## Decades of Learning, and Relearning . . .

<table>
<thead>
<tr>
<th>Year</th>
<th>Location/Event</th>
<th>Deaths</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>Flixborough, England / VCE</td>
<td>28</td>
<td>?</td>
</tr>
<tr>
<td>1976</td>
<td>Seveso, Italy / Runaway Reaction</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>1984</td>
<td>Mexico City, Mexico / LPG release</td>
<td>650</td>
<td>?</td>
</tr>
<tr>
<td>1984</td>
<td>Bhopal, India / MIC release</td>
<td>2,000+</td>
<td>?</td>
</tr>
<tr>
<td>1985</td>
<td>Institute, WV / MIC event</td>
<td>0</td>
<td>135</td>
</tr>
<tr>
<td>1987</td>
<td>Grangemouth, Scotland / VCE</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1988</td>
<td>Henderson, NV / Explosion</td>
<td>2</td>
<td>350</td>
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<tr>
<td>1989</td>
<td>Prince William Sound / Grounding</td>
<td>0</td>
<td>9</td>
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<tr>
<td>1989</td>
<td>Pasadena, TX / VCE</td>
<td>24</td>
<td>132</td>
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<tr>
<td>1990</td>
<td>Channelview, TX / Tank explosion</td>
<td>17</td>
<td>0</td>
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<tr>
<td>1997</td>
<td>Martinez, CA / Runaway reaction</td>
<td>1</td>
<td>46</td>
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<tr>
<td>1998</td>
<td>Longford, Australia / VCE</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>2001</td>
<td>Toulouse, France / Explosion</td>
<td>31</td>
<td>2,400+</td>
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<tr>
<td>2005</td>
<td>Texas City, TX / VCE</td>
<td>15</td>
<td>170</td>
</tr>
<tr>
<td>2010</td>
<td>Gulf of Mexico / VCE</td>
<td>11</td>
<td>17</td>
</tr>
</tbody>
</table>
Even More Learning and Relearning . . .

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<tr>
<th>Year</th>
<th>Location/Event</th>
<th>Deaths</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>Three Mile Island / Core damage</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>1979</td>
<td>Chicago, IL / Airplane crash</td>
<td>241</td>
<td>0</td>
</tr>
<tr>
<td>1981</td>
<td>Kansas City, MO / Walkway collapse</td>
<td>114</td>
<td>216</td>
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<tr>
<td>1986</td>
<td>Kennedy Space Center / Explosion</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>Chernobyl, USSR / Meltdown</td>
<td>30+</td>
<td>?</td>
</tr>
<tr>
<td>2000</td>
<td>Paris, France / Airplane crash</td>
<td>113</td>
<td>6</td>
</tr>
<tr>
<td>2003</td>
<td>Skies over Texas / Reentry failure</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>Upshur County, WV / Mine explosion</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>2008</td>
<td>Port Wentworth, GA / Dust cloud expl’n</td>
<td>14</td>
<td>?</td>
</tr>
</tbody>
</table>

Evolution of PSM Systems

- Technology and standards
- HSE management systems
- Management System
  - Integrated HSE MS
  - Reporting
  - Assurance
  - Competence
  - Risk Management
- Standards
  - Engineering improvements
  - Hardware improvements
  - Design review
  - Compliance
- Culture
  - Organizational and individual behaviour aligned with goals
  - “Felt” leadership
  - Personal accountability
  - Shared purpose & belief

