Designing Facilities to Prevent Deflagration

[Managing Fire and Explosion Risk]
Presentation Outline

• Presentation Set-up & Paper Abstract
  > The Presenter
  > Definition of a Hazard
  > ‘Process’ Hazards & Process Safety
  > Abstract

Step I  – Identifying Hazardous Locations/Areas

Step II  – Identifying Ignition Sources

Step III – Evaluating Equipment and Processes
  [with the objective of mitigating the consequences of deflagrations]

• Summary

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Manager - Consulting & Training Services

- Chemical Engineer – NYU Polytechnic
- Memberships: American Institute of Chemical Engineers (AIChE)
  American Society of Safety Engineers (ASSE)
- 28+ years experience in the chemical and manufacturing industries
  including: polymers, textiles, coatings, food additives, fragrances, etc.
  - 16 years Consulting - Process Safety, Technology Transfer,
    Process/Project Engineering, DuPont, ICI, American Cyanamid, etc.
  - 12 years Production – Process/Project Management, Maintenance,
    Construction Mgmt/Safety, Process Safety Management, ISO9000
- Specialties include: Program Mgmt, PSM, Hazard Area Classification,
  Training, Combustible Dust, Design...(Ex, EE, GMP, AFFF System, others)
- PSM Program Manager: >250,000 gallons flammable liquids
- Process Hazard Assessments of hundreds of facilities in 20 countries
Educational Objectives

- Raise awareness of flammable atmosphere and ignition sources
- Increase participant’s ability to recognize and differentiate these Process Safety Hazards
- Provide participants with a methodology by which to evaluate the hazard risk

*For the ultimate purpose of maintaining the health and safety of People, Property, and Business Continuity*
Definition of a Hazard

Element of a site’s activities, products, and services that has the **potential to cause harm** to employees, contractors, or other personnel in the workplace.

A hazard is a **condition, event, or circumstance** that could lead to or contribute to an unplanned or undesirable event which in turn could result in loss of life, injury, property damage both for your company and/or the community, or damage to the environment.
Definition of a **Process** Hazard

A hazard that is inherent to materials, equipment or technology of a process that if not controlled or contained can cause or lead to a **catastrophic release**

Usually a chemical or physical condition with the potential for causing damage to people, property and/or the environment

Process Hazards differ from occupational hazards, construction hazards or industrial hygiene exposures!
Typical Process Hazards

- Flammable liquid / vapor / gas
  - $H_2$, CO, Propane, Coatings/Solvents (MEK, Acetone, Alcohols)

- Combustible Dusts
  - Metals, Plastics, Wood, Coal, Food, Pharmaceuticals, Waste recycle

- Toxic and/or corrosive chemicals
  - $N_2$, Ar, $CO_2$, Flue Gas, Ammonia, Pharma API, Acids / Caustic

- Equipment operating under pressure or vacuum
  - Compresses gases (Air, $H_2$, $O_2$, $N_2$, Ar)

- Reactive materials & chemicals
  - Water/air reactive metals, nitrates, exothermic reactions, etc.
<table>
<thead>
<tr>
<th>Occupational Safety</th>
<th>Process Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slips, Trips, Falls</td>
<td>Solvent Fire/Explosion</td>
</tr>
<tr>
<td>Injured by Tools</td>
<td>Metal Fire/Explosion</td>
</tr>
<tr>
<td>Injured by Machinery</td>
<td>Organic Dust Explosion</td>
</tr>
<tr>
<td>Welding Fire</td>
<td>Equipment Rupture</td>
</tr>
<tr>
<td>Noise Exposure</td>
<td>Toxic Inhalation</td>
</tr>
<tr>
<td>Heat/Cold Stress</td>
<td>Runaway Reaction</td>
</tr>
<tr>
<td>Electric Shock</td>
<td>Loading/Unloading Spill</td>
</tr>
<tr>
<td>Construction Accident</td>
<td>Sampling/Testing Incidents</td>
</tr>
<tr>
<td>Vehicle Accident</td>
<td>Caustic/Acid Burn</td>
</tr>
<tr>
<td></td>
<td>Environmental Catastrophes</td>
</tr>
</tbody>
</table>
Fundamentals of Process Safety

