Fenwal Protection Systems

- Part of UTC Fire and Safety, largest fire and explosion protection company in the world
- Explosion Suppression
- Explosion Isolation
- Explosion Venting
- Material Evaluation (Combustion Research Center)

Industries at Risk

- Chemical
- Petrochemical
- Grain
- Food
- Pharmaceutical
- Aerosol
- Steel
- Cement
- Wood
Deflagrations - What Happens

- Flame Speed 30 ft/s
- Pressure Wave 1100 ft/s
- Secondary Explosions
- Flame Propagation

Deflagration Pressure vs. Time

Explosibility Calculation

\[ P_{\text{max}} = \frac{V^{1/3}}{R_{\text{max}}} \]

Where:
- \( P_{\text{max}} \) = The maximum pressure
- \( R_{\text{max}} \) = The maximum rate of pressure rise
- \( V \) = The volume of the test vessel

\[ K_0 = P_{\text{max}} V^{1/3} \text{ [bar-m/s]} \]
ST Classification and Kst

<table>
<thead>
<tr>
<th>ST Classification</th>
<th>Kst Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST - 1</td>
<td>1 - 200</td>
</tr>
<tr>
<td>ST - 2</td>
<td>201 - 300</td>
</tr>
<tr>
<td>ST - 3</td>
<td>301 and above</td>
</tr>
</tbody>
</table>

Example: Pittsburgh seam coal has a $K_s$ value of 129 bar m/s; it is therefore considered an ST - 1 dust.

NFPA and Explosion Protection

Applicable Codes (USA)

- NFPA 654 Combustible Particulate Solids
- NFPA 684 Wood Processing
- NFPA 61 Agricultural and Food Products
- NFPA 30B Aerosol Products
- NFPA 484 Combustible Metals
- NFPA 68 Venting of Deflagrations
- NFPA 69 Explosion Prevention Systems

OSHA Combustible Dust Directive

- Chemical Safety Board
  - Independent Federal Agency 1998
  - Investigates industrial chemical accidents
  - Determines and reports root cause
  - 2003 investigate three fatal dust explosions
  - These events led to a 2005/2006 commission to study dust explosion
Chemical Safety Board Findings

Study Findings
- 300 dust explosions over 25 year period
- 119 fatalities, almost 800 injured
- MSDS for combustible dusts do not contain explosion hazard information
- US safety regulations do not address dust explosion mitigation requirements
- Consensus standards provide guidance, but are voluntary unless adopted by state or local AHJs
- OSHA responsible per General Duty Clause requiring safe and healthful workplace

Combustible Dust National Emphasis Program

OSHA Directive CPL 03-00-008

National Emphasis Program on Combustible Dusts

“Purpose. This instruction contains policies and procedures for inspecting workplaces that handle combustible dusts that are likely to cause dust deflagrations, other fires, or explosions. These dusts include, but are not limited to:
- Metal dust such as aluminum and magnesium.
- Wood dust
- Coal and other carbon dusts
- Plastic dust and additives
- Biosolids
- Other organic dust such as sugar, paper, soap, and dried blood.
- Certain textile materials.”
OSHA Directive CPL 03-00-008

National Emphasis Program on Combustible Dusts
- General Duty Clause requiring safe and healthful workplace
- Testing samples for combustibility
- Explosion mitigation requirements per NFPA 654
- Deflagration isolation required per NFPA 654
- Reviewing housekeeping (1/32”)
- Citations and Fines

OSHA Fact Sheet and Poster

Explosion Protection Methods

- Containment
- Inerting
- Deflagration Relief Venting
- Deflagration Suppression
- Deflagration Isolation
Containment

- Withstand Maximum Deflagration Pressure
- ASME Pressure Vessel Code
- Initial Pressure 30 psig max.
- NFPA 69

Containment Vessel

Inerting

- Lowering Oxygen Concentration
- Inert Gases: Nitrogen, Carbon dioxide, Argon
- NFPA 69
Min. Safe Oxygen Concentration

