Agenda

• Hazardous Areas Overview

• Electrical Protection Methods –
  – XP, Intrinsic Safety, Purge, Non-Incendive
  – General Guidelines
  – Typical Applications
  – Strengths and Weaknesses
Hazardous Locations

- Imperial Sugar in Georgia (2008)
- West Fertilizer in Texas (2013)
- BP Oil Refinery in Texas (2005)
- Timet Metals in Pennsylvania (2015)
Hazardous Locations

1986 Space Shuttle Challenger Disaster

The NASA and Morton-Thiokol lesson learned on Safety Decisions
Hazardous Locations

Definition

• A hazardous location is an area containing (or possibly containing) an ignitable concentration of flammable gas, vapor, or dust where a source of sufficient energy (electrical/thermal) cause an explosion.

• Identified by:
  – Material type
  – Risk
  – Boundaries
Hazardous locations

Ignition Triangle

- Energy
- Air
- Fuel
Hazardous Locations

Elements of a hazardous Location

• Combustible material
  – Gas, vapor, dust

• Energy
  – Electrical
  – Thermal

• Oxygen
Hazardous Locations

Ignitable Energy of a hazardous Location

- Typically very low voltages and currents
- Varies by gas type
- Energy of ignition in some areas as little as a nickel or penny falling over
Hazardous Locations

Classification of the Hazardous Location

• North America – Prefers Division Method
• European – Prefers Zone Method
• Rest of World – Mixture of both
Hazardous Locations – DIVS.

Classification – Material Type

Plants and installations are classified according to the nature of the hazard

AREA CLASSIFICATION - DIVISIONS

Class I.............. Gas
Class II.............. Dust, Powder
Class III............. Fibers & Flyings
Hazardous Locations – DIVS

Classification – Divisions

• The PROBABILITY that the hazardous atmosphere will be present determines the DIVISION

• Division 1 - Ignitable mixtures exist during:
  – normal operation
  – repair/maintenance
  – leakage
  – Assumes greater than 10 hours per year of dangerous levels of gas

• Division 2 – Ignitable mixtures exist during:
  – abnormal operation
  – Area adjacent to Div 1
  – Assumes between 1 hour to 10 hours per year of dangerous levels of gas
Hazardous Locations – DIVS
Classification – Material Type

Groups – Division Method

- Group A - Acetylene
- Group B - Hydrogen
- Group C - Ethylene
- Group D - Propane
- Group E - Metal Dust
- Group F - Carbon Dust
- Group G - Flour, Grain, Starch Dust
No Group for Fibers/Flyings
### Hazardous Locations – DIVS
### Classification – Material Group

<table>
<thead>
<tr>
<th>Representative (Test) GAS</th>
<th>CSA 22.1 Divisions 1 &amp; 2</th>
<th>Spark ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylene</td>
<td>Group A</td>
<td>Ease of ignition from spark energy</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Group B</td>
<td></td>
</tr>
<tr>
<td>Ethylene</td>
<td>Group C</td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td>Group D</td>
<td></td>
</tr>
</tbody>
</table>
### Hazardous Locations – DIVS

#### Classification – Temperature Class

<table>
<thead>
<tr>
<th>Divisions</th>
<th>°C</th>
<th>°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>450</td>
<td>842</td>
</tr>
<tr>
<td>T2</td>
<td>300</td>
<td>572</td>
</tr>
<tr>
<td>T2A</td>
<td>280</td>
<td>536</td>
</tr>
<tr>
<td>T2B</td>
<td>260</td>
<td>500</td>
</tr>
<tr>
<td>T2C</td>
<td>230</td>
<td>446</td>
</tr>
<tr>
<td>T2D</td>
<td>215</td>
<td>419</td>
</tr>
<tr>
<td>T3</td>
<td>200</td>
<td>392</td>
</tr>
<tr>
<td>T3A</td>
<td>180</td>
<td>356</td>
</tr>
<tr>
<td>T3B</td>
<td>165</td>
<td>329</td>
</tr>
<tr>
<td>T3C</td>
<td>160</td>
<td>320</td>
</tr>
<tr>
<td>T4</td>
<td>135</td>
<td>275</td>
</tr>
<tr>
<td>T5</td>
<td>100</td>
<td>212</td>
</tr>
<tr>
<td>T6</td>
<td>85</td>
<td>185</td>
</tr>
</tbody>
</table>
Hazardous Locations – DIVS
Classification – Temperature Class