1. Identify the Hazards within the facility
2. Assess the Hazards within the facility
3. Control the Risk of the Hazard within the facility
2003 - West Pharmaceutical, North Carolina
6 Killed, 37 Injured (Polyethylene Dust)
2003 - CTA Acoustics, Kentucky
7 Killed, 37 Injured (Phenol-Formaldehyde Resin)
2008 - Imperial Sugar, Georgia
14 Killed, > 40 injured (Sugar Packaging)
2012 – Lakeland Mills, Canada
3 Killed, 24 injured (Wood Dust)
Frequent Event - Direct Charging of Powders into a Flammable Atmosphere

Isolated events, without severe injury, often go unreported outside companies.
The Basic Plan for Maintaining Safe Process Operations

1. Identify Hazard
   - Do Process Safety Hazards exist at your Facility?
     - Flammables / Combustible dust / toxins / reactive mtrls / compressed gases
   - Hazard awareness and Identification
     (Associated regulatory responsibility for code compliance)

2. Assess Hazard
   - Hazard Qualified by Lab Testing of Material Properties
   - Review of Site Conditions / Operations (PSA/PHA/HAC)
   - Actionable Recommendations for Safety Compliance

3. Control the Risk
   - Conceptual Design from Implementing Chilworth Recommendations
   - Client implements SOPs & System EPC (Eng’g, Procure, and Construction)
   - Verification of Adequacy – auditing / re-assessment

Items in red are core services provided by Chilworth
Explosion Severity – Deflagration (‘Explosible’)  

**Deflagration Pressure/Time Curve**

- **Maximum Pressure**, $P_{\text{max}}$ [barg]
- **Maximum Rate of pressure Rise**, $(dP/dt)_{\text{max}}$ [bar/s]
- **Deflagration Index**, $K_g$ or $K_{St}$ [bar m/s]

Note: 1 bar = 14.5 psi

A deflagration (propagating combustion front) is in general limited by either the fuel or oxidant available and will “run-out-of-steam” (usually < 300 ms)
Abstract

*Designing Facilities to Prevent Deflagration*

This paper describes three distinct steps for the assessment and management of *deflagration hazards* associated with combustible solids, flammable and combustible liquids, and flammable gases in chemical processes. This includes rapid combustion in the form of explosion or flash-fire.

**Step I:** Identifying Hazardous Locations/Areas

**Step II:** Identifying Ignition Sources

**Step III:** Evaluating Equipment and Processes, with the Objective of Mitigating the Consequences of Deflagrations
Step I: Identifying Hazardous Locations/Areas

- For many years, hazardous area classification procedures have been used to select and install suitable electrical equipment in flammable atmospheres to ensure that the electrical equipment does not become a source of ignition to the identified flammable atmosphere. The same hazardous area classification approach may be used to identify areas where ignitable atmospheres could be present under both normal and abnormal processing conditions.

- Per NFPA 70 (the National Electrical Code); NFPA 497; and NFPA 499 hazardous locations are identified by Classes and Groups which distinguish between different types of flammable atmospheres.

- A hazardous area classification establishes the dimensional extent of the “classified” area and involves due consideration and documentation of the following:
  - The flammable materials that may be present;
  - The physical properties and characteristics of each of the flammable materials;
  - The sources of potential releases, including spills and releases from equipment;
  - Maximum ambient temperatures (and pressures);
  - Pressures and temperatures within equipment containing the flammable materials;
  - How explosible atmospheres could result from equipment failures;
  - Availability, reliability, and rates of ventilation (forced and natural);
  - Range of dispersion of released vapors and dusts, within the flammable limits;
  - Housekeeping practices;
  - The probability of each spillage and release scenario.
Step I – Identifying Hazardous Locations/Areas

A. Flammable Atmospheres
B. Electrical Equipment Selection – Code Compliance
C. Hazardous Area Classification
**IA. Flammable Atmosphere**

The “Fire Triangle”

- **FUEL** – Liquid (vapor or mist), gas, or solid capable of being oxidized. Combustion always occurs in the vapor phase; volatile liquids are vaporized, and solids are decomposed into vapor prior to combustion.

