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Presentation Outline

- Introduction – Motivation
- Fire Analysis and PFP optimization Methods
- A Unified Risk based Approach
- Pipe and Vessel Response to Fire and PFP
By Kathrine Schmidt in Houston 01 April 2015 14:44 GMT

Pemex has confirmed that four workers died and 16 were injured, at least two critically, in a fire that broke out early on Wednesday at the Abkatun Alpha platform in the Bay of Campeche.

The Mexican state-led company said one of the deceased was employed by Pemex, one by marine contractor Cotemar. The other two remained unidentified.

The fire first broke out at around 3 am on the north side of the shallow-water platform, according to a statement from local authorities, after which 302 workers were evacuated from the facility.

Marine firefighting work was still continuing as of mid-afternoon to extinguish the intense flames shooting into the air, with photos widely shared on social media.

Images from later in the day showed diminished flames but appeared to show the platform beginning to collapse in on itself. Pemex later said such images were inaccurate and that the structure was still standing.

"Sadly we confirm the deaths of four workers in the accident that occurred today," Pemex said in a statement Wednesday.

The injured, which are both from Pemex and the Cotemar marine contractor, were brought...
Ultimately trying to prevent….
Fire Response of Structures

Axial Strength Curve

- Elastic Strength
- Static Load

Failure at 990 secs (16.5 mins)
Passive Fire Protection (PFP)
## Structural Integrity for Fire and PFP Optimization Methodologies

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk-based Analysis Considering Fire Event Frequencies</strong></td>
<td>Define design flame length for a given event frequency (e.g. $10^{-4}$).</td>
<td>Ignores structural response to fire and high consequence associated with low event frequencies. Can be over-conservative.</td>
</tr>
<tr>
<td><strong>Global fire and/or individual member failure</strong></td>
<td>Applying global (uniform) heat flux to entire structure</td>
<td>Large areas are expected to be PFP’d. Very conservative approach.</td>
</tr>
<tr>
<td><strong>Redundancy analysis</strong></td>
<td>Remove a member or members at a time and perform static analysis using operational loads</td>
<td>No relationship to any fire load cases, as a result, a conservative PFP scheme may be obtained.</td>
</tr>
<tr>
<td><strong>Conventional PFP analysis using Ductility Limit Analysis (DLA) according to API RP 2FB</strong></td>
<td>Deterministically apply fire loads and analyze response of the structure. Develop initial PFP scheme based on analysis and optimize the PFP based on input from all disciplines (e.g. technical safety, operations, structures, etc.)</td>
<td>Widely used method in the industry.</td>
</tr>
<tr>
<td><strong>Risk-based PFP analysis using Ductility Limit Analysis (DLA)</strong></td>
<td>Develop fire scenarios in a particular target zone based on exceedance curves. Perform ductility level analysis to determine the consequence. Link the consequence of the structure to individual risk.</td>
<td>Amount of PFP to be applied on the structure is fully based on the risk that is produced by fire scenarios in target zones or areas.</td>
</tr>
</tbody>
</table>
Benefits of Proposed PFP Optimization

• Significant Reduction in **Installation Cost of PFP** (Up to 50%),
  
  – $2 - $15 million saving, Recent Onshore and Offshore Projects

• Significant Reduction in **Maintenance Cost**

• Reduction in **Weight** of the Structure
Fire Size – Flame Length Exceedance Curve

- ~ 2.0 m for 1E-04
- ~ 12.0 m for 1E-05

Cumulative Frequency (per year)

Fire Size (Flame Length), [m]
Plastic Utilization Contours
Failure time = 5 - 6 mins

Crane Pedestal and its Support - Fire Response without PFP
Fire Response of Reactor Frame

Reactor Frame Dimensions:

Reactor Frame Load Carrying Story:
Deformation (m) in the Reactor Frame (50% Utilization)
Deformation (m) in the Reactor Frame (35% Utilization)
• Use your Blast&Fire hazards experience and knowledge

