An Analysis of CSB Investigation Reports

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Outline

- Introduction
- Explicit Inherent Safety Considerations in CSB Reports
- Results of CSB Report Analysis
- Inherent Safety Learnings
- Concluding Remarks
- Acknowledgements
Introduction

• **Scope**
  - Analysis of CSB reports with respect to hierarchy of risk controls

• **Motivation**
  - Significant value of CSB reports with respect to lessons learned

• **Objective**
  - Highlight role of ISD within hierarchy of risk control measures and process safety management systems
Analysis Framework

- **85 CSB reports** – investigation reports, case studies, safety bulletins, urgent recommendations
  - Second analysis: 25 reports (2010 – 2016)

- By category in hierarchy of safety measures

  - INHERENT SAFETY
  - PASSIVE ENGINEERED (ADD-ON) SAFETY
  - ACTIVE ENGINEERED (ADD-ON) SAFETY
  - PROCEDURAL (ADMINISTRATIVE) SAFETY
Analysis Framework

- By risk component
  - Likelihood → Prevention
  - Severity → Mitigation

- By Process Safety Management (PSM) element
  - 12-element CSChE PSM system (PSM Guide, 4th ed.)

- By inherent safety (ISD) principle
<table>
<thead>
<tr>
<th>Quote</th>
<th>Type of safety measure</th>
<th>Rationale</th>
<th>P/M</th>
<th>PSM Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSB concluded that... the lack of an automatic sprinkler system plausibly contributed to the detonation.</td>
<td>Active</td>
<td>An automatic sprinkler system would act as an active add-on device.</td>
<td>M</td>
<td>PRM</td>
</tr>
<tr>
<td>The West Volunteer Fire Department did not conduct pre-incident planning.</td>
<td>Procedural</td>
<td></td>
<td>M</td>
<td>PRM</td>
</tr>
<tr>
<td>Ventilation at ground level was limited to only a few louvered vents.</td>
<td>Passive</td>
<td>Ventilation louvers are passive safety devices.</td>
<td>P</td>
<td>Capital Project Review and Design Procedures</td>
</tr>
<tr>
<td>[An example of simplification would be to] Limit the types of FGAN blends sold to minimize the need for staff to handle FGAN.</td>
<td>ISD - Simplification</td>
<td>This example is found in Table 6, which explicitly mentions ISD - simplification when addressing this example.</td>
<td>P</td>
<td>PRM</td>
</tr>
</tbody>
</table>
Explicit Inherent Safety Considerations in CSB Reports

- Earlier CSB reports generally have implicit examples of ISD and limited use of ISD terminology (or language)

- Trend in recent investigations to explicit use of ISD terminology
  - inherently safer approaches (alternatives)
  - eliminating the hazard
  - hierarchy of controls
  - substitution
Xcel Energy

- Cabin Creek, CO
- October 2007
- Penstock fire
- 5 deaths + …
- Recoating of enclosed penstock (tunnel)

**Substitution**
- Non-flammable solvent instead of highly flammable MEK
West Fertilizer

- West, TX
- April 2013
- Ammonium nitrate plant explosion
- 15 deaths
## West Fertilizer

Table 6. Inherently Safer Approaches for handling FGAN

<table>
<thead>
<tr>
<th>Inherently Safer Strategy</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substitution</td>
<td>Replacing a hazardous material with a safer option</td>
<td>Use a fertilizer with less explosive potential than FGAN</td>
</tr>
<tr>
<td>Minimization</td>
<td>Reducing the quantity of a hazardous material used in a chemical process</td>
<td>Store FGAN in purpose-built buildings holding smaller quantities of materials, well separated from one another and from potential sources of contamination</td>
</tr>
<tr>
<td>Moderation</td>
<td>Using a hazardous material under the least hazardous conditions</td>
<td>Store FGAN in bins constructed of materials impervious to the effects of AN and in areas where electric service is not required</td>
</tr>
<tr>
<td>Limitation of effects (a form of moderation)</td>
<td>Change designs or reaction conditions rather than adding protective equipment</td>
<td>Construct FGAN storage bins to minimize the consequences of a possible explosion</td>
</tr>
<tr>
<td>Simplification</td>
<td>Eliminating process complexity to provide fewer opportunities for error and equipment failure</td>
<td>Limit the types of FGAN blends sold to minimize the need for staff to handle FGAN</td>
</tr>
</tbody>
</table>
Results

