What is an Explosion Protection System?

- Hardware added to a process that has been designed to mitigate and control the flame and pressure from an explosion in that process and to control flame propagation away from the ignition.
Outline

- EPP Process
- EP Technologies
- Implementation Process
- “Practical Issues”
  - Design?
  - Installation?
  - Operations?

Process of Explosion Protection

- Identify and Characterize the Hazard
- Determine the Explosion Protection Objective
  - Prevention
  - Protection
    - Control Pressure and Flame
    - Control Pressure
    - Control Propagation
- Design the Engineering Approach

The Explosion Protection Process

Identify and Characterize the Hazard

- What Processes are at Risk?
- What are the Fuels?
- What are the Oxidants?
- What are the Ignition sources?
- Characterize the Deflagration (Explosibility Parameters)
The Explosion Protection Process

Determine the Objectives

- Explosion Prevention
- Explosion Protection
  - Control Pressure and Flame
  - Control Pressure
  - Control Propagation

Is the material combustible?
Is the enclosure located outdoors?
Can a discharge duct be used and maintain an acceptable P(0)?
Is flameless venting acceptable and maintain an acceptable P(0)?
Does enclosure have interconnections?

Explosion Isolation
Explosion Suppression

The Engineering Approach - Engineering Solutions; pros and cons

- Control Pressure and Flame
  - Active Suppression (Containment)
- Control Pressure
  - Venting
- Control Propagation
  - Active, Passive Isolation [Flame, Pressure Propagation]
- Combinations are common
Deflagration Suppression

Objective:
Decrease (limit) the maximum explosion pressure below the design pressure of the vessel such that catastrophic damage does not occur.

Suppression Systems

System Components

- Deflagration Pressure Detector to sense the incipient stages of the explosion
- Control Panel to monitor detectors and activate containers
- Discharge Containers with suppressant to extinguish the explosion

Detection, Activation, Discharge

Suppression agent released through dispersion nozzle.
Open-Air HRD Discharge

Explosion Suppression
• Fuel – 4.5% Propane in Air
• Ignition Source – 5 kJ Chemical Igniter
• Suppression – 2.5 L HRD, 5 lbs. SBC, 900 psig N₂

Explosion Suppression Elements of Success
• Early detection
• Optimum Suppression System must quickly deliver a sufficient amount of suppressant agent to stop further development of the explosion.
• Cover entire hazard volume
• Proper location of discharge hardware
**Explosion Suppression General Performance Trends**

- Low detector activation = Low $P_{\text{red,max}}$
- Increase Number of Suppressors = Lower $P_{\text{red,max}}$
- Increase Agent Concentration = Lower $P_{\text{red,max}}$
- Models used to match deflagration dynamics with suppression system dynamics to conservatively estimate $P_{\text{red,max}}$

**Performance Calculation**

*Software Tool*

$$P_{\text{red}} = f\{(K_{st})^a(Vol.)^b(Throw)^c(P_{act})^d\}$$

**Deflagration Venting**

- How does it work, what does it achieve, video
- Physical options (panels, doors, FQ, ducts,...)
- Performance Design ala NFPA 68 rules
  - Prescriptive equations
  - $Av = f(\text{input variables})$
  - Process controlled (Vol, Pred, Kst, Pmax, flow, vent location, equipment location)
  - Design controlled (Vent location and L/D, Pstat, Vent Inertia)
  - Calculated Pred
Explosion Venting

- Fuel – Cornstarch (500 g/m³)
- Ignition Source – 5 kJ Chemical Igniter
- Explosion Vent – Roof-Top CV, P_{STAT} = 3 psig
- Volume ≈ 2.6 m³

Vent Location: determines L/D
L/D affects Av/Pred

Dust Collector Volume and L/D
Vent Placement – 8.7.1(1)

If all vent area is below the filters;
   And
The spacing between bags is less than the radius;
   Then
Calculate the volume “below the bags only”
If the bags extend below the vent and are modified, i.e. the bags are either completely removed or shortened so that they do not extend below the top of the vent for a distance of one vent diameter from the vent.

