CFD OIL 2008
COMPUTATIONAL MODELING OF JET FIRES

August 19th, 2008
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Marcelo Mendes
## BV Brazil’s AIM Division – MAIN SERVICES

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<td>► HAZOP, PHA, HAZID, SIL and LOPA Analyses&lt;br&gt;► QRA (Quantitative Risk Analysis)&lt;br&gt;► Consequence Analysis on Accidents in O&amp;G Plants</td>
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<td><strong>3-D Gas Dispersion</strong></td>
<td>► 3-D Gas Dispersion Calculations (CFD)&lt;br&gt;[CFD = \textit{Computational Fluid Dynamics}]&lt;br&gt;► Gas Detectors Positioning Studies&lt;br&gt;► Air Pollution</td>
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<td><strong>3-D Fire Simulations</strong></td>
<td>► Fire Computational Simulations&lt;br&gt;► Passive Protection Studies&lt;br&gt;► Thermal Analysis – Flare, Helideck</td>
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<td>► Deluge, Foam, CO₂</td>
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<td><strong>Acoustic Studies</strong></td>
<td>► Noise Mapping and Reduction&lt;br&gt;► P.A. Systems Studies</td>
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<td><strong>Vibration Studies</strong></td>
<td>► Dynamic Analysis</td>
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<tr>
<td><strong>Structural Dynamic Analyses</strong></td>
<td>► Thermal studies, stress and strain measurements</td>
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</table>
Gas Accidents - History

- The reports cover the Gulf of Mexico, Pacific, Alaska and Atlantic areas under US government control from years 1956 to 1990 (MMS 92-0058) and 1990 to 1994 (MMS 95-0052). The Figure 1 show the frequency of some kinds of important accidents, from 1964 to 1994.

Fig. 1 - Percentage of Fire and Explosions associated with gas realted to the total number of Fire and Explosion accidents (918) at Gulf of Mexico, from 1964 to 1994

- Fire and Explosions associated with gas 36%
- Others 64%
Using accident reports, items of equipment with higher accident frequency were identified. The results of the research are shown on Figure 2, where the individual contribution of each group of equipment is highlighted.

Fig. 2 - Frequency (%) of the presence of equipment in Fire and Explosions associated with gas (total = 110) at Gulf of Mexico from 1985 to 1994

- Compressor: 33%
- "Production header": 2%
- "Production sump": 3%
- Draining pipes: 2%
- Generator: 6%
- others: 22%
- Not specified: 6%
- Glycol System: 4%
- Separator: 3%
- Test Separator: 3%
- Oil Piping Pump: 3%
- Line Heater: 3%
- Start Motor: 2%
- Deck draining System: 2%
- Gas washer: 3%

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The ROAs, covering a period from January/92 to December/95 and comprising platforms both fixed and semi-submersible, are a reliable and updated picture of the operational accidents in the Company’s platforms.

**Fig. 3 - Gas Leakages at PETROBRAS’ Offshore Platforms**

- Wells: 21%
- Vessels: 11%
- Gas Lift: 10%
- Turbo Compressor: 10%
- Daniel Valve: 7%
- Gas Export: 5%
- Gas Export: 5%
- Chicksan Piping: 5%
- SDV: 3%
- Separators: 4%
- Lines: 5%
- Instrument: 5%
- Heat-exchangers: 1%
- Christmas Tree: 1%
- Ball Valve: 1%
- Water Disch.: 1%
- Low-pressure Gas Export: 1%
- Flexible Line: 1%
- Motor Compressor: 1%
- Dehydration Tower: 1%
ADVANCED COMPUTATIONAL SIMULATIONS
ADVANCED COMPUTATIONAL SIMULATIONS

- Thermal, fluid-dynamics, structural, non-linear, plasticity

Includes “specific analyses”:

- Fire Simulations
- Gas Dispersion simulations
- Simulation of gas release through Vents
- Explosion Simulations
- Thermal Analysis for Flare
- Dynamics analysis of equipment and structures
FIRE SIMULATIONS

METHODOLOGY

- Fire scenarios identification
- Flame modeling (Pool and Jet Fires)
- Temperature calculation
- Stress analysis
- Collapse evaluation
- Passive fire protection design