- Dusts: 9 - 16%
- Aluminum: 5
- Propane: 11
- Hydrogen: 5

Use data for determining inerting system design

Max. Pressure vs. Oxygen Concentration

- Oxygen Concentration (Vol. %): 8, 10, 12, 14, 16, 18, 20, 22
- Pressure Bar Ga: 1, 2, 3, 4, 5, 6, 8, 9

Deflagration Relief Vents

- Rupture-style
- Flat or domed
- Square or rectangular
- Optional burst sensors
**Vented Dust Explosion**

- Fireball 7x volume of vessel
- Flame ejection >50’
- Must vent to safe area
- Combustible must be safe to vent outside

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**Vented Explosion**

![Pressure-Time Graph](image)

- **Unvented**: Strength of Vessel
- **P_{max}**: Vented Detonation Pressure
- **P_{vap}**: Vent Opening Pressure
- **P_{red}**: Vented Deflagration Pressure

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**Vented Dust Explosion**

Venting of Inside Vessels
- Ducts less than 6 meters
- Ducts straight (no bends)
- Ducts strength sufficient
- Additional vent area/vessel strength required
### Flameless Explosion Vents

- Passive protection means
- Decreases the energy emitted from a vented deflagration
- Allows inside venting to be performed without vent ducts
- Temperatures cooled to approx. 90°C
- Burst sensor for signaling activation

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### Explosion Suppression

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Explosion - Unsuppressed vs. Suppressed

![Graph showing deflagration suppression](image)

Deflagration Suppression

![Graph showing deflagration suppression](image)

Explosion Suppression Components

![Components diagram](image)
Explosion Pressure Detector

Static or Dynamic Detector
• S/s diaphragm
• Field adjustable
• Paired sensors for false alarm safeguard
• Often mounted with standoffs for vibration isolation

Control Unit

• Microprocessor-controlled
• NEMA 4 Enclosure
• Wall-Mount
• Keyswitch
  Arming/Disarming
• Self-diagnostic LED indicators for alarm and trouble conditions
• Includes battery backup
• Equipment Interlocking

Explosion Suppression Extinguisher

• Sodium-bicarbonate agent
• Used for suppression and chemical explosion isolation
• Supervised, integral OSHA lockout/tag-out plate.
• Dust-ignition proof, weatherproof NEMA enclosure.
• DOT/TC approved.
• Nitrogen pressurized at 900 psi
PistonFire - Discharge

Computer Model

- Vessel Volume
- Length/Diameter Ratio
- Explosivity Characteristics
  - $K_{ST}$, $P_{MAX}$, AIT
- Detection Setpoint
- Extinguisher Orientation
- Style of HRD
- Type of Suppressant
- Volume of Suppressant
- Agent Throw

Explosion Propagation
Detection – Recirculated Exhaust

- Must stop transmission of explosion or fire if exhaust is recycled back into plant per NFPA 654
- Explosion detector on vessel, IR flame detector on exhaust
- Mechanical or chemical isolation

Collector Passive Explosion Isolation

Explosivity Testing

- Dust cloud reactivity (Pmax and Kst)
- Dust cloud minimum ignition temperature
- Dust layer minimum ignition temperature
- Dust cloud minimum ignition energy
- Minimum explosible dust concentration
- Minimum safe oxygen concentration

20-Liter test vessel for Kst, Pmax determination

Go-No Go Test
Silos/Hoppers

Bucket Elevator

Combustible Vapor - Manned
- Chemical Storage Rooms
- Chemical Mixing Rooms
- Aerosol Fill Rooms/Gashouses
- Hydrocarbon Gas Filling
- Hydrocarbon Reclaim Areas
System Inspections and Support

- Quarterly inspections required per NFPA 69
- Local Fire Protection Distributor to stock and supply spare parts as needed
- Emergency reconditioning after system discharge – 24/7
- Minor system troubleshooting

Explosion Hazard Evaluation

A thorough review of the plant, processes, equipment and materials

CONSIDER:
Normal, Abnormal and Upset Conditions
Ignition Sources
Geometry and Strength
Housekeeping
Process Temperature and Pressure Limits
Existing Explosion Prevention and Protection Measures
Material Hazards