Auto Ignition Temperature

- Methane – 580 Celsius
- Hydrogen – 560 Celsius
- Propane – 493 Celsius
- Ethylene – 425 Celsius
- Acetylene – 305 Celsius
- Naptha – 290 Celsius
- Carbon Disulfide – 102 Celsius
- Sugar – 460 Celsius
- Wood – 340 Celsius
- Flour – 340 Celsius
- Grain Dust – 300 Celsius
- Tea – 300 Celsius
Hazardous Locations – DIVS

Area Classification for a fixed-roof tank

Tank vents

Liquid surface

Flammable Substance

Containment wall

Key

- Zone 0
- Zone 1
- Zone 2 / Div 2

Division/Zone Classification Example
Hazardous Locations

Overview – Divisions

• Division Method – Class; Division, Group, Temp
  – Class I, Division 1, Group A,B,C,D; T4 (haz. Present all the time)
  
  – Class I, Division 2, Group A,B,C,D; T4 (haz present abnormally or adjacent to Div 1)
Hazardous Locations - Zones
Classification – Material Type

AREA CLASSIFICATION - ZONES

Class I..........Flammable Gas or Vapor
Hazardous Locations - Zones

Classification – Zones

• The PROBABILITY that the hazardous atmosphere will be present determines the Zone

• Zone 0 - Ignitable mixtures exist:
  – Continuously
  – Extended periods of time

• Zone 1 – Ignitable mixtures likely to exist:
  – Adjacent to Zone 0
  – Normal operation
  – During maintenance

• Zone 2 – Ignitable mixtures likely to exist:
  – Adjacent to Zone 1
  – Not likely under normal operation
  – For Short periods of time
Hazardous Locations - Zones
Classification – Material Type

Groups – Zone Method

Group I – Methane (mine use only)
Group IIC – Acetylene, Hydrogen
Group IIB – Ethylene
Group IIA – Propane
## Hazardous Locations - Zones

### Classification – Material Group

<table>
<thead>
<tr>
<th>Representative (Test) GAS</th>
<th>CSA 22.1</th>
<th>Spark ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEC 505</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zones 0,1 &amp; 2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Group IIC</th>
<th>Ease of ignition from spark energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hazardous Locations - Zones

Classification – Temperature Class

- **Zones**
  - T1 - 450°C  842°F
  - T2 - 300°C  572°F
  - T3 - 200°C  392°F
  - T4 - 135°C  275°F
  - T5 - 100°C  212°F
  - T6 - 85°C   185°F
Hazardous Locations - Zones

Area Classification for a fixed-roof tank

Tank vents

Liquid surface

Containment wall

Flammable Substance

Key

- Zone 0
- Zone 1
- Zone 2 / Div 2

Division/Zone Classification Example
## Hazardous Locations - Zones Classification – Grade of Release

- **Zones** (quantified compared to Divisions)

<table>
<thead>
<tr>
<th>Grade of release</th>
<th>Nature of release</th>
<th>Presence in hours/year</th>
<th>Hazardous Zones/Divisions Gas or Vapors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Continuously or for long periods</td>
<td>&gt;1000h</td>
<td><strong>ZONE 0</strong></td>
</tr>
<tr>
<td>Primary</td>
<td>Periodically or occasionally during normal operation</td>
<td>10h to 1000h</td>
<td><strong>ZONE 1</strong></td>
</tr>
<tr>
<td>Secondary</td>
<td>Not in normal operation, infrequently and for short periods</td>
<td>0.1h to 10h</td>
<td><strong>ZONE 2</strong></td>
</tr>
</tbody>
</table>
Hazardous Locations - Zones

Overview – Zones

• Zone 0 – hazardous continuous or more than 100hrs

• Zone 1 – Likely to be hazardous under normal operation (10 to 100hrs)

