Process Safety & Barrier Management

Lessons from major hazard industries

Engineers Ireland, Fire & Safety Division Conference

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Who We Are

MMI provides engineering, safety, and risk management consulting services

Service areas

- Technical and Process Safety & Risk Management
- Major Hazards Engineering
- Structural Integrity, Analysis and Design
- Fluid System Modelling and Design

Sectors

- Oil and Gas/Petrochemical
- Nuclear
- Utilities
- Aerospace & Defence
- ‘Green’ & Renewable Energy
- Commercial
MMI Engineering Locations

- GB/N.Ireland
  - Warrington, Bristol, Aberdeen, Leeds, Belfast, Teesside

- USA
  - Houston, San Francisco, Los Angeles, Seattle

- Malaysia
  - Kuala Lumpur

- Western Australia
  - Perth
Technical Process Safety & Risk Management

§ Services

§ Sample Clients
– Centrica, Total, SBM, BG, EoN, OMV, Woodside, BP, Shell, Talisman, Petronas.
Major Hazard Modelling

- **Hazards:**
  - Explosion, fires, smoke, release, dispersion.
  - Hydrocarbons, hydrogen, CO$_2$, multi-phase

- **Tools:**
  - FLACS, CEBAM
  - KFX, Vessfire, OPENFire
  - ANSYS-CFX, OPENFoam
  - PHAST, CIRRUS, FRED

- **Projects:**
  - Overpressure exceedance, CAP437, exhaust emissions, Fire Risk Assessment, Vessel Time to Failure, flare modelling, fire and gas detection optimisation, PM84 compliance.

- **Clients**
  - Centrica, Total, BG, Shell, SBM, Woodside, ConocoPhillips, Worley Parsons
Presentation content

- Definition of process safety
- Process safety vs personal safety
- The characteristics of process safety incidents
- Significant past incidents
- Incident statistics
- “Swiss cheese” model
- “Bow tie” model
Process safety is concerned with the prevention of harm to people and the environment from major incidents* such as fires, explosions and accidental releases of hazardous substances.

*Process-related incidents involving the uncontrolled release of energy and/or hazardous substances posing serious danger to people and/or the environment. ‘Process’ in this context covers the sourcing, generation, processing, storage and supply of energy. ‘Serious danger’ means (a) widespread severe distress or requirement for medical attention, serious injury to some people or the death of highly susceptible people or (b) severe, widespread or long term damage to the natural or man-made environment.
Process safety vs Personal safety

Esso, Longford, 1997
13 million man-hours without an lost-time injury

25 Sep 1998
Hydrocarbon release and fire
2 killed, 8 injured
The characteristics of major accidents

1. They can happen to us

Morecambe Central Production Complex, 2002

Rough 47/3B platform, 2006

BP platform

Time stamp from SAR helicopter
The characteristics of major accidents

... that they’ve probably already happened to someone else
The characteristics of major accidents

... we can’t afford to have one

The human cost:

<table>
<thead>
<tr>
<th>Location</th>
<th>Fatalities</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico City, 1984</td>
<td>600</td>
<td>7000</td>
</tr>
<tr>
<td>Bhopal, 1984</td>
<td>&gt; 2000</td>
<td>100,000</td>
</tr>
<tr>
<td>Piper Alpha, 1988</td>
<td>167</td>
<td>-</td>
</tr>
<tr>
<td>Texas City, 2005</td>
<td>15</td>
<td>180</td>
</tr>
</tbody>
</table>

The environmental cost:

<table>
<thead>
<tr>
<th>Location</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seveso, 1976</td>
<td>3300 animals died, 80,000 slaughtered; 4500 acres of land contaminated</td>
</tr>
<tr>
<td>Sandoz, 1986</td>
<td>250 km stretch of the Rhine contaminated; thousands of fish killed</td>
</tr>
</tbody>
</table>
The characteristics of major accidents

... we can’t afford to have one

The financial cost:

<table>
<thead>
<tr>
<th>Location</th>
<th>Cost ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grangemouth, UK, 1987</td>
<td>150</td>
</tr>
<tr>
<td>Pasadena, Texas, 1989</td>
<td>1456</td>
</tr>
<tr>
<td>La Mede, France, 1992</td>
<td>458</td>
</tr>
<tr>
<td>Milford Haven, UK, 1994</td>
<td>150</td>
</tr>
<tr>
<td>Toulouse, France, 2001</td>
<td>3000</td>
</tr>
<tr>
<td>Buncefield, UK, 2005</td>
<td>1500</td>
</tr>
<tr>
<td>Texas City, 2005</td>
<td>3000+</td>
</tr>
</tbody>
</table>

The reputational cost:

Post-Texas City, BP’s share price significantly underperformed the market:
The characteristics of major accidents

... they typically arise from the accumulation of well-intentioned, minor failings

- superficial safety management
- defective PTW system
- inadequate training
- inadequate risk assessment
- inadequate platform design
- inadequate emergency response

Piper Alpha, 1988
The characteristics of major accidents

... they’re entirely preventable

Safety improvements in the offshore industry since Piper Alpha:

- “Safety case” regime
- PTW systems
- industry training
- risk assessment
- platform design
- emergency preparedness
- workforce involvement
- incident reporting
- independent verification
The characteristics of major accidents

i. ... they can happen to us

ii. ... that they’ve probably already happened to someone else

iii. ... we can’t afford to have one

iv. ... they typically arise from the accumulation of well-intentioned, minor failings

v. ... they’re entirely preventable
Significant past incidents - chemical process industries

Flixborough, UK
1974

28 killed, 36 injured

Important lessons:

• Regulations and standards
• Safety management
• Inherent safety
• Design and location of occupied buildings
• Vapour cloud explosions

Drove introduction of:

• EU Seveso Directive
• Pressure Systems Regulations (UK)
Bhopal, India
1984

> 2000 killed
100,000 injured

Important lessons:

• Regulatory oversight
• Planning control
• Safety management
• Safety-critical systems
• Plant maintenance
• Plant isolation
Pasadena, Texas 1989

23 killed, 130 injured

Important lessons:

• Safety management
• Plant layout
• Plant isolation
• Safety-critical systems
Ocean Ranger, Canada 1982

84 killed

Important lessons:

• Rig design
• Training
• Evacuation and survival equipment

This incident revolutionised the training regime for HS&E in the Canadian offshore oil and gas industry
Significant past incidents - chemical process industries

Milford Haven, UK
1994

26 injured

Important lessons:

- Safety management
- Human factors
- Plant design
- Plant modifications
- Inspection systems
- Emergency planning

Led to development of:

- Guidance on design of alarm systems (EEMUA 191)
Longford, Australia
1998

2 killed, 8 injured

Important lessons:

• Hazard identification
• Alarm systems
• Communications
• Focus on major hazards
• Auditing
• Technical support
• Regulatory regime

Led to introduction of:

• State of Victoria major hazards regulations
Significant past incidents - chemical process industries

- Ironbridge, UK, 1998
- Teeside, UK, 1996 and 2001
- Dallman Unit 31, US, 2007
- Kleen Energy, US, 2010
### Incident statistics

<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
<th>UK</th>
<th>EU</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>EU-reportable major accidents, 1999-2006</td>
<td></td>
<td>26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major hydrocarbon leaks on offshore installations, 1996-2008 (Note 1)</td>
<td></td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>Major accidents reportable under EU Seveso II Directive, 2000-2009</td>
<td></td>
<td>216</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>DoT gas transmission and gas gathering systems incidents, 1986-2009</td>
<td></td>
<td>65 fatalities</td>
<td>269 injuries $1.4 bn property damage</td>
</tr>
<tr>
<td></td>
<td>OSHA PSM incidents, 1992 - 2005</td>
<td></td>
<td>138 fatalities</td>
<td>553 injuries</td>
</tr>
<tr>
<td></td>
<td>OSHA refinery National Emphasis Program (2007-2009)</td>
<td></td>
<td></td>
<td>17.4 PSM violations per refinery</td>
</tr>
<tr>
<td>Alberta</td>
<td>ERCB statistics for 2008</td>
<td></td>
<td></td>
<td>29 blowouts 39 pipeline ruptures 73 ‘Priority 1’ spills (Note 2)</td>
</tr>
</tbody>
</table>

**Note 1:** ‘Major’ means > 300kg or > 1kg/s for 5 minutes (gas)

**Note 2:** ‘Priority 1’ spills are those that pose the most serious potential environmental and public impact
“Swiss Cheese” model

Some holes are due to active failures

PROCESSES
eg change control

PEOPLE
eg behaviours

PLANT
eg safety equipment

Hazards

Other holes are due to latent conditions

Successive layers of “defence”

Incidents
Hazard: driving

PEOPLE
Driver training
“Drink-drive” programmes

PLANT
Vehicle safety features
Road safety features

PROCESSSES
Vehicle licensing
Statutory vehicle safety checks

Accident
Holistic Process Safety Management

To be or not to be... In Control

Leadership & Behaviour

Operational Safety

Containment

Availability / Reliability

Assets

Customer Requirements

Ageing Assets

Competence Status

Operational Control

Inherent Safety, Compliance & Risk Reduction

Incident Investigation

Monitoring & Audit

Hazard Identification & Risk Assessment

Training & Competence

Information

People Safety
Threat = Potential Cause of Hazard Release

Hazard and Hazard Source

Activities

Threat 1

Threat Controls are high level groups of Tasks (e.g. Design, Maintenance). Tasks are the actions that provide barriers to the potential Major Accident

Business Model

Activities are high level groups of Tasks (e.g. Design, Maintenance). Tasks are the actions that provide barriers to the potential Major Accident

Threat Controls and Recovery Preparedness Measures are barriers to prevent the Major accident and are provided by HSE Critical Tasks

Escalation Factor = Reason why control may fail

Result of hazard release = Major Accident Hazard

Consequence = Worst Case Escalation of Major Accident

Consequence 1

Consequence 2

Consequence 3
Engineering a Safer World

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