FPST 3373 Fire Dynamics
Explosion

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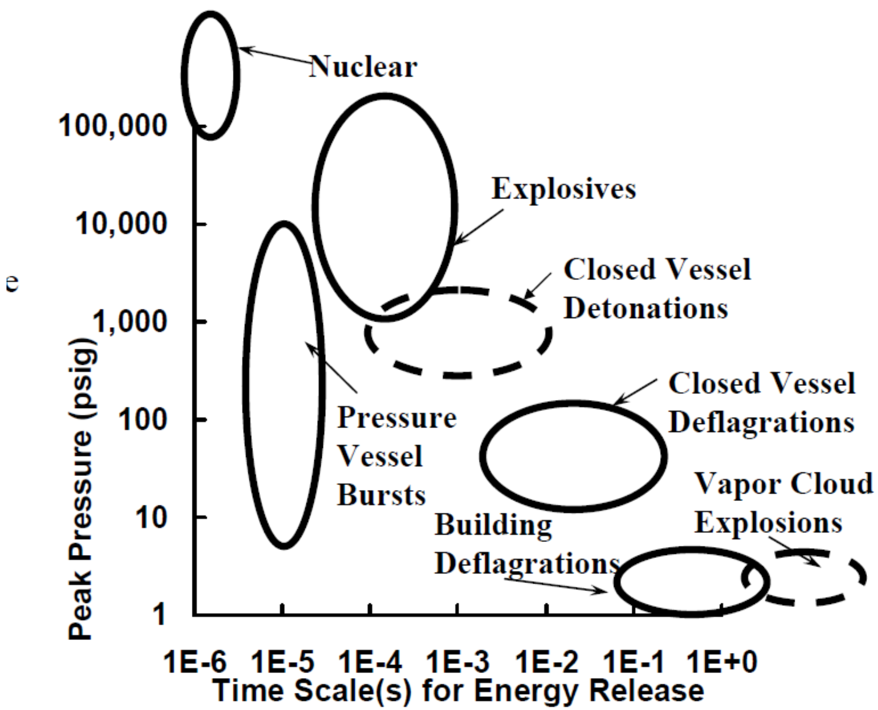
Objectives

- Understanding types of explosion
  - Gas / liquid explosion
  - Dust explosion
- Understanding deflagration and detonation
- Understanding pressure impact on human

Explosion/fire types

- Flashfire
  - Direct flame contact / thermal radiation
- Deflagration (subsonic)
  - Unconfined Vapor Cloud Explosion (UVCE)
    - https://www.youtube.com/watch?v=-XodEpvbgLY
  - Confined explosion (vapor or dust explosions)
    - https://www.youtube.com/watch?v=4hS6IGO2tdA
  - BLEVEs (boiling liquid expanding vapor explosion)
    - https://www.youtube.com/watch?v=UM0jtD_OWLU
- Detonation (supersonic)
  - https://www.youtube.com/watch?v=_KuGizBjDXo

Explosion overpressure and time scale



Basic approach:
Most building structure can be significantly damaged by any of these explosion!

Initiation requirements

- Fuel
- Oxidant
- Ignition source
  - **Delayed ignition**
- **Confinement**
  - Partial or complete

Consequence of overpressure

Pressure (psig)	Pressure (kPa)	Consequences
0.15	1.03	Typical pressure for glass breakage
2	13.8	Partial collapse of walls and roofs of houses
5-7	34.5-48.2	Nearly complete destruction of houses
10	68.9	Probable total destruction of building
5-14.5	35-100	Eardrum rupture
29-72	200-500	Lung damage
101-217	700-1500	Lethality