19th Century 1970s 1990s
Examples of Some Common Codes and Standards

- ASME Sec. I
- ASME B31.1
- ASME Sec. V
- ASME Sec. IX
- ASTM
- ASNT
- SNT–TC–1A
- NBIC
- Boiler External Piping
- (“PP” Stamped)
- Non-Boiler Steam Piping
- ASME B31 1 or B31 3
- ASME Sec. V
- ASME Sec. IX
- ASME Sec. II
- ASME Sec. IV
- ASME Sec. I
- ASME Sec. IX
- ASTM
- ASNT
- SNT–TC–1A
- API 570
- API 510 or NBIC
- API 570
- API 510 or NBIC
- Boiler External Piping
- (“PP” Stamped)
- Non-Boiler Steam Piping
- (“PP” Stamped)
- Pressure Vessels/Unfired Boilers
- (“U” Stamped)
- ASME Sec. I
- ASME Sec. II
- ASME Sec. V
- ASME Sec. IX
- ASTM
- ASNT
- SNT–TC–1A
- API 570
- API 510 or NBIC
- Pressure Vessels/Unfired Boilers
- (“U” Stamped)
- ASME Sec. I
- ASME Sec. II
- ASME Sec. V
- ASME Sec. IX
- ASTM
- ASNT
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- ASNT
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KEY for CODE INDEX

CODES for: Inservice Inspection, Repairs, Alterations, Rerating

CODES for New Construction

- Management Systems: OSHA’s 14 PSM Elements
- c) Employee Participation
- d) Process Safety Information
- e) Process Hazard Analysis
- f) Operating Procedures
- g) Training
- h) Contractors
- i) Pre-startup Safety Review
- j) Mechanical Integrity
- k) Hot Work Permits
- l) Management of Change
- m) Incident Investigation
- n) Emergency Planning and Response
- o) Compliance Audits
- p) Trade Secrets

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**Employee Participation**

Gas Explosion, Longford, Australia, September 1998

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**Process Safety Information**

Runaway Reaction Involving Hydroxylamine Hanover Township, PA, February 1999
Process Hazard Analysis

Unknown or unsafe operation

Safe operating envelope

Normal operating envelope

Operating Procedures

Ammonium Nitrate Explosion
Port Neal, Iowa
December 1994
Training

Boiling Liquid Expanding Vapor Explosion
Feyzin, France, 1966

A Isolation valve
B Drain valve
C Sample valve

Contractors

Phillips HCC
 Pasadena, Texas, October 1989

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Pre-startup Safety Review

Initial Thiokol recommendation at second teleconference [on the evening before the launch]:

* O-ring temp must be $\geq 53^\circ F \sim 12^\circ C$ at launch

**Recommendations:**
- O-ring temp must be $\geq 53^\circ F$ at launch
- Development motors at 47°F to 52°F with putty packing had no blow-by
- SEM 15 (the best simulation) worked at 53°F
- Project ambient conditions (temp & wind) to determine launch time

Mechanical Integrity

Repair “Short Cut” Dooms AA Flight 191
Chicago, IL, May 25, 1979
Pipe Rupture Results in > 600 Offsite Fatalities

Mexico City
November 1984

Hot Work Permit (Safe Work Practices)
Management of Change

Piping System Change
Flixborough, UK, June 1, 1974

20-inch bypass line installed in late March 1974

Flixborough, UK
June 1, 1974
Incident Investigation

Space Shuttle Columbia
January 2003

- Spec required no foam shedding
- Foam shedding observed on at least 65 previous missions, including six instances of foam shedding from same location that caused the Columbia disaster
- Severe foam shedding reported on STS-112 in October 2002
- Successful return of damaged orbiters seemed to indicate that foam shedding was acceptable

Emergency Planning and Response
Compliance Audits

Bhopal, India
December 3, 1984

Trade Secrets

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The Problem with PSM Regulations ...

- Drives “in/out” approach based on “coverage”
- Tendency toward minimum compliance strategy
- Tends to discount risk

Wastewater Treatment Process, ARCO Chemical, Channelview, TX

AIChe Center for Chemical Process Safety

- Formed in 1985 as a U.S. industry response to the Bhopal tragedy to conduct research and provide objective, technical information on process safety issues
- 100+ member companies
- Managing Board, Technical Steering Committee, and numerous technical project committees
- Has published over 100 guidelines on process safety subjects
The Case for the RBPS Approach

- CCPS published its original 12 PSM elements in 1989 and followed it with 3 other management system books thru 1994
- A lot of experience and lessons have been learned since then; CCPS wanted to update its PSM framework to be useful to industry as a thought and action leader for the next 15 years
- RBPS came about for two reasons:
  - Generate better results with fewer resources
  - Provide an approach for companies of all “needs levels” to implement, correct, and improve PSM systems

