Consistent Consequence Severity Estimation

“Making LOPA semi-quantitative on risk”

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President
SIS-TECH

- 2009 ISA Fellow
- Technical editor, CCPS Guidelines for Safe and Reliable Instrumented Protective Systems
- 1 of 5 US Experts to the IEC 61508/IEC 61511 committee
- Working Group Chair, TR84.00.02 (SIL Verification) and TR84.00.04 (Guidance on ISA 84.00.01-2004)
- Member of more than 20 industrial committees and forums
- Ph.D. and Engineering Fellow, The University of Alabama
- Licensed Professional Engineer in the State of Texas
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Question
- What is the consequence severity?

- Releasing waste hydrocarbons to the atmosphere?

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<th>SAFETY</th>
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<td>3</td>
<td>Hospitalization injury (e.g., serious burns, broken bones) and/or Multiple lost work day injuries and/or Injury to the public</td>
</tr>
<tr>
<td>2</td>
<td>Lost work day injury and/or recordable injuries (e.g., skin rashes, cuts, burns) and/or Minor impact to public</td>
</tr>
<tr>
<td>1</td>
<td>Recordable injury and/or No impact to the public</td>
</tr>
</tbody>
</table>
Risk Analysis

- Everything begins with the hazards identification and risk analysis.
- Initial step: PHA - Qualitative Review
  - Benefits
    - Allow prioritization of risk sources and actions
    - Supports screening of events for more detailed analysis
  - Problems
    - Inconsistency of consequence severity estimate
    - Inadequate evaluation of the validity of safeguards
    - Estimating likelihood of significant consequence events that hopefully the team has never seen
Question
- What is the consequence severity?

- Releasing 2000 gallons of waste hydrocarbons to the atmosphere?

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Many PHAs have evolved into Big Risk, Big List exercises

- The bigger the consequence severity
- The bigger the list of safeguards needed

You don’t need a big list of safeguards

You need the right list of well designed and managed safeguards
Evolution of the risk analysis for serious consequences

- Next Step: LOPA - semi-quantitative

Benefits
- Define initiating event frequency
- Understanding event propagation
- Analyze safeguards for robustness
- Analyze independence of causes and protection layers

Problems
- Does not address consequence severity
Consequence Severities are Inconsistent

- Problems:
  - Little guidance on consequence severity
    - lots on frequency
  - Little training
  - Little experience

- Results are highly influenced by team personalities, site culture and local folktales

- Teams tend to estimate high with flammable releases
Conditional Modifiers
Can (not) Fix It!

- Does not change consequence severity
  - Prioritization and event screening is still based on wrong consequence severity

- Conditional modifier estimate prone to same error
  - Estimate does not rely on process operation or team experience

- Changes frequency estimate to likelihood of harmful event
  - Appropriate for use when risk criteria is based on harmful rather than hazardous event frequency
  - Basic LOPA uses Hazardous Event Criteria.
Templates
Can (not) Fix It!

- Standard LOPA scenarios.
  - Attractive for multiple identical units.
- Proven to be difficult for “similar” units.
  - Teams “given” the answer may not analyze unique local conditions
  - Differences distract teams into discussing the differences rather than the hazardous event
- Template consensus depends on agreement on consequence severity ranking
LOPA follows the PHA

- LOPA teams are driven through quantitative guidance to recommend sufficient independent protection layers for a given severity.

- The next logical step is to introduce quantitative guidance for estimating consequence severity.
The Method

- Estimate a hole size based on:
  - Line size
  - Shaft / seal size (either directly or inferred from pump horsepower)
  - Percentage overpressure compared to MAWP
  - Gasket types

- Select a leak rate based on:
  - Hole size
  - Pressure
  - Liquid or vapor state inside the process
# Liquid Release

<table>
<thead>
<tr>
<th>Psig / inch</th>
<th>1/16</th>
<th>1/8</th>
<th>1/4</th>
<th>1/2</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2</td>
<td>8</td>
<td>31</td>
<td>120</td>
<td>500</td>
<td>1100</td>
<td>2000</td>
<td>4500</td>
<td>7900</td>
<td>17900</td>
</tr>
<tr>
<td>50</td>
<td>4</td>
<td>17</td>
<td>69</td>
<td>280</td>
<td>1100</td>
<td>2500</td>
<td>4400</td>
<td>9980</td>
<td>17700</td>
<td>X</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>25</td>
<td>98</td>
<td>390</td>
<td>1600</td>
<td>3500</td>
<td>6300</td>
<td>14100</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>150</td>
<td>8</td>
<td>30</td>
<td>120</td>
<td>480</td>
<td>1900</td>
<td>4300</td>
<td>7700</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>300</td>
<td>11</td>
<td>42</td>
<td>170</td>
<td>680</td>
<td>2700</td>
<td>6100</td>
<td>10900</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>500</td>
<td>14</td>
<td>55</td>
<td>220</td>
<td>880</td>
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<td>7900</td>
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<td>X</td>
<td>X</td>
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<td>1200</td>
<td>5000</td>
<td>11200</td>
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<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2000</td>
<td>27</td>
<td>110</td>
<td>440</td>
<td>1800</td>
<td>7000</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
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<tr>
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<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30000</td>
<td>110</td>
<td>420</td>
<td>1700</td>
<td>6800</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>50000</td>
<td>137</td>
<td>550</td>
<td>2200</td>
<td>8800</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</table>

"X" = no details are provided, since the release is equivalent to category 5.
Modeling

- Various alkanes and alkenes between C1-C10
- Aloha used to determine “zones of damaging overpressure”
- Models reached steady state in approximately 5 minutes
Hazard Zones

- Zone area covered by 3.5 psi compared to 400 ft by 400 ft unit footprint.
- Severity correlated to % of unit exposed to 3.5 psi
## Correlation – Impact Zone to Severity

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<tr>
<th>Leak Rate</th>
<th>Impact area Unit area</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 lb/min</td>
<td>And Over</td>
<td>&gt;1.00*</td>
</tr>
<tr>
<td>1,000 lb/min</td>
<td>10,000 lb/min</td>
<td>0.66 to &gt;1.00*</td>
</tr>
<tr>
<td>100 lb/min</td>
<td>1,000 lb/min</td>
<td>0.33-0.66</td>
</tr>
<tr>
<td>10 lb/min</td>
<td>100 lb/min</td>
<td>0.16-0.33</td>
</tr>
<tr>
<td>0 lb/min</td>
<td>10 lb/min</td>
<td>&lt;0.16</td>
</tr>
</tbody>
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* Upper bound is 3.5 psi over 3 times unit area
Question
- What is the consequence severity?

- Releasing 2000 gallons of waste hydrocarbons to the atmosphere through the stack of a blowdown drum?

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**Question**

- What if 2000 gal waste hydrocarbons is released to atmosphere in 1.5 minutes?
  - Approx 7600 Lb/min

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<tr>
<td>0 lb/min</td>
<td>10 lb/min</td>
</tr>
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Consistent LOPA

- RISK = Frequency and Consequence Severity

- Risk determination drives required risk reduction

- Typical LOPA procedures yield very consistent frequency estimates but provide little guidance for consequence severity estimation

- Severity ranking guidance is needed to get consistent RISK estimate.