• Use Consequence analysis knowledge well

• **Know your Risk!**

• “The safest risk is the one you didn't take”.
### Defining Risk – Generic Risk Matrix

**Risk = Frequency x Consequences**

<table>
<thead>
<tr>
<th>Severity Level – Financial M=million</th>
<th>Severity Level - Human</th>
<th>Likelihood of Risk Event/Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5M USD loss</td>
<td>Minor Health/safety impact</td>
<td>A  An event has not yet occurred in the industry, Freq. = $10^5$</td>
</tr>
<tr>
<td>0.5M – 1M USD</td>
<td>Medium Health/safety impact</td>
<td>B  An event has occurred somewhere in the industry, Freq. = $10^{-4}$</td>
</tr>
<tr>
<td>1M – 10M USD</td>
<td>Permanent Injuries, high health impact</td>
<td>C  An event has occurred once in the organization or more than once in the industry, Freq. = $10^{-3}$</td>
</tr>
<tr>
<td>10M – 100M USD</td>
<td>1-3 fatalities</td>
<td>D  An event has occurred once or twice in the particular facility lifetime, Freq. = $10^{-2}$</td>
</tr>
<tr>
<td>&gt; 100M USD</td>
<td>3-10 fatalities</td>
<td>E  An event has occurred at least once per year at the particular facility, Freq. &lt; $10^{-1}$</td>
</tr>
<tr>
<td>&gt; 1000M USD</td>
<td>&gt; 10 fatalities</td>
<td>Not Acceptable (Marginally Tolerable Risk) region</td>
</tr>
</tbody>
</table>

**Severity Level - Human**

- **Minor** Health/safety impact
- **Medium** Health/safety impact
- **Permanent** Injuries, high health impact
- **1-3 fatalities**
- **3-10 fatalities**
- **> 10 fatalities**

**Severity Level – Financial M=million**

- **< 0.5M USD loss**
- **0.5M – 1M USD**
- **1M – 10M USD**
- **10M – 100M USD**
- **> 100M USD**
- **> 1000M USD**

**Not Acceptable (ALARP)**

- Tolerable Risk
- Acceptable Risk

**Event**
Defining Risk – A Unified Approach

- Structural Response Analysis,
- Consequence Analysis, → Severity Levels

Identify Risk using Risk Matrix

- Probability of Damage, Fragility Curves
- Damage Frequency Matrix,
- Individual Risk Matrix → Likelihood of Risk

Hazard Curve
- Pressure Exceedance Curve
- Probability of Exceeding of Hitting vs Vessel Impact Energy
- Annual Exceedance Curve

Develop Mitigation/Repair/Strengthening Options, if Risk is not acceptable
Unified Risk Based Approach for Fire Design and PFP Optimization

**Consequence:**
- Structural response analysis MDOF
- Calculate Damage Probability for Each Damage Levels for each Flame length in a Target Zone
- Calculate OV/OPP for each damage level
- Calculate Expected fatalities for Each Damage Levels

**Likelihood of Risk:**
- Determine frequencies associated with Each Flame Length in a Target zone
- Calculate Damage Frequency for Each Flame length in a Target Zone
- Calculate Individual Risk

**Hazard Curve:**
- Define a Target Zone
- Event Frequency for Each Target zone
- Flame Length vs. Duration
- Flame length vs. Flame width

**Identify Risk using Risk Matrix**

Develop Mitigation/Repair/Strengthening Options, if Risk is not acceptable
In Conclusion….

• Existing Approaches are excellent screening tools – however the methodologies as they stand require updating

• For new facilities, this kind of Front End Thinking provides
  – cost reductions in final design
  – as well as practical risk mitigating measures for operations

• For existing facilities, the proposed methods can
  – allow operators to improve both existing safety measures
  – as well as maintaining reasonable costs for implementation of new mitigation solutions
Thank You! Questions?

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