- By initial, second, and combined analysis
  - Initial 60-report analysis
  - Second 25-report analysis
  - Combined 85-report analysis
- ISD analysis
- Hierarchy analysis
- Prevention & mitigation analysis
Initial Analysis

93 ISD Examples

Inherent Safety

- Simplify 28%
- Minimize 25%
- Moderate 25%
- Substitute 22%
Second Analysis
82 ISD Examples

Inherent Safety

- Moderate: 42%
- Substitute: 29%
- Minimize: 17%
- Simplify: 12%
Overall Analysis
175 ISD Examples

Inherent Safety

- Simplify 27%
- Minimize 20%
- Moderate 28%
- Substitute 25%
Initial Analysis

ISD Analysis by PSM Element

6 – Process and Equipment Integrity
2 – Process Knowledge & Documentation
3 – Capital Project Review and Design Procedures
5 – Management of Change
Second Analysis

ISD Analysis by PSM Element

4 – Process Risk Management
10 – Company Standards, Codes, and Regulations
3 – Capital Project Review and Design Procedures
6 – Process and Equipment Integrity
Overall Analysis

ISD Analysis by PSM Element

PSM Element #

0 5 10 15 20 25 30

ISD Examples [%]

4 – Process Risk Management
6 – Process and Equipment Integrity
3 – Capital Project Review and Design Procedures
2 – Process Knowledge and Documentation
Initial Analysis
258 Hierarchy Examples
70% Prevention / 30% Mitigation

Hierarchy of Controls

- Procedural: 42%
- Inherent: 36%
- Active: 14%
- Passive: 8%
Second Analysis

421 Hierarchy Examples

76% Prevention / 24% Mitigation

Hierarchy of Controls

- Procedural: 51%
- Inherent: 19%
- Active: 18%
- Passive: 12%
Overall Analysis
679 Hierarchy Examples
74% Prevention / 26% Mitigation

Hierarchy of Controls

- Active: 14%
- Inherent: 27%
- Passive: 11%
- Procedural: 48%
Initial Analysis

Hierarchy Analysis by PSM Element

- 6 – Process and Equipment Integrity
- 8 – Training and Performance
- 2 – Process Knowledge and Documentation
- 3 – Capital Project Review & Design Procedures
Second Analysis
Hierarchy Analysis by PSM Element

4 – Process Risk Management
6 – Process and Equipment Integrity
8 – Training and Performance
10 – Company Standards, Codes, and Regulations
Overall Analysis

Hierarchy Analysis by PSM Element

4 – Process Risk Management
6 – Process and Equipment Integrity
8 – Training and Performance
2 – Process Knowledge and Documentation
Second Analysis
Prevention

Prevention within the Hierarchy of Controls

Inherent 23%
Active 11%
Passive 8%
Procedural 58%
Second Analysis
Mitigation

Mitigation within the Hierarchy of Controls

- Active 38%
- Passive 24%
- Procedural 31%
- Inherent 7%
Inherent Safety Learnings

Findings here are generally consistent with:

• Kidam et al. (2010): 13th Intl Symp. Loss Prevention
  • Failure Knowledge Database (Japan)
  • e.g. high percentage of procedural safety issues

• Yang et al. (2009): Hazards XXI
  • Analysis of case histories for common lessons learned
  • e.g. importance of all levels in the hierarchy of controls

• Fyffe et al. (2016): Analysis of key issues in CSB reports
  • Predominance of design & engineering issues
  • Predominance of process hazard analyses
Concluding Remarks

- Procedural safety is most popular
- Active safety common among mitigation efforts
- Prevention consistently more common than mitigation
- ISD has clear role to play in process incident prevention/mitigation
- All ISD principles are relevant to process safety assurance
Acknowledgements

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