Lessons from process chemical incidents and accidents

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A History of Disasters

- Bhopal, India, 1984
- Chernobyl, Ukraine, 1986
- Shell Oil Norco, Louisiana, 1988
- Piper Alpha, North Sea, 1988
- Exxon Valdez, Alaska, 1989
- Phillips 66, Texas, 1989
- Kader Toy Factory Fire, Thailand, 1993
- Enschede Fireworks disaster, 2000
- Toulouse, France, 2001
- BP Texas City, USA, 2005
- Buncefield, UK, 2005
- Caribbean Petroleum Corporation, Puerto Rico, 2009
- Kleen Energy Explosion, USA, 2010
- Deepwater Horizon, USA, 2010
- Fukushima Daiichi, Japan, 2011

Major Moments for Learning

- Bhopal Disaster – 1984
- Toulouse, France – 2009
- BP Texas City – 2005
- Buncefield Terminal Fire – 2005
- Deepwater Horizon – 2005
- Fukushima Daiichi – 2011

Overview of Selected Accidents

- **Bhopal, India – 1984**
  - MIC release resulted from the mixing of incompatible materials and the failure of several layers of protection.
  - Over 2000 fatalities (estimate varies).
  - Several of the failures/deficiencies blamed on budgeting.
- **BP Texas City, USA – 2005**
  - Vapor cloud explosion (VCE) resulting from improper start-up and over-filling of isomerization unit.
  - 15 fatalities
  - Disaster caused by: inadequate and obsolete process design, poor maintenance, improper temporary building siting, worker fatigue, etc.

Overview of Selected Major Recent Disasters

- **Deepwater Horizon Oil Spill – 2010**
  - Loss of well integrity in the final stages of drilling resulted in a fire, explosion, and oil spill.
  - 11 fatalities, rig lost.
  - BP failed to follow best practices and heed warning signs.
  - Insufficient emergency response capabilities.
- **Buncefield Fire, UK – 2005**
  - Vapor cloud explosion caused by over filling of a gasoline storage tank and the resulting loss of containment.
  - Automatic high level alarm and shutdown switch failed.
  - Destroyed 20 large storage tanks

Overview of Selected Major Recent Disasters

- **Toulouse, France – 2001**
  - Explosion of "off-spec" Ammonium Nitrate (AN) in a warehouse
  - 30 fatalities, 10000+ injuries, 27000+ houses damaged
  - Most likely cause: incompatibility of AN with chlorinated compounds lead to decomposition and detonation of AN
- **Fukushima Daiichi NPP, Japan – 2011**
  - Tsunami flooded rooms emergency generators, causing power system damage and affecting seawater intake structures.
  - Lack of cooling, 3 reactors went into meltdown, hydrogen accumulated, causing explosions and releasing radioactive material
  - 20-km exclusion zone, thousands of people affected

Lessons Learned Applicable to Chemical Security

- Inherently Safer Design
- Process Hazard Analysis
- Facility Siting and Layout
- Leading Indicators and Warning Signs
- Layers of Protection Analysis (LOPA)
- Emergency Response and Planning
- Risk Communication
- Role of Academia

Inherently Safer Design (ISD)

- Inherent – Permanent, inseparable

ELIMINATE
REDUCE

rather than

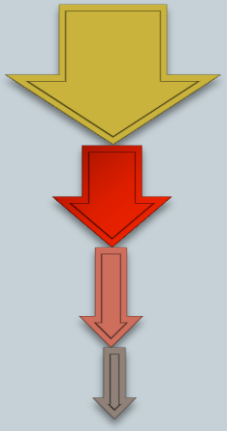
CONTROL

Hazard

Actual risk

Safer ≠ Safe

Hazard



Actual risk

Inherently Safer Design (ISD)

- Inherent Safety (IS) can help reduce/eliminate the hazard, thus the escalation of consequences.
- Reduction of hazards may make the facility less interesting as a target.
- Application of the four main strategies for IS:
  - Minimize – *"What you don't have, can't leak"* – Kletz, 1978
  - Substitute
  - Moderate
  - Simplify
- IS strategies do not necessarily remove the threat(s).
- Issue – How to determine inherently safer alternative?

Process Hazard Analysis (PHA)

- It is necessary to identify hazards in order to implement appropriate prevention and mitigation measures
  - Safety: Prevent *release* of hazardous materials
  - Security: Prevent *access* to hazardous materials
- Equivalent to PHA: **Security Vulnerability Analysis**

$$\boldsymbol{Security\ Risk} = \boldsymbol{f}[\boldsymbol{C}, \boldsymbol{T}, \boldsymbol{V}, \boldsymbol{A}]$$

  - C = *Consequence*
  - T = *Threat*
  - V = *Vulnerability*
  - A = *Attractiveness*

Facility Siting and Layout

- Minimize potential for domino effects or escalating consequences
  - Locate facilities away from communities
  - Need for better Land Use Planning (LUP)
    - Avoid the growth of communities in the surroundings of the facility

Leading Indicators and Warning Signs

- Before incidents occur, there are usually warning signs
- Lack of knowledge management may impede the identification of serious problems

"what is unknown does not coincide with what is impossible" (Paltrinieri et al., 2012)

Layers of Protection Analysis (LOPA)

- Objective: Reduce vulnerability of facility by making it less attractive and increasing difficulty to attack.
- Multiple independent layers are needed.
- No layer of protection can be perfect.
- Watch out for common cause failures or single point failures
- Devices should not be considered “fail-safe” unless it can be proven.

Integrity, Reliability, Availability of IPLs

- Risk can be reduced by reducing the likelihood or the consequences of an incident
  - Inherent
  - Passive
  - Active
  - Procedural
- A good safety program involves **ALL** strategies
- Layers must be inspected and maintained on a regular basis
- Layers must be able to operate upon demand.

Emergency Response Planning

- Plant personnel, local authorities and community should be prepared to respond to emergencies
  - Need for coordinated response
- Prepare for inevitable occurrence of accidents (earthquakes, tsunamis) – known unknown events
- Train responders in non-technical skills
  - Decision making, task leadership, communication, teamwork
  - Manage high uncertainty and stressful situations

Emergency Response Planning

- Crisis Management and response
  - Clarify supervisory roles
    - Who is in charge?
  - Ensure emergency power and utilities
  - Communicate honestly and frequently with the media
    - Acknowledge unknowns and uncertainties

Risk Communication

- Communicating information to the public
  - Need to balance between “right-to-know” and “security issues”
  - Revealing information has benefits and consequences
    - Build credibility
    - Make the facility of special value when times are tough
    - Terrorist can benefit from information released
- Need to educate society and risk communicators so that they have a more accurate perception of risk
- Public lack of awareness of hazards may escalate the consequences of the incident

Role of Academia

- Teach undergraduate and graduate students, and integrate engineering solutions in education and research curriculum
- Provide innovative and inherently safer solutions to industry problems

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Thank you

Questions?