Then

The bags immediately adjacent to the vent shall be removed and the remaining bags shall be restrained from passing through the vent.

Calculate

The entire volume below the tube sheet minus the bag volume.
Equipment Location: Flameless Venting

Isolation Process and Objective
- Equipment added to a process line at X feet that stops the passage of flame and/or pressure

Why deflagration isolation?
- Explosion pressure and flame will propagate through process interconnections to other plant equipment or personnel occupied areas.
- Explosions in connected vessels tend to be of higher severity than explosions occurring in single unconnected vessels because of precompression and flame-jet ignition
- Deflagrations can accelerate to detonation velocities while traveling through pipelines
- NFPA says so
Flame Accelerates in a Duct

Effect of Pipe Diameter on Flame Velocity
4% Propane

Active Isolation Performance - Timing

- $T_{\text{barrier}} < T_{\text{flame}}$ at point of isolation
- Time for barrier formation
  - Detection (Kst, volume, activation setting)
  - Activation
  - Barrier formation
- Time for flame arrival
  - Kst
  - $P_{\text{max, Pred}}$
  - Volume
  - Duct parameters
Explosion Isolation Types

<table>
<thead>
<tr>
<th>Passive</th>
<th>Active</th>
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<td>Ventex</td>
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Explosion isolation types and performance

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<td></td>
<td>Diverter</td>
<td>Ventex</td>
</tr>
<tr>
<td>Protected vessel ((P_{inert} &lt; 510, \text{Pa}))</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Unprotected vessel ((P_{max} \leq 12\text{bar}))</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stop flame</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stop pressure</td>
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How did you get to “implementation” of explosion protection

• Self-motivated
• Corporate Safety directive; review all of our dust collectors and develop a plan
• Incident response; “don’t let it happen again”
• OSHA Inspection with remediation requirements
• Insurance company inspection with protection requirements

“…..implementation”

• What’s the process?
• Who’s involved?
  – Owner/operator
  – System Manufacturer
  – Consultant, Insurer, Government
• What are these practical aspects? (Problems)

Process Steps

✓ Hazard Areas Identified
✓ Risk Analysis
• Performance Requirements
• Site Survey, Data Collection
• Explosion Protection Design, first round
• Design Review, Revision
• Hardware Ordered
• Installation
• Commissioning, Post-commissioning
Design Requirements

- New Construction?
  - Yes
    - New Process
      - Specify Process
      - Equipment Performance
      - Control Process
      - Conditions
  - No
    - Modify existing process or equipment
      - Documentation of equipment (strength, vol)
      - Documentation of process conditions
      - Operating stability, range, SU/SD

Site Survey

- Hours to days
- Confirm hazards, discuss protection objectives, design requirements, options
- Begin data collection
  - Process conditions, drawings/sketches, P&ID, photos
- Budgetary quotation?

First Round EP Design

- Review process conditions
- Verify objectives, Options
- Prepare protection design; transfer to drawings
- Budgetary quotation
Design Review and Revision

- Validate protection objectives, adjust
- Validate process data
- Design modified as needed
- Installation drawings, BOMs prepared

Commissioning, Post-commissioning

- Actual process conditions
- Startup, shutdown, simulated upsets…
- Troubleshoot
- Surprises?
- Training
- Inspection and Maintenance

The Practical Issues

The process of protecting a process may result in a change of the process
The Practical Issues

• Site survey add-ons
• Prioritization of actions
• Process drawings
• Need for On-site expertise (process knowledge)
• Can’t design to the process (equipment)
• Hardware installation, creativity
• Product properties
• Process and Operating conditions
• Environmental effects
• Scheduling
• Retro-fits, upgrades

Site Survey can lead to a Design Change

“We need you to look at our dust collector...”
Found: indoor, but close to a wall