- **OXIDANT** – A substance which supports combustion – Usually the oxygen in air.

- **IGNITION SOURCE** – An energy source capable of initiating a combustion reaction.

![Diagram of the Fire Triangle](image)
IA. Flammable Atmosphere

Compare material flammable properties with equipment operation & design
IA. Flammable Atmosphere

Range of vapor volume concentration that will create an ignitable mixture with air when a source of ignition is present.

Flammability range is between LFL and UFL

METHANE: 5% v/v 15% v/v
IA. Flammable Atmosphere

- Oxidant
- Confinement
- Suspended (Cloud)
- Fuel
- Combustible Dust
- Ignition Source
IA. Flammable Atmosphere
IA. Flammable Atmosphere

Range of exploisable dust concentrations in air at normal temperature and atmospheric pressure for a typical natural organic dust (maize starch), compared with typical range of maximum permissible dust concentrations in the context of industrial hygiene, and a typical density of deposits of natural organic dusts (Eckhoff)

**Industrial Hygiene**

**Explosible Range**

**Dust Deposits**

**Mass of Powder/Dust per Unit Volume (g/m³)**

- $10^{-3}$
- $10^{-2}$
- $10^{-1}$
- $10^1$
- $10^2$
- $10^3$
- $10^4$
- $10^5$
- $10^6$
- Do not blow down dust deposits:
  » Generates dust clouds
  » Causes the finest, most hazardous particles be deposited on ledges, joists and other high places
IB. Electrical Equip Selection – Code Compliance

NFPA 70 (NEC) Electrical classification for flammables vapor / gas:

1) **Class – Type of Hazard**
   - **Class I** - Locations with the potential for **flammable gases or vapors** in the atmosphere sufficient to burn or explode

2) **Division – Likelihood of Hazard Presence**
   - **Division 1** - Ignitable concentrations **exist continuously**, or periodically during normal operations, frequently during repair or maintenance, or during breakdown or improper operation with failure of electrical equipment at the same time. *(Equivalent EU Zone 0/1)*

   - **Division 2** - Flammable liquids or gases can escape only due to an accidental rupture, **breakdown or abnormal operation** or, a location where ignitable concentrations are prevented by mechanical ventilation, but could occur if the ventilation fails. *(Equivalent EU Zone 2)*

3) **Group – Specific Material or Chemical Hazard**
   - **Group A** (Acetylene), **B** (H2), **C** (methanol), **D** (IPA/ethanol)
NFPA 70 (NEC) Electrical classification for powder/dust:

1) **Class – Type of Hazard**
   - **Class II** - Locations with the potential for *combustible dusts* in the atmosphere sufficient to burn or explode
   - **Class III** - Locations with easily ignitable *fibers or flyings* present in the area but not likely to be suspended in the atmosphere in quantities sufficient to ignite

2) **Division – Likelihood of Hazard Presence**
   - **Division 1** - Ignitable concentrations *exist continuously*, or periodically during normal operations, frequently during repair or maintenance, or during breakdown or improper operation with failure of electrical equipment at the same time. *(Equivalent EU/CN Zone 20/21)*
   - **Division 2** - Flammable liquids or gases can escape only due to an accidental rupture, *breakdown or abnormal operation* or, a location where ignitable concentrations are prevented by mechanical ventilation, but could occur if the ventilation fails. *(Equivalent EU/CN Zone 22)*

3) **Group – Specific Material or Chemical Hazard**
   - **Group E** (Metals), **F** (Carbon Material), **G** (All other dusts)
IB. Electrical Equip Selection – Code Compliance

