AN APPLICATION OF RISK-BASED DESIGN CRITERIA

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OUTLINE

• Background/Objectives
• Methods
• Results
• Conclusions
BACKGROUND

• HF Alkylation Unit operated by Ultramar Refining in Wilmington, CA
• Decision to install an (acid) Automatic Isolation and Evacuation System (AIES)
• Proposed local regulation in place specifying AIES design (based on API RP-751)
• Several design/operational options available
RISK-BASED DESIGN SELECTION

• Operational risk/reliability identified by Ultramar as key design selection criterion
  – Study commissioned

• Study objectives:
  – Quantify accident risks associated with each of three AIES design options
  – Identify and understand design features that drive risk profiles
  – Develop robust basis for selection among designs
OPTIONAL DESIGN CONCEPTS

• Option 1:
  – Emergency acid receiving vessel located outside battery limits
  – Given acid release, leak location diagnosed and acid transferred to receiving vessel

• Option 2:
  – Unit reconfigured from Series Recycle (SRC) to Series Acid Configuration (SAC)
OPTIONAL DESIGN
CONCEPTS - Contd.

• Option 2 (Contd.):
  – Given acid release, all major acid holding vessels isolated. If release persists, leak location diagnosed and acid transferred to intact settler

• Option 3:
  – Combination of previous options:
    • Unit converted to SAC design
    • Given release, acid evacuated to remote receiving vessel
RISK METHODS

• Integrated Risk Model:
  – Front End: Model potential causes, locations, sizes, and likelihoods of acid releases from system
  – Analysis of system capabilities: identify those releases that are mitigatable by each AIES design option
    • Successful mitigation: release less than 1,500 gallons
    • Consideration of diagnosis and response times
RISK METHODS - Contd.

– Back End: Model potential failure modes of each AIES system design, and estimate failure likelihoods

– Analysis of system reliabilities
  • reliability block diagram analysis
  • systematic identification of failure modes: human errors, equipment failures, support system failures

– Analysis of consequences of unmitigatable or unmitigated releases:
  • Release size used as surrogate consequence measure
UNDERLYING RISK FORMULA

• $R = \sum (I_m \times A_{mn} \times C_m) + \sum (J_i \times D_i)$
• $R =$ Risk metric
• $I_m =$ Annual probability of mitigatable leak at location/size $m$
• $J_i =$ Annual probability of unmitigatable leak at location/size $i$
• $A_{mn} =$ Probability of AIES failure via mode $n$ given leak $m$
• $C_m/D_i =$ Consequence severity of leak $m/i$
### AIES FAILURE MODES: EXAMPLE CUT-SETS

**AIES OPTION:** 3  
**RESPONSE MODE FOR:** RELEASE IN ACID STORAGE SECTION  
**TOTAL FAILURE PROBABILITY =** 1.21E-01

<table>
<thead>
<tr>
<th>CUT-SET</th>
<th>DESCRIPTION</th>
<th>BE_PROB(a)</th>
<th>CS_PROB(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PEVAC-STFL</td>
<td>Evac Pump PEVAC Fails to Start from Cold and Evac Acid from Storage Section</td>
<td>6.46E-02</td>
<td>6.46E-02</td>
</tr>
<tr>
<td>2 H-DET-HFOK-OP1/3</td>
<td>Operators Fails to Detect Release Given HF Detector Alarm</td>
<td>3.67E-02</td>
<td>3.67E-02</td>
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<tr>
<td>3 HF-DET-FL</td>
<td>HF Detectors Fail to Respond to Release</td>
<td>1.98E-01</td>
<td>9.41E-03</td>
</tr>
<tr>
<td>4 MOV-J-FC</td>
<td>MOV J Fails Closed</td>
<td>5.09E-03</td>
<td>5.09E-03</td>
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<tr>
<td>5 MOV-K-FC</td>
<td>MOV K Fails Closed</td>
<td>5.09E-03</td>
<td>5.09E-03</td>
</tr>
<tr>
<td>6 H-MOV-DIS</td>
<td>Failure to Reconnect MOV Power After PLC Logic Test</td>
<td>3.00E-03</td>
<td>3.00E-03</td>
</tr>
<tr>
<td>7 H-XFER-OP1/3</td>
<td>Operator Fails to Diagnose Release Location and Initiate Evacuation</td>
<td>2.67E-03</td>
<td>2.67E-03</td>
</tr>
</tbody>
</table>