Found P1

...and an inlet from the mill below

Found 2

Dust collector protected by a ducted vent and inlet isolation
...and isolation on the mill

Process Drawings:
Prepare Installation Drawing based on Process Drawings and Design

– Lack of (age, lost, out of business)
– Out of date (changes not noted)
– Un-dimensioned sketches

Site Survey Sketch
Design vs Process

- Can’t apply the first or preferred design to the process
- Something has to change

Can’t apply the first or preferred design

Vented dust collector; one side available
8.7.1(1) vs 8.7.1(3)

Can’t apply the first or preferred design - Isolation Xmin

Top view of fluid bed dryer
Can’t apply the first or preferred design - Isolation Xmin

Can’t apply the first or preferred design
Silo Venting

Can’t apply the first or preferred design
Calculated required vent area. Add vents at the top on the side (no room on the top)
Can’t apply the first or preferred design
OK with Intended process operation?

Product covering lower section of vents!

Can’t apply the first or preferred design
Change the process.
Bring fill level back down

Hardware Installation, existing process; need for creativity

Floor cutout to accommodate Suppressor placement
Hardware Installation, existing process; need for creativity

EXPLOSION PROTECTION SOLUTIONS
Hardware Installation, existing process; need for creativity

Raise high the roof beam....

Product Properties - Sticky
Product Properties - Sticky

Product Properties - Size
Large particle impact

Product Properties - Size
Particle impact on detector at 0 ms; ~ 2 psi
Process and Operation conditions

- Operating conditions
  - Pressure, temperature, flow, maintenance, etc.
  - Operating vs capability
  - Particle characteristics
- Unknown, incomplete, not as expected

Process and Operation conditions

Slow Pressure Rise: Static activation at 250 mbar (3.6 psi)

Process maintenance

High pressure washing of process vessel
Environmental Conditions
northern location

Solution to wet process stream, northern location

Environmental conditions
Vent hoods on top of silo, northern location
Homework: Protect this process

Summary
- Effective Site Survey is Key
- Clear understanding and communication of objectives and performance expectations.
- Complete, accurate process conditions with accurate process/equipment drawings
- Anticipate that process conditions may need to be adjusted, or the design changed
- A stable protection system requires a stable process

When all else fails, read the manual
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- Explosion Protection Process
- Explosion Protection Technologies
- Implementation Process
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- Characterize the Deflagration (Explosibility Parameters)
The Explosion Protection Process

**Determine the Objectives**

- Explosion Prevention
- Explosion Protection
  - Control Pressure and Flame
  - Control Pressure
  - Control Propagation

**TESTING**

- Can product be safely released to the atmosphere?
  - Yes
- Is enclosure located outdoors?
  - Yes
- Can a discharge duct be used and maintain an acceptable Pred?
  - No
- Is flameless venting acceptable and maintain an acceptable Pred?
  - No
- FLAMELESS VENTING
  - Yes
- EXPLOSION VENTING
  - Yes
  - Yes
  - Yes
- Does enclosure have interconnections?
  - EXPLOSION ISOLATION
  - Yes
  - EXPLOSION SUPPRESSION
  - No
  - No

**The Explosion Protection Process**

**Determine the Engineering Approach - Engineering Solutions; pros and cons**

- Control Pressure and Flame
  - Active Suppression (Containment)
- Control Pressure
  - Venting
- Control Propagation
  - Active, Passive Isolation [Flame, Pressure Propagation]

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• Fuel – 4.5% Propane in Air
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Explosion Suppression
Elements of Success
• Early detection
• Optimum Suppression System must quickly deliver a sufficient amount of suppressant agent to stop further development of the explosion.
• Cover entire hazard volume
• Proper location of discharge hardware
Explosion Suppression Performance as Pred

- Models (software tools) are used to match deflagration dynamics with suppression system dynamics to conservatively estimate $P_{\text{red, max}}$
- $P_{\text{red}} = f(K_{\text{st}})^{a}(\text{Vol.})^{b}(\text{Throw})^{c}(P_{\text{act}})^{d}$