- Incorrectly specified and/or installed electrical equipment is a potent ignition source
  - Sparks: brushes or switches in motors
  - Overloaded (hot) motors
  - General-purpose plugs and receptacles
  - General-purpose equipment

- In facilities handling combustible or flammable materials, electrical equipment must be suitable for the environment in which it is to be used:
  - Class II, Group G for many dusts
  - Division 1 for frequent dust clouds
  - Division 2 for very-infrequent dust clouds

- Control: Classification map; conformance to standards
IB. Electrical Equip Selection – Code Compliance

A location is unclassified [“general-purpose” equipment] where:

It has been determined that the location is NOT Class I / II / III, Division 1 or 2; or Zone 0, 1, 2, 20, 21, or 22, or the material is non-combustible.

For Class II Areas, it is not ‘usually’ necessary to classify [NFPA 499]:

• Areas where materials are stored in sealed containers [bags, drums, or fiber packs, on pallets or racks];

• Areas where materials are transported in well-maintained closed piping systems or are within closed tanks;

• Areas where dust-removal systems [local exhaust ventilation] and excellent housekeeping prevent visual dust clouds and layer accumulations that make surface colors indiscernible;

• Areas outside dust-containing operations, where walls with closed doors or lightweight partitions provide separation.
IC. Hazardous Area Classification

- **NFPA 497**  Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- **NFPA 499**  Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- **EN 60079-10-2**  Explosive atmospheres. Part 10-2 Classification of areas. Combustible dust atmospheres.
- **EN 60079-14**  Explosive atmospheres. Electrical installations design, selection and erection.
- **EN 60079-17**  Explosive atmospheres. Electrical installations inspection and maintenance.
- **GB12476.1-2000**
IC. Hazardous Area Classification

Reference: NFPA 497

FIGURE 5.9.6 Drum Filling Station Located Either Outdoors or Indoors in an Adequately Ventilated Building. The material being handled is a flammable liquid.
IC. Hazardous Area Classification

Reference: NFPA 499

FIGURE 5.8(b) Group E Dust — Indoor, Unrestricted Area; Open or Semi-Enclosed Operating Equipment.
IC. Hazardous Area Classification

To start the exercise:

- Get the flammability data,
- Get the drawings & procedures,
- Assemble the necessary expertise in a team.
IC. Hazardous Area Classification

HAC Procedure

- Identify potential flammable release points.
- Identify the duration of a release.
- Consider room ventilation, extraction and housekeeping.
- Assign and estimate areas affected.
- Report, Document and Map
IC. Hazardous Area Classification

Example – HAC Mapping
Step II: Identifying Ignition Sources

The assessment of ignition hazards arising from mechanical equipment may be performed by using the following four-step approach:

• Equipment and/or component description;
• Identification of ignition hazards, including internal fire or explosion;
• Ignition hazard estimation, including energy, power, and/or temperature;
• Ignition risk evaluation (what is the likelihood that the ignition source is incendive to the atmosphere of interest).

Information required for the ignition/explosion hazard assessment includes:

• The intended process operations and operating conditions;
• The Ignition Sensitivity, Thermal Instability, Explosion Severity, and perhaps the Electrostatic-chargeability/resistivity properties of the materials to be processed;
• Equipment maintenance programs and practices;
• Accident history of similar devices (if available);
• Design drawings and specifications (speeds of motion; energies of impact); and
• Results of tests and examinations performed on the equipment.
**Step II – Identifying Ignition Sources**

A. **Hot Work & Sources of Ignition**  
B. **Ignition Risk Assessments**  
C. **Flammability Data for Design**  
D. **Ignition Probability**
IIA. Hot Work & Sources of Ignition

Conditions for an Explosion

- The vapor / dust must be explosible

- Process material must be dispersed

- Concentration must be within explosible range

- The atmosphere must support combustion (usually air)

- An ignition source of sufficient energy must be present
IIA. Hot Work & Sources of Ignition

Subpart Q: Welding, Cutting & Brazing - 29 CFR 1910.252

(vi) **Prohibited areas.**

*Cutting or welding* shall not be permitted in the following situations:

(A) In areas not authorized by management.