References:

11 FPSO units: P-31, P-32, P-34, P-37, P-38, P-43, P-47, P-48, P-50, P-54, FPSO Cidade de São Mateus

22 Fixed and semi-submersible platforms
GAS DISPERSION SIMULATIONS

METHODOLOGY

► Identification and characterization of leakage scenarios
► Construction of 3-D model
► Wind calculation
► Gas Dispersion Analysis, for each scenario
► Superposition of gas clouds => gas detection
► Definition of position of Vents
► Special Studies (Cargo Tanks, smoke, temperature, Gas accumulation, air changes, etc)
GAS DISPERSION SIMULATIONS

► Fixed platform - FLACS and CFX models

FLACS (GexCon)  CFX
GAS DISPERSION SIMULATIONS

Gas leakage at SDV
(SE wind = 5.19 m/s,
Leak direction = vertical to floor)

FLACS (length = 44 m)

Gas leakage at SDV
(SE wind = 5.19 m/s,
Leak direction = Horizontal, S to N)

FLACS

CFX (length=44,3m)

CFX
Jet Fire (ARGOS)

Heat flow:

\[ Q = f(V, P_c, F) \]

\( V \) = leak flow
\( P_c \) = Heat of combustion
\( F \) = Diffusivity parameter

Flame length:

\[ L = f(V, \text{Pressão}, \text{Gas properties}) \]

Flame tilting angle:

Iterative method

\[ \alpha = f(v_{\text{wind}}, \mu_{\text{wind}}, V, D, \mu_{\text{gas}}, L) \]
FIRE SIMULATIONS

► Thermal model  
  FPSO

Module P01-A

► Structural model  
  FPSO Skid

Module P01-A
Jet Fire

Table 1 - Gas Export Pipeline (9.13")

<table>
<thead>
<tr>
<th>Flame Characteristics</th>
<th>Orifice Leakage Size/ Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Time: 1 min.</td>
<td></td>
</tr>
<tr>
<td>Flame Length (m)</td>
<td>72.97</td>
</tr>
<tr>
<td>Heat Radiation (MW)</td>
<td>1099</td>
</tr>
<tr>
<td>Time: 15 min.</td>
<td></td>
</tr>
<tr>
<td>Flame Length (m)</td>
<td>48.32</td>
</tr>
<tr>
<td>Heat Radiation (MW)</td>
<td>463.7</td>
</tr>
<tr>
<td>Duration (min.)</td>
<td>92</td>
</tr>
</tbody>
</table>

Table 2 - Gas Lift Riser (2.5")

<table>
<thead>
<tr>
<th>Flame Characteristics</th>
<th>Orifice Leakage Size/ Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Time: 1 min.</td>
<td></td>
</tr>
<tr>
<td>Flame Length (m)</td>
<td>72.97</td>
</tr>
<tr>
<td>Heat Radiation (MW)</td>
<td>1099</td>
</tr>
<tr>
<td>Time: 15 min.</td>
<td></td>
</tr>
<tr>
<td>Flame Length (m)</td>
<td>-</td>
</tr>
<tr>
<td>Heat Radiation (MW)</td>
<td>-</td>
</tr>
<tr>
<td>Duration (min.)</td>
<td>9</td>
</tr>
</tbody>
</table>

FPSO

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FIRE SIMULATIONS

↑ Flame calculation  FPSO

Gas Export Line

Large flow

Medium flow
FIRE SIMULATIONS

► Flame calculation  

FPSO Balcony and Skid

Gas Lift riser
FIRE SIMULATIONS

► Flame calculation  **FPSO Skid**

CFD
Flame length = 35.2 m

ARGOS
Flame length = 36 m
FIRE SIMULATIONS

► Flame calculation  

**FPSO floor isolation**

Jet fire - Compressor Vessel

Without bottom beams

With bottom beams

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FIRE SIMULATIONS

Radiation analysis  FPSO

Riser Balcony

Jet Fire at the Production Separator

Jet Fire at the 3rd Stage Compressor

Jet Fire at the Safety Gas KO Drum
Thank you for your attention!

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