Deflagration Venting – Controls Pressure

- How does it work, what does it achieve, video
- Physical options (vent location, Flameless venting, ducts, …)
- Performance Design iaw NFPA 68 rules
  - Prescriptive equations determine vent area where
    - $A_v = f(\text{input variables})$
      - Process controlled (Vol, Pred, Kst, Pmax, flow, vent location, equipment location)
      - Design controlled (Vent location and L/D, Pstat, Vent Inertia)
    - Calculated $A_v$ for a specified $P_{\text{red}}$

Explosion Venting

- Fuel – Cornstarch (500 g/m³)
- Ignition Source – 5 kJ Chemical Igniter
- Explosion Vent – Roof-Top CV, $P_{\text{STAT}} = 3$ psig
- Volume ≈ 2.6 m³
Vent Location: determines L/D
L/D affects Av/Pred

Dust Collector Volume and L/D
Vent Placement – 8.7.1(1)
If all vent area is below the filters;
And
The spacing between bags is less than the radius;
Then
Calculate the volume “below the bags only”

Dust Collector Volume and L/D
Vent Placement – 8.7.1(3) TIA 928
• Redefines case 3 of dust collector design
  – (3) Locate the vents such that the bottom of the vent(s) is above below the bottom of the bags, as shown in Figure 8.7.1(e), and the row of bags closest to the vent are restrained from passing through the vent. For this case, the volume used to calculate the vent area shall be the entire volume (clean and dirty) below the tube sheet
**Isolation Process and Objective**

- Equipment added to a conveyance line at X feet that stops the passage of flame and/or pressure
Why deflagration isolation?

- Explosion pressure and flame will propagate through process interconnections to other plant equipment or personnel occupied areas.
- Explosions in connected vessels tend to be of higher severity than explosions occurring in single unconnected vessels because of precompression and flame-jet ignition.
- Deflagrations can accelerate to detonation velocities while traveling through pipelines.
- NFPA says so.

Flame Accelerates in a Duct

Active Isolation Performance - Timing

- $T_{\text{barrier}} < T_{\text{flame}}$ at point of isolation, $X_{\text{min}} - X_{\text{max}}$
- Time for barrier formation:
  - Detection ($K_{\text{st}}$, volume, activation setting)
  - Activation
  - Barrier formation
- Time for flame arrival:
  - $K_{\text{st}}$
  - $P_{\text{max}}$, $P_{\text{pred}}$
  - Volume
  - Duct parameters
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### “……implementation”

- What’s the process?
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  - Owner/operator
  - System Manufacturer
  - Consultant, Insurer, Government
  - Installation contractors
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• Installation
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Design Requirements

New Process?
- Specify Process Equipment Performance
- Control Process Conditions

Modify existing process or equipment
- Documentation of equipment (strength, vol)
- Documentation of process conditions
- Operating stability, range, SU/SD

Site Survey

• Hours to days
• Confirm hazards, discuss protection objectives, design requirements, options
• Begin data collection
  – Process conditions, drawings/sketches, P&ID, photos
• Budgetary quotation?
First Round, Explosion Protection Design,

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…and an inlet from the mill below

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Dust collector protected by a ducted vent and inlet isolation

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Can't apply the first or preferred design - Isolation Xmin

TOP VIEW OF FLUID BED DRYER

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TOP VIEW OF FLUID BED DRYER

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Hardware Installation, existing process; need for creativity

Raise high the roof beam....

HRD rotated to fit under beam and above hopper
Product Properties - Sticky

Product Properties - Sticky

Product Properties - Size
Large particle impact
Particle impact on detector at 0 ms; ~ 2 psi

Process and Operation conditions

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  - Pressure, temperature, flow, maintenance, etc.
  - Operating vs capability
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- Unknown, incomplete, not as expected

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High pressure washing of process vessel

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northern location

Solution to wet process stream, northern location
Environmental conditions
Vent hoods on top of silo, northern location

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