(B) In sprinklered buildings while such protection is impaired.

(C) *In the presence of explosive atmospheres* (mixtures of flammable gases, vapors, liquids, or dusts with air), or explosive atmospheres that may develop inside uncleaned or improperly prepared tanks or equipment which have previously contained such materials, or that may develop in areas with an accumulation of combustible dusts.
IIA. Hot Work & Sources of Ignition

CSB Video - Hot Work (Daytona Florida 2006)
IIB. Ignition Source Risk Assessment

Typical Ignition Sources Found in Industry

- Smoking
- Open flames
- Welding
- Cutting
- Grinding
- Hot surfaces
- Frictional heating
- Mechanical impacts

- Electric sparks
- Electrostatic discharges
- Lightning strikes
- Exothermic runaway chemical reactions/thermite reaction
- Self-heating/spontaneous combustion/decomposition
IIB. Ignition Source Risk Assessment

Ref: EU Standard EN 1127-1

1. Mechanically generated **sparks**
2. Self-heating (including self-ignition of dusts) and other exothermic reactions
3. Hot surfaces – including frictional heating
4. Electrostatic discharges
5. **Flames** and hot gases
6. **Electrical Apparatus**
7. Stray electrical currents, cathodic corrosion protection
8. Lightning
9. Electromagnetic radiation, $10^4$ Hz to $3 \times 10^{12}$ Hz (RF)
10. Electromagnetic radiation, $10^{11}$ Hz to $3 \times 10^{15}$ Hz (visible)
11. Electromagnetic radiation (ionising)
12. Adiabatic compression and shock waves
13. Ultrasonic
IIB. Ignition Source Risk Assessment

Centrifugal Pump

- Coupling Rub
- Guard catching shaft
- Hot Bearing
- Surface Temperature
- Electrical Sparks
- Static Discharge
- Hot Seal / Throttle bush
# Example of ignition assessment layout

## Identified Ignition source

<table>
<thead>
<tr>
<th>Potential Ignition Source EN 1127-1</th>
<th>Normal operation (Category 3)</th>
<th>Expected malfunction (Category 2)</th>
<th>Rare malfunction (Category 1)</th>
<th>Measures applied to prevent the source becoming effective</th>
<th>Ignition protection used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface temperature</td>
<td>Pump surface</td>
<td>N/A</td>
<td>N/A</td>
<td>Pump internals cooled by process fluid below 300 deg C. Motor rated T1. Mechanical friction due to wear and tear of moving components will be detected at routine inspections before they are an issue.</td>
<td>EN 13463-1 :2001 Section 5.2.5</td>
</tr>
</tbody>
</table>

## Findings of risk assessment and control measures

**Mechanical Equip Ignition Risk Assessment - M.E.I.R.A.**
IIC. Flammability Testing for Design

Static Electricity is Common in Everyday Life
It can be useful  It can be fun
IIC. Flammability Testing for Design

Static Electricity is Common in Everyday Life

- It can be painful
- It can be scary

The Global Experts in Explosion & Process Safety
IIC. Flammability Testing for Design

Static and Flammable Atmospheres Don’t Mix!
IIC. Flammability Testing for Design

Typical MIE Energies

From NFPA 77-2007, FIGURE 5.3.1 Approximate Energies of Types of Discharges Compared with Minimum Ignition Energies (MIEs) of Typical Combustible Materials.
**Minimum Ignition Energy (MIE)**

MIE of a flammable material is the minimum spark energy needed to ignite an optimum concentration of the material using a capacitive spark under ideal conditions.