• Zone 2 – Not likely to be hazardous under normal operation (0.1 to 10hrs)
Hazardous Locations
Classification – Comparison

### Divisions Vs. Zones

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>HAZARD</th>
<th>CONTINUOUS</th>
<th>PRIMARY (Likely)</th>
<th>SECONDARY (Not Likely)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European / International</td>
<td></td>
<td>ZONE 0</td>
<td>ZONE 1</td>
<td>ZONE 2 ZONE 22</td>
</tr>
<tr>
<td>North American Zones</td>
<td></td>
<td>ZONE 0</td>
<td>ZONE 1</td>
<td>ZONE 2</td>
</tr>
<tr>
<td>North American Divisions</td>
<td></td>
<td>DIVISION 1</td>
<td>DIVISION 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Normal Operation)</td>
<td>(Abnormal Op)</td>
<td></td>
</tr>
</tbody>
</table>
# Hazardous Locations Classification – Comparison

- **Divisions Vs. Zones**

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>IEC CENELEC</th>
<th>NEC 505</th>
<th>NEC 500</th>
<th>Ignition Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>METHANE</strong></td>
<td>GROUP I (Mining)</td>
<td>Under M.S.H.A jurisdiction</td>
<td>Class I Group A</td>
<td>&gt;320µJ</td>
</tr>
<tr>
<td><strong>ACETYLENE</strong></td>
<td>Group IIC</td>
<td>Group IIC</td>
<td>Class I Group B</td>
<td>&gt; 20µJ</td>
</tr>
<tr>
<td><strong>HYDROGEN</strong></td>
<td>Group IIC</td>
<td>Group IIC</td>
<td>Class I Group C</td>
<td>&gt; 20µJ</td>
</tr>
<tr>
<td><strong>ETHYLENE</strong></td>
<td>Group IIB</td>
<td>Group IIB</td>
<td>Class I Group D</td>
<td>&gt; 60µJ</td>
</tr>
<tr>
<td><strong>PROPANE</strong></td>
<td>Group IIA</td>
<td>Group IIA</td>
<td></td>
<td>&gt;180µJ</td>
</tr>
<tr>
<td><strong>Metallic Dusts</strong></td>
<td>In Preparation</td>
<td>None</td>
<td>Class II Group E</td>
<td>More Easily ignited</td>
</tr>
<tr>
<td><strong>Carbon Dusts</strong></td>
<td>In Preparation</td>
<td>None</td>
<td>Class II Group F</td>
<td>More Easily ignited</td>
</tr>
<tr>
<td><strong>Non-Cond. Dusts</strong></td>
<td>In Preparation</td>
<td>None</td>
<td>Class II Group G</td>
<td>More Easily ignited</td>
</tr>
<tr>
<td><strong>Fibers &amp; Flyings</strong></td>
<td>None</td>
<td>None</td>
<td>Class III</td>
<td></td>
</tr>
<tr>
<td><strong>GROUP I (Mining)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ACETYLENE</strong></td>
<td></td>
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<tr>
<td><strong>PROPANE</strong></td>
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<td><strong>Metallic Dusts</strong></td>
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<tr>
<td><strong>Carbon Dusts</strong></td>
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<tr>
<td><strong>Non-Cond. Dusts</strong></td>
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<td></td>
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<tr>
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<td></td>
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</tbody>
</table>
Hazardous Locations

A “simple” label example
3 Basic Principles

- Containment
- Segregation
- Prevention
Methods of Protection

NEC Classified Methods

• Explosion or Flame Proof (Exd)
• Purging / Pressurizing (Exp)
• Non-Incendive (ExnA & nl)
• Intrinsic Safety (Exi *)
Methods of Protection

Lesser Used Methods

• Hermetically Sealed
• Dust-Tight
• Increased Safety
• Encapsulated
• Oil-Filled (or other media)
Methods of Protection

Flame proof / Explosion proof (Exd)

Containment
Methods of Protection

Flame proof / Explosion proof (Exd)

- NEC Rule #1: Must be able to contain an internal explosion enough, or prevent an internal spark enough, to prevent a much larger explosion external to the box.