Premise of Risk Based Process Safety

- Management systems should be the simplest that they can be while still being fit-for-purpose
- The following issues determine management system “rigor”
  - complexity, hazard, and risk
  - resource demands/availability
  - culture
- Effective process safety management systems must include continuous improvement
Balanced System

Resources  Results

RBPS Helps You Move the Fulcrum

Resources  Results

Risk Based Process Safety Elements

Commit to Process Safety
1. Process Safety Culture
2. Compliance to Standards
3. Process Safety Competency
4. Workforce Involvement
5. Stakeholder Outreach

Understand Hazards and Risk
6. Process Knowledge Management
7. Hazard Identification and Risk Analysis

Manage Risk
8. Operating Procedures
9. Safe Work Practices

Manage Risk (cont.)
10. Asset Integrity and Reliability
11. Contractor Management
12. Training and Performance
13. Management of Change
14. Operational Readiness
15. Conduct of Operations
16. Emergency Management

Learn from Experience
17. Incident Investigation
18. Measurement and Metrics
19. Auditing
20. Management Review and Continuous Improvement
Safety Culture Failures

- NASA - Challenger & Columbia
- Piper Alpha
- Longford
- Chernobyl
- Bhopal
- BP Texas City

Strong Leadership

Recommendations:

* O-ring TEMP must be ≥ 53°F at launch

Development motors at 47° to 52°F with putty packing had no blow-by. SRM 15 (the best simulation) worked at 53°F.

* Project ambient conditions (temp & wind) to determine launch time.
Formalize the Approach

DuPont’s Process Safety and Risk Management Model

- Auditing
- Process Technology
- Operating Procedures and Safe Practices
- Management of Change
- Process Hazards Analysis
- Quality Assurance
- Prestart-Up Safety Reviews
- Mechanical Integrity
- Management of “Subtle” Change
- Training and Performance
- Contractor Safety and Performance
- Incident Investigation and Reporting
- Management of Change
- Emergency Planning and Response

Through Operational Discipline

Achieving “Operating Excellence”

MANAGEMENT LEADERSHIP & COMMITMENT

Enforce High Standards; Avoid Normalization of Deviance

Commuter train collides with freight train, Los Angeles, California, September 12, 2008

Graphic courtesy of E.I. DuPont de Nemours and Company

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Maintain a Sense of Vulnerability

To stop work
To ask questions/voice concerns
To do their work

Empower Individuals
Defer to Expertise

Ensure Open Communication

“That [the foam strike to the left wing] is a turnaround issue, right?”
Establish a Learning Environment

Respond to Concerns in a Timely Manner

Flixborough, UK
Unsafe modification made late March 1974
Release and explosion occurred over 60 days later
The Problem with Some Companies…
They Are Taught a Lot of Lessons, But They Never Seem to Sustain Learning

Or they don’t know how to identify and fix root causes

They either don’t see hazards below the waterline

They fail to understand hazards and risk

Or their “fixes” don’t hold up

What is Risk?

Managing Risk

What can go wrong?  
How likely is it?  
What are the impacts?

Historical Experience  
Analytical Approaches  
Intuition and Judgment

What does it mean and what should you do about it?

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Layers Can Fail . . . .

- Technology failures
- Management system failures
- External factors
- Human failures

Better Risk Management Means Reducing/Managing:
Some activities must be monitored using leading indicators if they want to improve, not just by having accidents happen.

Use a human health care analogy:
- **Lagging indicator** = an autopsy after a heart attack
- **Leading indicator** = blood pressure, cholesterol, EKG
- **Culture indicator** = proper diet/exercise

We must use leading indicators in process safety if we hope to drive continuous improvement; we must address culture for sustainable performance.
Mars Climate Orbiter requires 10x more inflight propulsion maneuvers than expected prior to 1999 crash

**Management Review**

- Are we achieving the desired results?
- If not, identify possible corrective actions
  - not working on the right things
  - not doing the right things very well
- Even if the results are satisfactory, are resources being wasted because:
  - some tasks could be done more efficiently
  - other tasks should not be done at all
Time for Questions