**Minimum Ignition Energy Apparatus**

- **D.C. Voltage Source**
- **Capacitor**
- **Current Limiting Resistor**
- **Switch**
- **Electrostatic Voltmeter**
- **Decoupling Resistor**
- **Switch**
- **Ignition Chamber**
## IIC. Flammability Testing for Design

<table>
<thead>
<tr>
<th>Atmosphere</th>
<th>Material</th>
<th>Minimum Ignition Energy (mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust Cloud</td>
<td>PVC</td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td>ZINC</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>WHEAT FLOUR</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>POLYETHYLENE</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>SUGAR</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>MAGNESIUM</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>SULPHUR</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>ALUMINUM</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>EPOXY RESIN</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>ZIRCONIUM</td>
<td>5</td>
</tr>
<tr>
<td>Vapor / Gas</td>
<td>PROPAKOL</td>
<td>0.650</td>
</tr>
<tr>
<td></td>
<td>ETHYLE ACETATE</td>
<td>0.460</td>
</tr>
<tr>
<td></td>
<td>METHANE</td>
<td>0.280</td>
</tr>
<tr>
<td></td>
<td>PROPANE</td>
<td>0.250</td>
</tr>
<tr>
<td></td>
<td>ETHANE</td>
<td>0.240</td>
</tr>
<tr>
<td></td>
<td>METHANOL</td>
<td>0.140</td>
</tr>
<tr>
<td></td>
<td>ACETYLENE</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>HYDROGEN</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>CARBON DISULPHIDE</td>
<td>0.009</td>
</tr>
</tbody>
</table>
Static Charging of People

A person just has to be near a charged object – pile of powder, plastic IBC, charged liquid, etc.

People can also get charged just by walking across insulating flooring

Suitable grounding will prevent this.
Isolated Conductors are not Always Obvious!
IIC. Flammability Testing for Design

The MIT of a dust cloud is typically higher than the MIT of a dust layer

Example:

<table>
<thead>
<tr>
<th>Dust</th>
<th>MIT (Cloud)</th>
<th>MIT (Layer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl Cellulose</td>
<td>420 °C</td>
<td>380 °C</td>
</tr>
</tbody>
</table>
IIC. Flammability Testing for Design

Self-Heating – Thermal instability

Bulk Powder (Diffusion Cell) Screening Test

- Oven temp
- Sample top
- Sample upper
- Sample lower
- Sample base
IID. Ignition Probability

Myth – Stainless steel is ok because it’s non-sparking

Stainless Steel Rubbing Temperatures
IID. Ignition Probability

- A = mechanical friction/heating
- B = smouldering
- C = static discharges
- D = fire, flames
- E = self heating
- F = hot surfaces
- G = hot work
- H = electrical equipment
- I = unknown, not determined
- J = other

German Accident Report – 600 dust explosions
IID. Ignition Probability

Lightning Strike Rate (No. / km² /yr)

from http://science.nasa.gov/science-news/science-at-nasa
### IID. Ignition Probability – Risk Assessment

#### 5x6 Risk Matrix with 4 Risk Categories
(Based on example in CCPS LOPA book)

<table>
<thead>
<tr>
<th>CONSEQUENCES</th>
<th>LIKELIHOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Each level is an order of magnitude from adjacent levels.
Fundamentals of Process Safety

1. Identify the Hazards within the facility
2. Assess the Hazards within the facility
3. Control the Risk of the Hazard within the facility
IID. Ignition Probability

Risk Reduction Hierarchy

*(In order of preference)*

1. Inherently safe design
2. Avoidance of flammable atmosphere
3. Avoidance of ignition/initiation event
4. Mitigate the consequences – explosion protection
Step III: Evaluating Equipment and Processes

If the prevention of flammable atmospheres within or around the process equipment or device is not possible, preventive or protective measures should be considered, in the following order:

- Ensure that ignition sources are not present (by design);
- Ensure that ignition sources that can occur are controlled (administrative, including permits);

Electrical equipment and installation methods are evaluated against the requirements of the National Electrical Code (NEC), as presented in NFPA 70; NFPA 497; NFPA 499.