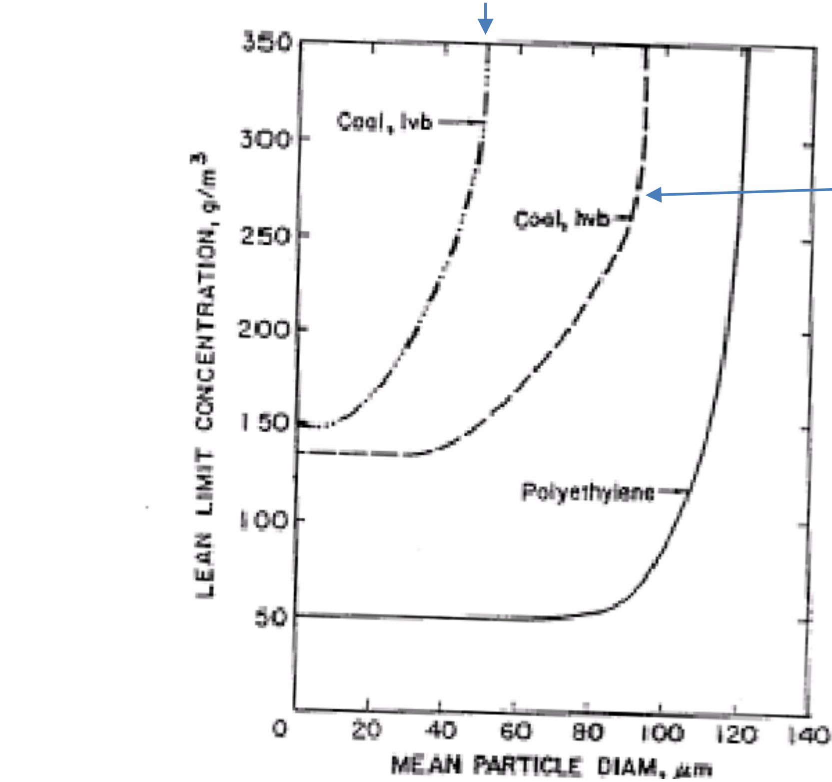
Dust explosion

- Particle size < 400 μm
- Cloud concentration > 20 – 200 g/m^3
  - 20 g/m^3: highly combustible fuel
  - 200 g/m^3: weakly combustible fuel
- Ignition source: typically stronger than gases
  - MIE for gases being on the order of mJ or less

Dust explosion
minimum explosive concentration (MEC)

Low volatile bituminous (lvb)

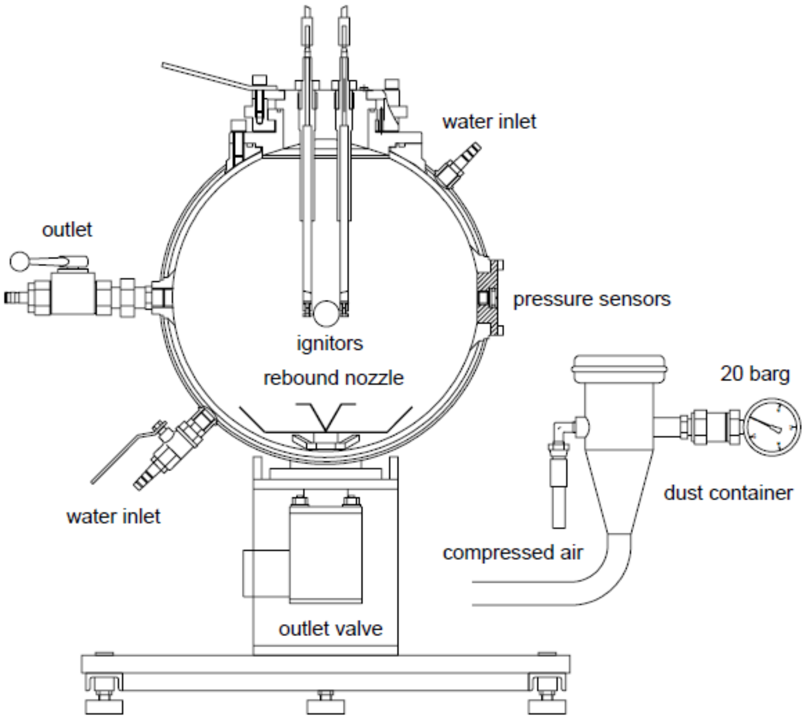
high volatile bituminous (hvb)



Polyethylene particle is more explosive than coal particles

Standard 20 L vessel

- Kuhner 20 L sphere test apparatus



Maximum pressure

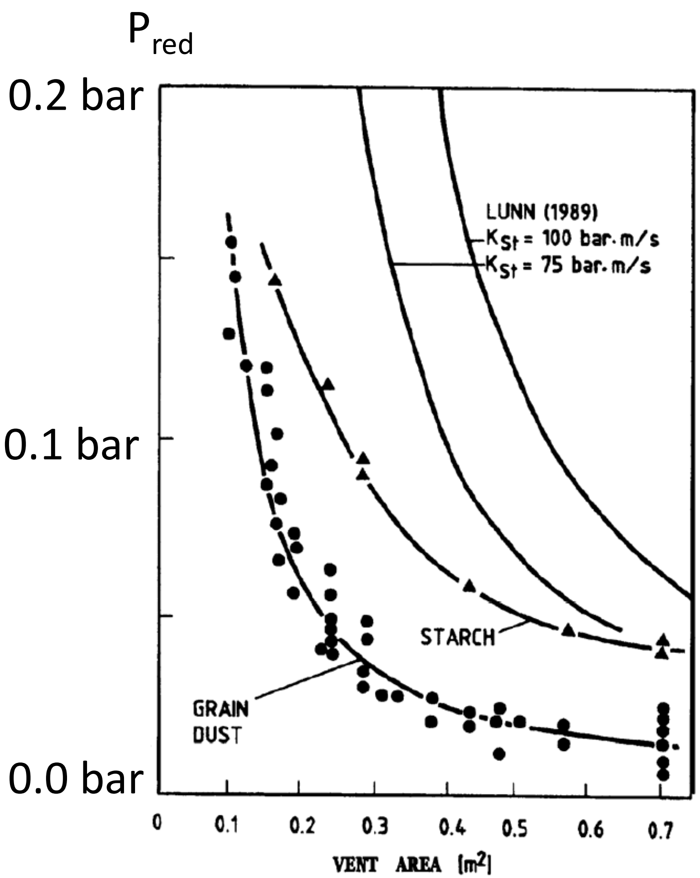
$$For\ dust: K_{ST} = \left(\frac{dP}{dt}\right)_{max} V^{1/3} \quad [\text{bar} \cdot \text{m/s}]$$