\(a\) Probability of basic event given demand on AIES  
\(b\) Probability of cut-set (= product of constituent basic event probabilities) given demand on AIES
## AIES RELIABILITY

### AIES RESPONSE MODES

<table>
<thead>
<tr>
<th>AIES OPTION</th>
<th>MODE</th>
<th>RELEASE SITE</th>
<th>UNAVAILABILITY</th>
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<tbody>
<tr>
<td><strong>OPTION 1</strong></td>
<td>1</td>
<td>Acid Storage Section</td>
<td>1.21E-1</td>
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<tr>
<td></td>
<td>2</td>
<td>Reactor No. 1 Section</td>
<td>7.09E-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Reactor No. 2 Section</td>
<td>7.09E-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Acid Settler No. 1 Section</td>
<td>7.56E-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Acid Settler No. 2 Section</td>
<td>7.56E-2</td>
<td></td>
</tr>
<tr>
<td><strong>OPTION 2</strong></td>
<td>1</td>
<td>Line or Reactor Vessel</td>
<td>2.85E-2</td>
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<tr>
<td></td>
<td>2</td>
<td>Acid Circulation Pump</td>
<td>9.54E-3</td>
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<tr>
<td></td>
<td>3</td>
<td>Acid Storage Vessel</td>
<td>1.03E-1</td>
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<td></td>
<td>4</td>
<td>An Acid Settler Vessel</td>
<td>6.66E-2</td>
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<tr>
<td><strong>OPTION 3</strong></td>
<td>1</td>
<td>Acid Storage Section</td>
<td>1.21E-1</td>
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<td></td>
<td>2</td>
<td>Reactor No. 1 Section</td>
<td>7.09E-2</td>
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<td>3</td>
<td>Reactor No. 2 Section</td>
<td>7.09E-2</td>
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<tr>
<td></td>
<td>4</td>
<td>Acid Settler No. 1 Section</td>
<td>6.62E-2</td>
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<tr>
<td></td>
<td>5</td>
<td>Acid Settler No. 2 Section</td>
<td>6.62E-2</td>
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</table>

* a Probability of AIES failure given the event of a mitigatable release
## RISK ESTIMATES

<table>
<thead>
<tr>
<th>Risk Parameter</th>
<th>AIES Option</th>
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<tbody>
<tr>
<td></td>
<td>Option 1</td>
</tr>
<tr>
<td>Release (IE) Frequency</td>
<td>1.8E-1</td>
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<tr>
<td>Unmitigatable Release Frequency</td>
<td>6.6E-4</td>
</tr>
<tr>
<td>Unmitigated Release Frequency</td>
<td>1.4E-2</td>
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<tr>
<td>AIES Unavailability</td>
<td>7.6E-2</td>
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<tr>
<td>Risk</td>
<td>1.5</td>
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</tbody>
</table>
RISK DRIVERS

• SAC (Options 2 and 3) have lower leak probability
  – Single active pump
  – Fewer potential leak sites

• Leak isolation (Option 2) more reliable than acid evaluation
  – Isolation less reliant on leak location diagnosis
  – Greater hardware reliability for isolation
  – Need to transfer acid is unlikely
CONCLUSIONS

• Acid isolation/transfer design selected in preference to acid evacuation design
• Risk-based case for AIES design selection accepted by regulatory agency
• Unit now operational with AIES in place