Examples of technical measures (engineering controls) for ensuring safety:

- Proper selection of electrical equipment;
- Control of static electricity
- Improvements in general and local exhaust ventilation to prevent accumulations of flammables;
- Improvements in local exhaust ventilation to prevent accumulations of combustible dust;
- Explosion relief or suppression and isolation systems for equipment and dust collectors;

Examples of organizational measures (administrative controls) for ensuring safety:

- Permit-to-work procedures and permits for potentially hazardous activities;
- Operator and staff training with regard to recognition and control of deflagration hazards;
- Written operating procedures for operators and maintenance personnel in hazardous areas;
- Mechanical integrity policies and preventive maintenance procedures and inspections;
- Emergency evacuation and response procedures and drills;
Step III – Evaluating Equipment and Processes

[With the objective of Mitigating the Consequence of Deflagration]

Preventive and Protective Measures

A. Engineering Controls
B. Administrative Controls

Dust Flame Arrester

- Stainless Steel Construction
- Flame Arrester
- Dust Filter
- Bursting Disc
- Housing

explosion-resistant construction
III A. Engineering Control Measures

Term – ‘Basis of Safety’

- Basis of Safety (EU), similar to PSM (USA), is a series of safeguards that, working together, prevent or mitigate the hazard

Safeguards are:
- Preventions; and/or Mitigations

Safeguards can be:
- Active [Admin controls, alarms, emerg. shutdown system, interlocks, fire sprinklers] or
- Passive [containment, vessel design, inherent safe design]

- Safeguards are often applied in layers to accomplish the desired level of control and risk management and account for reliability issues

[Administrative safeguards are least reliable due to human error and safety culture failings.]
III. Engineering Control Measures

The “Fire Triangle”

- **FUEL** – Liquid (vapor or mist), gas, or solid capable of being oxidized. Combustion always occurs in the vapor phase; volatile liquids are vaporized, and solids are decomposed into vapor prior to combustion.

- **OXIDANT** – A substance which supports combustion – Usually the oxygen in air.

- **IGNITION SOURCE** – An energy source capable of initiating a combustion reaction.
III. Engineering Control Measures

- **Avoidance of flammable atmospheres**
  - Local Exhaust Ventilation (concentration)
  - Exclusion of oxygen by adding inert gas

- **Control of Ignition Sources**

- **Explosion Suppression**

- **Mitigation of Consequence**
  - Explosion Containment
  - Explosion Venting
  - Explosions Isolation
III A. Engineering Control Measures

Can Static be Controlled?
Electrostatics commonly perceived as black magic

However
Electrostatic effects:
are predictable and
can be controlled
IIIA. Engineering Control Measures

Is this Drum Mixer Grounded?
"Designed" to penetrate painted surfaces
Controlling Ignition Sources

Internal Metal Spiral to Ensure Electrical Continuity and shielding
(not electrostatic control or elimination)
Controlling Ignition Sources

Examples of Good Bonding
IIIA. Engineering Control Measures
III A. Engineering Control Measures

ElectroStatic Dissipative ‘ESD’ Footware Tester
Control of Ignition Sources?

- A seagull has been mentioned as the most likely ignition source of a fire in a large floating roof storage tank.
- The bird was seen with burning tail feathers, supposedly ignited by the flare stack.

Is Management of Ignition Sources a Reliable Primary Basis of Safety?
IIIA. Engineering Control Measures

Relies on early detection of an explosion and rapid injection of suppressant. Typically at moment of detection, explosion pressure is 35 to 100 m bar g. Suppressant extinguishes the flame within approximately 50msec.

To achieve explosion suppression, the following are required:
- Explosion Detector
- Control Unit
- Suppressor
- Suppressant

Explosion Suppression
III A. Engineering Control Measures

Venting of Deflagrations, NFPA 68

Relies on rapid opening of panel(s) or door(s) hence allowing the release of hot gases and unburnt product from within a process component or room.