$$For\ vapor: K_{G} = \left(\frac{dP}{dt}\right)_{max} V^{1/3} \quad [\text{bar} \cdot \text{m/s}]$$

Material	Mass Median Diameter (μm)	Minimum Flammable Concentration (g/m^3)	P_{max} (bar)	K_{St} (bar-m/s)
Cellulose	33	60	9.7	229
Cellulose pulp	42	30	9.9	62
Cork	42	30	9.6	202
Corn	28	60	9.4	75
Egg white	17	125	8.3	38
Milk, powdered	83	60	5.8	28
Milk, nonfat, dry	60	—	8.8	125
Soy flour	20	200	9.2	110
Starch, corn	7	—	10.3	202
Starch, rice	18	60	9.2	101
Starch, wheat	22	30	9.9	115
Sugar	30	200	8.5	138
Sugar, milk	27	60	8.3	82
Sugar, beet	29	60	8.2	59
Tapioca	22	125	9.4	62
Whey	41	125	9.8	140
Wood flour	29	—	10.5	205

Gas or Vapor	P_{max} (bar g)	Laminar Burning Velocity (cm/s)	K_G (bar-m/s)
Acetylene	10.6	166	1415
Ammonia	5.4	—	10
n-Butane	8.0	45	92
Diethyl ether	8.1	47	115
Ethane	7.8	47	106
Hydrogen	6.8	312	550
Isopropyl alcohol	7.8	41	83
Methane	7.1	40	55
Methyl alcohol	7.5	56	75
n-Pentane	7.8	46	104
Propane	7.9	46	100
Toluene	7.8	41	94

Explosion venting



P_{red} : max pressure in vented explosion

The larger the vented area, the less $P_{red.}$

Pred is influenced by;

- Gas or dust type (different K_G and K_{ST})
- Concentration
- volume or internal surface area
- Turbulence
- Vent area, release pressure, etc.

Vent area calculation

$$A_v = \frac{CA_s}{\sqrt{P_{red}}}$$

where,

A_v : Vent area [m^2 or ft^2]

C : fuel characteristic constant [$kPa^{0.5}$ or $psig^{0.5}$]

A_s : internal surface area of enclosure [m^2 or ft^2]

P_{red} : Overpressure damage threshold [kPa or psig]

Intended range of this correlation:

- 0.35 psig < P_{red} <1.5 psig
- P_{red} - P_{stat} >0.35 psi, where P_{stat} = vent opening pressure
- Enclosure length / hydraulic diameter <3,

where hydraulic diameter $= 4\frac{A}{p} = 4\frac{\text{cross-section area normal to length axis}}{\text{perimeter of the cross-section}}$

Vent area calculation

Table 3-16.5 *C Values in Swift-Epstein Equation*[8]

Fuel	English Unit C (psig)$^{1/2}$	Metric Unit C (bar)$^{1/2}$
Anhydrous ammonia	0.05	0.013
Methane	0.14	0.037
Gases with S_u values $<$ 60 cm/s	0.17	0.045
Dusts with $K_{ST} < 200$ bar·m/s	0.10	0.026
Dusts with $K_{ST} > 200$ and < 300 bar·m/s	0.12	0.030
Dusts with $K_{ST} > 300$ bar·m/s	0.20	0.051

Vent area calculation

Propane may be released in a 4 m by 4 m by 3 m room that has a threshold pressure of 1 psig. What would be the venting area if vent releasing pressure is 0.2 psig?

$$A_v = \frac{CA_s}{\sqrt{P_{red}}} = \frac{(0.17)(80m^2)}{\sqrt{1}} = 13.6\ m^2$$

NFPA Codes

- NFPA 68: Standard on Explosion Protection by Deflagration Venting
- NFPA 69: Standard on Explosion Prevention Systems