that they minimize the possibility of suspending the powder in air.; dissipate or discourage charge operations

With or Without Inductance

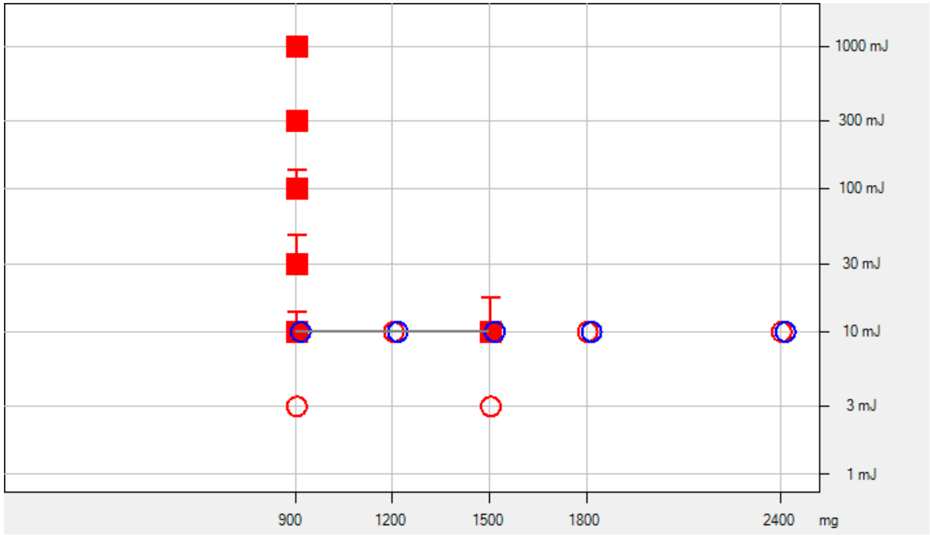


Fine Chemical 27 µm mean
With inductance Es = 4 mJ

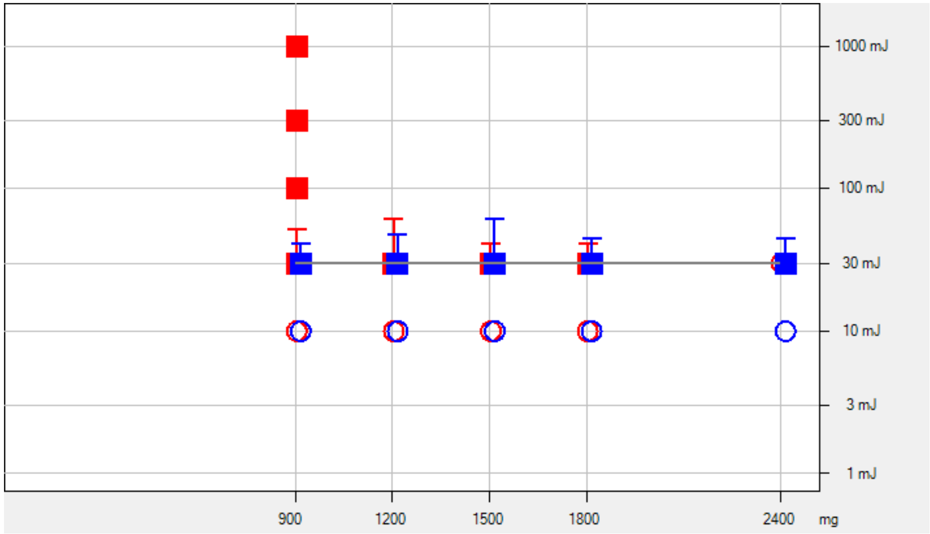


Fine Chemical 27 µm mean
Without inductance Es = 8 mJ

Particle Size Influence

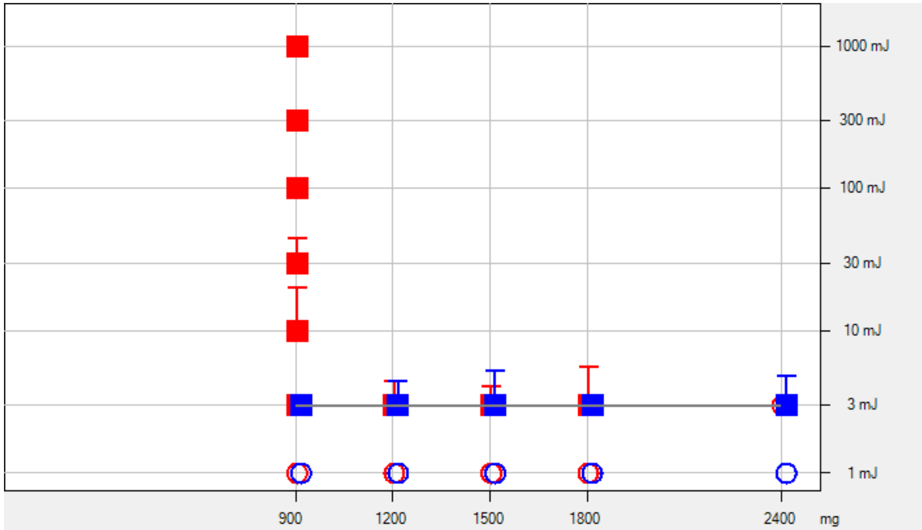