Advantages and disadvantages

- Relatively low cost
- Simple to install in most cases
- Not suitable for toxic materials
- Venting to inside of buildings is usually unacceptable
IIIA. Engineering Control Measures

Venting of Deflagrations, *NFPA 68*

Installation of special panels, doors, or diaphragms that are designed to burst at a predetermined pressure below the design pressure of the enclosure

Allows the deflagration to expand and flow, thus reducing the pressure build-up inside the enclosure
III A. Engineering Control Measures

Mechanical Explosion Isolation

- Ignition
- Propagation
- Initiation
- Detection
- Release
- Automatic Shut-off Valve
- No Further Propagation

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IIIA. Engineering Control Measures

Chemical Explosion Isolation

- Ignition
- Propagation
- Residual Pressure Wave
- Chemical barrier
- Flame Extinguished

Initiation
Detection
Release
### IIB. Administrative Control Measures

#### Organizational Measures - OSHA PSM

1. Employee Participation
2. Process Safety Information
3. Process Hazard Analysis
4. Operating Procedures (SOP)
5. Employee Training
6. Contractors
7. Pre-Start up Safety Review
8. Mechanical Integrity
9. Hot Work
10. Management of Change
11. Incident Investigation
12. Emergency Planning & Response
13. Compliance Audits
14. Trade Secrets

PSM is a summary of industry best practices, not just an OSHA regulation.
Summary – Design of facilities to prevent deflagration

- **Identify** Hazards to understand the explosive characteristics of your materials

- **Site Hazard Assessment:**
  - Understand process operations and review of all available information (drawings, specifications, process/operation description)
  - Identification of locations where flammable atmospheres are or could be present during normal and abnormal operating conditions
  - Identification of potential **ignition sources** that could be present under normal and abnormal conditions. On-site electrostatic measurements (electrical field, electrical continuity measurements, etc.), where applicable

- **Control the Risk** of Fire/Explosion:
  - **Proper process and facility design** to prevent and/or minimize the occurrence of ignition sources and protect against explosion consequences
  - Regular inspection and maintenance of equipment to minimize ignition sources and creation of flammable atmospheres
Globally Positioned

- Chilworth Technology 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. – Princeton NJ
    - Safety Consulting Engineers – Chicago IL
  - Italy – Chilworth Vassallo Srl
  - France – Chilworth SARL
  - Spain – Chilworth Amalthea SL
  - India – Chilworth Safety and Risk Management Ltd
  - Germany/Netherlands – [Dekra Exam]
  - China – Shanghai Sept 2012
- Chilworth Technology was acquired by DEKRA SE August 2011
- BST was acquired by DEKRA March 2012
One of the leading international expert organisations

DEKRA SE

Headquarters in Stuttgart
- Active in more than 50 countries
- Around 40% of employees work outside of Germany
- Organized into 3 business units
- 15 strategic service lines
- Revenues of more than 2.2 billion Euros
- More than 28,000 employees
3 Business Units with 15 strategic service lines

**AUTOMOTIVE SERVICES**
- Vehicle Testing
- Expertise
- Used Car Management
- Homologation and Type Approval
- Consulting and Mystery Shopping
- Claims Services

**INDUSTRIAL SERVICES**
- Building and Facilities
- Machinery and Plant Safety
- Health, Safety and Environment (HSE)
- Energy and Process Industries
- Systems Certification
- Product Testing and Certification

**PERSONNEL SERVICES**
- Qualification
- Temporary Work
- Out- and New Placement

*Consulting Services*
Chilworth Client Industries

- Bulk & Fine Chemicals
- Agro-Chemical
- Energy / Power Sector
- Food & Drink
- Flavor & Fragrance
- Machine/Equipment Mfg
- Government Agencies
- Engineering / Consultants
- Legal/Insurance/Risk
- Primary Metals & Machining
- Automotive & Aviation
- Personal & Household Products
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YOUR FEEDBACK IS IMPORTANT!
Design of Facilities to Prevent Deflagration

Question & Answers
Process Safety Orientation
ASSE Conference – June 2013

Designing Facilities to Prevent Deflagration

[Managing Fire and Explosion Risk]

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