What is LOPA and Why Should I Care?

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- Chemical Engineering
  - B.S. – University of California, Riverside
  - M.S. - University of California, Riverside
- HAZOP/LOPA experience
  - Upstream oil and gas
  - Refinery
  - Other chemical manufacturing facilities
  - Ammonia
  - Chlorine
- Quantitative Risk Analysis (QRA)
- Development of Operating Procedures and Control Narratives
- CalARP / RMP / PSM Program Development and Auditing
Key Topics

• What is LOPA?
  – Overview of LOPA

• Why do I care?
  – Changes to Regulatory Framework
  – Semi-Quantitative Analysis Easily Integrated into Qualitative Analysis Tools
What is Layer of Protection Analysis (LOPA)?
Layer of Protection Analysis (LOPA)

- **Semiquantitative risk assessment**
  - Evaluates the safety integrity of process operations
  - Semiquantitative → order of magnitude approximation

- **Typically used after a qualitative hazard evaluation (e.g., HAZOP)**
  - Corporate policy
    - Unsure of the frequency of ultimate consequence
    - Unsure of the consequences
    - High severity consequence
  - Relies on Multi-Disciplined Team

- **Implemented with pre-defined set of rules**
  - Published guidelines
  - Intracompany defined criteria
Layer of Protection Analysis (LOPA)

- Risk Acceptance (Tolerance) Criteria
  - Corporate policy

<table>
<thead>
<tr>
<th>Impact Event Consequence per Consequence Decision Tree</th>
<th>Risk Acceptance Criteria (RAC) Events per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catastrophic (1)</td>
<td>No more than once in 10,000 years (1 x 10^-4)</td>
</tr>
<tr>
<td>Severe (2)</td>
<td>No more than once in 1,000 years (1 x 10^-3)</td>
</tr>
<tr>
<td>Moderate (3)</td>
<td>No more than once in 100 years (1 x 10^-2)</td>
</tr>
<tr>
<td>Low (4)</td>
<td>No more than once in 10 years (1 x 10^-1)</td>
</tr>
<tr>
<td>Negligible (5)</td>
<td>(1 x 10^0)</td>
</tr>
</tbody>
</table>

- Typically generated during HAZOP
  - HAZOP Team ranks consequence as “Severe”
  - Corporate policy is to perform LOPA on all Severity ≥ 2
  - RAC = 1 x 10^-3
Layer of Protection Analysis (LOPA)

- **Initiating Event Frequency (Initiating Cause Likelihood)**
  - HAZOP → Likelihood of the Ultimate potential Consequence
  - LOPA → Initiating Cause Likelihood
    - Likelihood of operator misaligning valve, control system failure, etc.
    - Company generated based off of literature review
    - *E.g., Unloading/Loading Hose Failure*
      - Literature → $1 - 10^{-2}$ (PER YEAR)
      - Company → $1 \times 10^{-1}$ (PER YEAR)

<table>
<thead>
<tr>
<th><strong>Initiating Cause</strong></th>
<th>Frequency (events per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Error (routine task, performed once per week)</td>
<td>$10^0$</td>
</tr>
<tr>
<td>Human Error (non-routine task, performed &lt; once per month)</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>BPCS control loop failure</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
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<td>...</td>
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*CCPS – Layer of Protection Analysis: Simplified Process Risk Assessment*
**CCPS – Guidelines for Initiating Events and Independent Protection Layers**
Layer of Protection Analysis (LOPA)

• LOPA Ratio

\[
LOPA\_Ratio = \frac{RAC}{ICL \times PFD1 \times PFD2 \times PFD3 \times \ldots}
\]

• If LOPA Ratio \( \geq 1 \), then existing protection layers are adequate
• Current example

\[
LOPA\_Ratio = \frac{RAC}{ICL} = \frac{10^{-3}}{10^{-1}} = 10^{-2}
\]
Layer of Protection Analysis (LOPA)

- Probability of Failure on Demand
  - Value representing the probability of a system failing to respond at need

  “What’s the severity if we overpressure this vessel?”

  “We can’t overpressure, it’s got a PSV”

  - Quote from every HAZOP I’ve ever been in
Layer of Protection Analysis (LOPA)

- **Independent Protection Layer (IPL)**
  - Independent of the initiating event
  - Independent of other IPL’s (safeguards)
  - Follows specific guidelines as to applicability
    - **Switches**
      - Are the maintained, calibrated, and inspected at regular intervals
    - **Alarms**
      - Can an operator be expected to respond in time
    - **Pressure Relief**
      - Is it sized for the case under discussion
- **Passive or Active**
Layer of Protection Analysis (LOPA)

• Enabling Conditions (modifies initiating event likelihood)
  – A state that is not a failure/error but is conducive to generating the loss event, expressed as a probability
    • Seasonal Risks
    • Process State Risks

• Conditional Modifiers (modifies impact)
  – The probability of detrimental impact if the loss event were to occur
    • Probability that personnel are present at time of event
    • Probability of ignition
Layer of Protection Analysis (LOPA)

• Values are documented and defensible
  – Dispersion modeling
    • Goes to probability of developing hazardous atmosphere
  – Maintenance records
    • Goes to demonstrating reliability of safeguards (IPL’s)
  – Policies and procedures or signage designating a hazardous work area
    • Goes to personnel presence modifier
  – Electrical Classification documentation
    • Goes to probability of ignition
Layer of Protection Analysis (LOPA)

- **LOPA Ratio**

\[
LOPA\_Ratio = \frac{RAC}{ICL \times PFD1 \times PFD2 \times PFD3 \times \ldots}
\]

- If LOPA Ratio ≥ 1, then existing protection layers are adequate
- Probability of Failure on Demand

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<th>Independent Protection Layer (IPL)</th>
<th>Probability of Failure on Demand (PFD)</th>
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<tr>
<td>BPCS</td>
<td>(10^{-1})</td>
</tr>
<tr>
<td>Human Response to Abnormal Condition</td>
<td>(10^{-1})</td>
</tr>
<tr>
<td>Spring Operated Pressure Relief Valve</td>
<td>(10^{-2})</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
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Layer of Protection Analysis (LOPA)

- LOPA Ratio

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LOPA\_Ratio = \frac{RAC}{ICL \times PFD1 \times PFD2 \times PFD3 \times \ldots}
\]

- If LOPA Ratio ≥ 1, then existing protection layers are adequate

- Current example

\[
LOPA\_Ratio = \frac{RAC}{ICL \times PFD1} = \frac{10^{-3}}{10^{-3}} = 1
\]

  - Typically followed by recommendation to ensure device is added to critical instruments list

  - Ensure Reliability
Why Do I Care?
Safeguard Protection Analysis (SPA) *(CalPSM-R §5189.1(e), CalARP §2762.2.1)*

- **Objectives:**
  - Assess the effectiveness of existing and combined safeguards for each failure scenario identified in the PHA
  - Assure that safeguards are independent of the initiating event and each other

- **Evaluate:**
  - Passive, Active, or Procedural Safeguards
  - Using LOPA or “equally effective method”
LOPA Summary
(continued)

• LOPA can provide a vehicle for assimilating additional details, if needed, e.g.:
  – More accurate failure rates & probabilities
  – Results of detailed human error probability calculations, based on specific task analysis
  – More accurate consequence modeling

• LOPA is best implemented using a team approach, similar to a HAZOP Study, and may be conducted during or immediately after the HAZOP Study.

• The implementation of LOPA in tandem with the HAZOP Study is an excellent mechanism for verifying safeguard adequacy and providing a different perspective on the scenario.
Questions?

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