Fine Chemical 34 µm mean
With inductance Es = 7 mJ

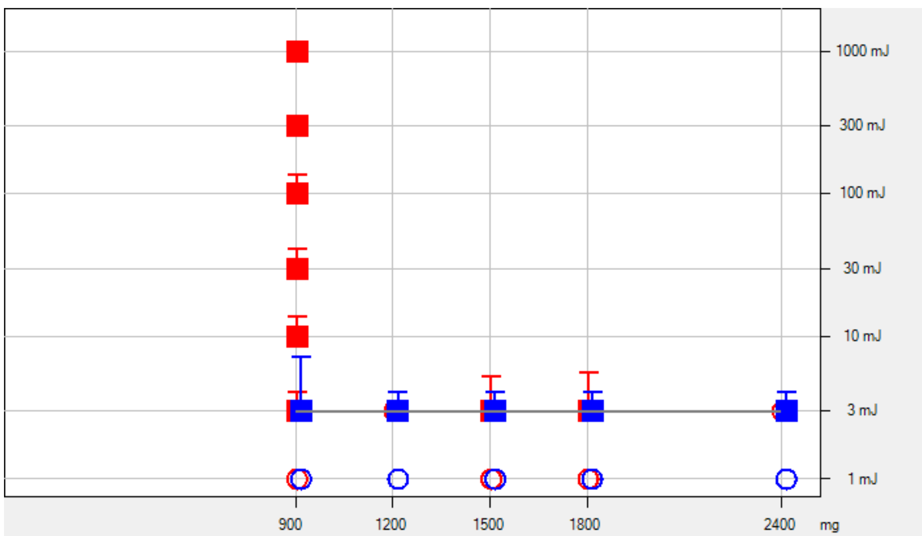


Fine Chemical 34 µm mean
Without inductance Es = 12 mJ

Particle Size Influence

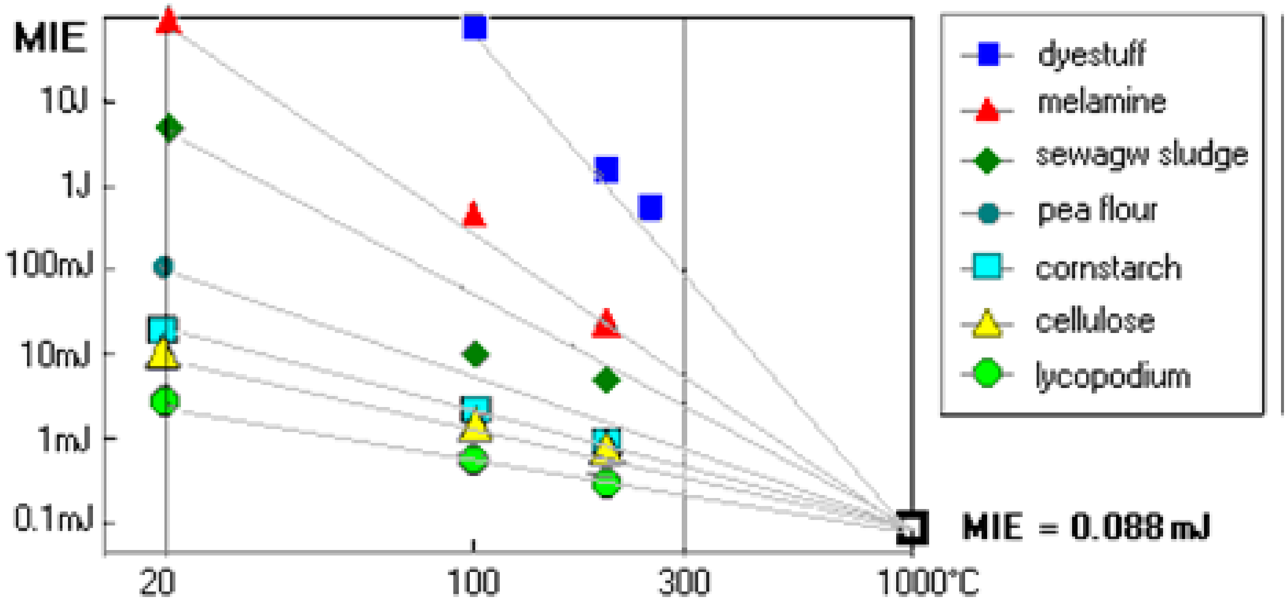


Fine Chemical 16 µm mean
With inductance Es = 1.2 mJ



Fine Chemical 16 µm mean
Without inductance Es = 1.2 mJ

MIE at Elevated Temperatures