- NEC Rule #2: Must be able to operate at a temperature (both internally and on the box surface itself) that is below the lower temperature threshold of the surrounding potential gas so as to avoid a temperature ignition from occurring.
Explosion Proofing

Gap

Flame Path Length
Strengths of XP

- Higher Power Applications
- Fairly Simple to Understand
- Widely Accepted in USA
- Applicable to a lot of applications and hazardous areas
Weaknesses of XP

- Compromised Flanges
- Forgotten Bolts
- Forgotten Conduit Seals
- Heavy / Expensive Metal
- Ignored Temperature Specs During Design
Typical XP Applications

- Some Higher Powered Motors
- Process Transmitters
- Panels with higher power or unclassified products inside
- Lights / Horns / Safety Equipment
- Some Pumps
Methods of Protection

Purging / Pressurizing

Segregation
Methods of Protection
Purge and Pressurization (Exp)

NEC Rule: Equipment defined in National Fire Protection (NFPA) 496 that will reduce, limit, or eliminate hazardous gases / dusts by using positive pressure ventilation with clean air or noble gas (nitrogen).
Methods of Protection

Purge and Pressurization (Exp)

**X Purge:** Panel or Room or Motor that is in a Division 1 hazardous area and must be reduced to a general purpose area on the inside due to unclassified equipment internally

**Y Purge:** EITHER (a) A Div 1 area with Div 2 equipment on the inside of the purged system, or (b) a Div 2 area with general purpose equipment on the inside of the purged system

**Z Purge:** Div 2 area with general purpose equipment on the inside of the purged system
Methods of Protection
Purge and Pressurization

How it works...
- Pressurized air fed into “sealed” enclosure
- The pressure of the cabinet is maintained to at least 0.1 inches of water column (Class 1)
- Four (4) total volume exchanges of protective gas before power permitted for panels
Methods of Protection

Purge and Pressurization
Strengths of Purge

- Great for panels and high power motors
- Fairly Simple to Understand
- Widely Accepted
- Applicable to a lot of applications and hazardous areas, including dust
Weaknesses of Purge

- Can be difficult to seal panel well enough
- More engineering know-how than XP
- Continual source of protective gas needed
- Live work inside panel requires gas sniffer to guarantee no potential issues with gas or dust
Methods of Protection

Intrinsic Safety

Prevention

MTL7700 SERIES

DIN rail mounting safety barriers
Methods of Protection

Intrinsic Safety (Exi_)

- Prevention
  - Temperature Ignition
  - Accidental Panel-sourced ignition
  - Build-up of electrical energy in device

- All Classes
- All Divisions and Zones
- Only approved solution for Zone 0
- Any wiring practice (easy)
DEFINING “I.S.”

Per NEC504 code and ISA RP12.6:

INTRINSIC SAFETY IS:
A system, .... intended for use in hazardous areas which is incapable of causing ignition.

Prompted by 1913 Coal Mine Disaster in England – The Senghenydd Colliery Disaster, which killed 440 miners
Intrinsic Safety – A SYSTEM

1. IS IT SAFE? 
2. WILL IT WORK? 

I.S. Approved

DEVICE

SAFETY BARRIER
Intrinsic Safety

Hazardous Location apparatus can be either:
- Certified, energy-storing (e.g. instruments) or
- Uncertified, "non-voltage producing, non-energy storing Simple Apparatus"

Simple Apparatus Definition:

"Devices in which, according to the manufacturer’s specifications, none of the values 1.2 V, 0.1A, 20µJ or 25mW is exceeded, need not be certified or marked"

Examples:
I.S. – Complex Apparatus

- Designed to operate in accordance to the entity parameters indicated by the manufacturers control drawing

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{max}}$</td>
<td>Maximum allowable open circuit voltage</td>
</tr>
<tr>
<td>$I_{\text{max}}$</td>
<td>Maximum allowable short circuit current</td>
</tr>
<tr>
<td>$C_{i}$</td>
<td>Internal capacitance</td>
</tr>
<tr>
<td>$L_{i}$</td>
<td>Internal inductance</td>
</tr>
<tr>
<td>$P_{i}$</td>
<td>Maximum allowable power</td>
</tr>
</tbody>
</table>
I.S. – Evaluation

System Concept (Loop)
I.S. – Evaluation

Entity Concept (Parametric)

Safety is determined by the comparison of Entity parameters of the Apparatus, Associated Apparatus, and interconnecting wires.

Intrinsically Safe Apparatus

Associated Apparatus

Cable Parameters
- \( C_{\text{cable}} \)
- \( L_{\text{cable}} \)
- 60pF/ft
- 0.2 µH/ft

Entity Parameters
- \( V_{\text{max}} \)
- \( I_{\text{max}} \)
- \( C_i \)
- \( L_i \)
- \( P_i \)

Entity Comparison
- \( V_{\text{max}} \geq V_{\text{oc}} \)
- \( I_{\text{max}} \geq I_{\text{sc}} \)
- \( P_i \leq P_o \)
- \( C_i + C_{\text{cable}} \leq C_a \)
- \( L_i + L_{\text{cable}} \leq L_a \)

Entity Parameters
- \( V_{\text{oc}} \)
- \( I_{\text{sc}} \)
- \( C_a \)
- \( L_a \)
- \( P_o \)
I.S. – Associated Apparatus

**I.S SHUNT DIODE ZENER BARRIERS**

**I.S. ISOLATORS, GALVANIC**

MTL7700 SERIES

DIN rail mounting safety barriers

MTL5500 Series
I.S. – Associated Apparatus

Zener Vs Galvanic

• I.S SHUNT DIODE ZENER BARRIERS
  – Simple and reliable parts
  – High integrity ground required
  – Generic applications
  – Inexpensive
  – Requires understanding of the application

• I.S. ISOLATORS, GALVANIC
  – Fairly complex, parts lower MTBF
  – Floating, Isolated
  – Application specific
  – Perceived more expensive
  – ‘Plug and Play’
Strengths of Intrinsic Safety

- Good for all Divisions and Zones
- Safest of the methods
- Allows hot-area work on equipment
- Easiest wiring
Weaknesses of Intrinsic Safety

- Somewhat complex electrical calculations
- Barrier failure can be confusing
- Limited to low voltage and DC applications (typically 50 VDC or less)
- Must have low resistance path to ground
Methods of Protection

Non-Incendive

Prevention and Segregation

“May the Force be With You”
- Dr. Who
Methods of Protection

Non Incendive (Exn)

- Prevention
- Class I, D2 / Z2
- ANSI/ISA S12.12, two categories: EXna and Exnl
Methods of Protection

NON INCENDIVE (DIVISION 2 ONLY)

ANSI/ISA S12.12 is the Standard
Falls into two categories:

NON ARCING/NON SPARKING, EXnA

Requires mechanical protection, hermetically sealed contacts.
24VDC or 120VAC may be used

NON INCENDIVE (Energy Limited), EXnL

Similar to intrinsic safety including entity parameters, relaxed ignition curves, approved Div. 2 field devices, but less well defined. Designed to eliminate hot surfaces or incendive sparks under normal operating conditions.
Methods of Protection

Non Incendive (ExnL)

- Energy limited, D2/Z2 only!
- Utilizes entity system
  - Capacitance Max
  - Inductance Max
  - Resistance Max
  - Voltage Max
  - Temperature Max
- Relies heavily on *probability* of no disruption to normal operation
Strengths of Non-Incendive

- Applicable for Division 2 areas, which companies prefer to have over Division 1 areas
- Less rigorous
- Helps to avoid intrinsic safety, purging, and explosion proof solutions
Weaknesses of Non-Incendive

- Can be complicated and confusing with what code really says, and use of entity parameters
- Still not as safe as intrinsic safety
- Equipment should not be worked on live in Non-Incendive applications
- Mistakes can be made with conduit/cable seals
Conclusion

- Remember to ask the question correctly: “Prove to me that it is safe”, NOT “Prove to me that it is unsafe”.
- Take into account safety, risk factors, costs, and effects on insurance
- Know the rules of each method
- Make sure you triple check both design AND implementation afterward