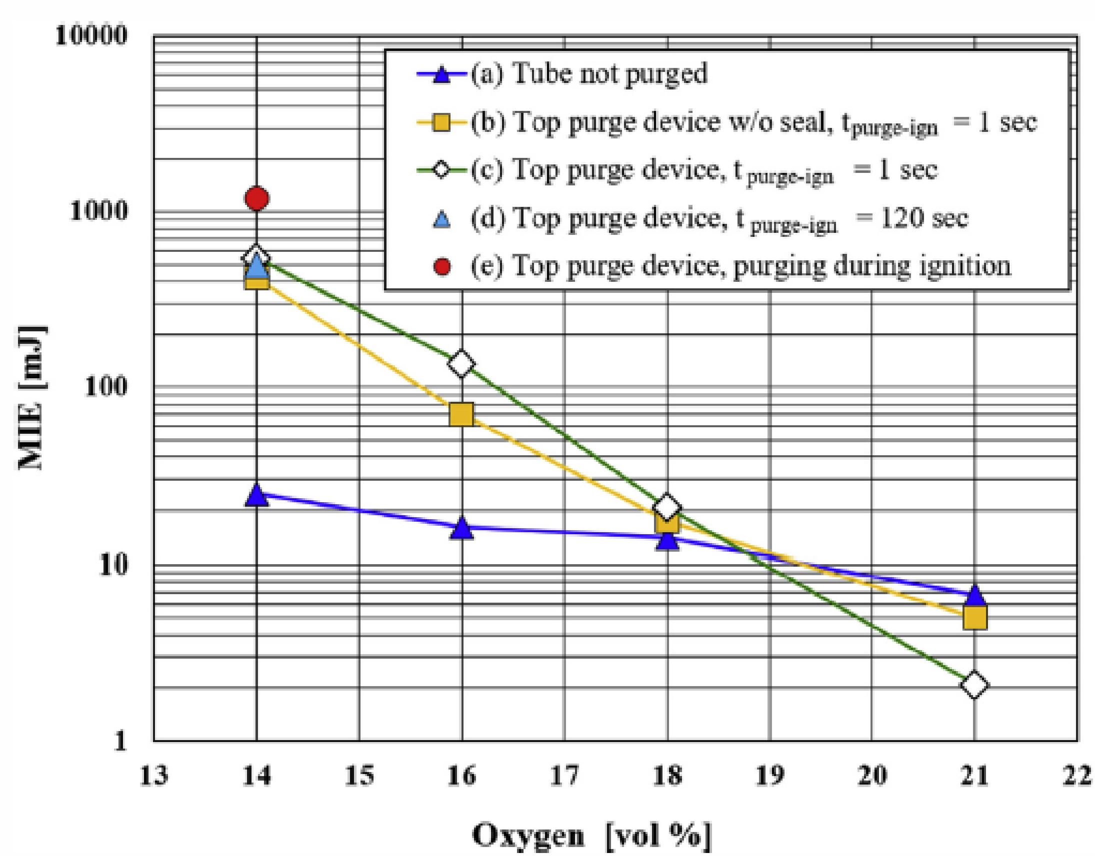


$$MIE(T) = 10^{-4.056 + (1.873 - 0.624 \log T) \cdot (\log MIE(25°C) + 4.056)}$$

Reduced Oxygen MIE

Kühner Mike 3

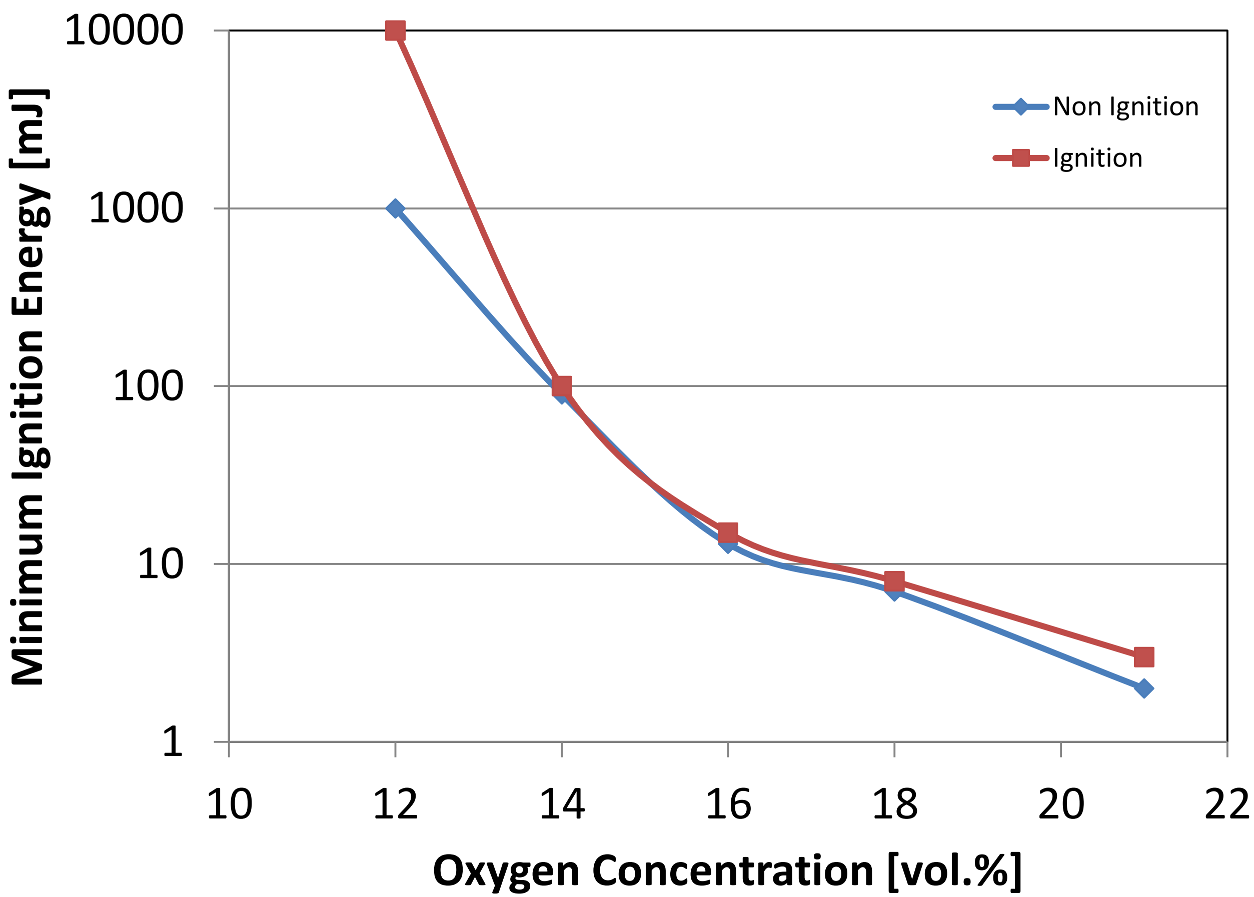
- Niacin
  - CaRo15
- Tested without inductance
- Different lines for different configurations



Chaudhari and Mashuga
Journal of Loss Prevention in the Process Industries 48 (2017) 145-150

Reduced Oxygen MIE

CTL MIE Unit



- Niacin
  - CaRo17
- Tested with inductance

Closing

- Minimum Ignition Energy (MIE)
  - Is not an intrinsic material property
  - Sample specific
    - Size distribution
    - Morphology
    - Moisture
- Run with or without inductance
  - Electronic Spark
  - Static Electric Spark
- Extension of the standard method
  - Temperature
  - Oxygen level
  - Pressure?

End