FITNESS FOR SERVICE OF CRACKED VALVE ON HIGH PRESSURE STEAM HEADER
MAKE SURE LOCK OUT BEFORE START THE WORK
Outline

1. Badak LNG Overview
2. Problem Description and Assessment Approach
3. Examination Result
4. Assessment Result
5. Conclusions
Badak LNG Overview

Shareholders:
- Pertamina: 55%
- Muara Badak (Chevron): 20%
- JILCO: 15%
- Total: 10%
Badak LNG Overview

No. Trains: 8 (22.5 MTPA LNG & 1.1 MTPA LPG)
Loading Docks: 3 (1 LNG, 2 LNG/LPG)
Feed Gas Supply: 3.7 BSCFD with 4 Pipelines 2@36”; 2@42”

LNG train
LNG storage tank
Problem Description

Boiler Utilities-1

Letdown Station

Compressor Driver

Back Press. Turbine

Boiler Utilities-2

Letdown Station

Compressor Driver

Back Press. Turbine

Condensing Turbine

Pump Driver

Condensing Turbine

Pump Driver

Surface Condensers

Surface Condensers

Steam Condensate Utilities-1

Steam Condensate Utilities-2

Note: Green : Open, Red : Close

HP Steam 61-62 kg/cm²g ; 450 °C

MP Steam 17.5 kg/cm²g ; 316 °C

LP Steam 3.5 kg/cm²g ; 218 °C
Problem Description

- **Design code**: ANSI B 16.34
- **Size / ANSI Class**: 24” / 600
- **Valve type**: Gate flexible wedge type disc
- **Year installed**: 1989
- **Material specification**: ASTM A217 WC6
- **Service**: High pressure superheated steam
- **Design pressure**: 75 kg/cm^2^g (1066 Psig)
- **Design temperature**: 450°C (842°F)
- **Operating pressure**: 61-62 kg/cm^2^g (882 psig)
- **Operating temperature**: 450°C (842°F)
- **Insulation**: N/A

Crack occurred at two locations: Body and Bonnet
Fitness for Service Approach

- Material Test
  - Flaws Sizing: Alternating Current Potential Drop (ACPD)
  - Thickness Measurement: Ultrasonic Test
  - Material Characterization:
    Chemical Composition, Tensile Testing, Fracture Toughness (CTOD) Testing, and Fatigue Growth Testing

- Finite Element Modelling: Abacus Software

- Fitness for Service Assessment: APII 579 Section 9 Level 3B

Crack A on valve Body

Red: Crack B, blue: Crack C, green: Crack D and yellow Crack E
Flaw Length
A = 170 mm, B = 33 mm, C = 120 MM, D = 70 mm, & E = 23 mm)
Note:
Thickness of Remaining Ligament = Average Thickness – Maximum Crack Height
## Material Test Result - 3

### Material Characterization

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Result and Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Composition</td>
<td>Meet Requirement ASTM A 217 Grade WC6 but silicon content exceeded 0.6%</td>
</tr>
<tr>
<td>Tensile Testing</td>
<td></td>
</tr>
<tr>
<td>➢ Test at 23 °C</td>
<td>Meet Requirement ASTM A 217 Grade WC6</td>
</tr>
<tr>
<td>➢ Test at 130 °C</td>
<td>YS = 225 MPa, TS = 487 MPa, EL = 16 %, RA = 23 %</td>
</tr>
<tr>
<td>Fracture Toughness (CTOD) at 130 °C</td>
<td>Minimum value is 0.38 mm</td>
</tr>
<tr>
<td>Fatigue Growth Testing at 130 °C</td>
<td>$A = 3.1 \times 10^{-17}$, $m = 4.4$ and $\Delta K_o = 184 \text{ Nmm}^{3/2}$</td>
</tr>
</tbody>
</table>
### Finite Element Modeling - 1

<table>
<thead>
<tr>
<th>Case</th>
<th>Location</th>
<th>Average Von-Mises stress (MPa)</th>
<th>Stress range, $\Delta\sigma$ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low temperature</td>
<td>Valve body</td>
<td>103.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bonnet</td>
<td>89.5</td>
<td>-</td>
</tr>
<tr>
<td>High temperature</td>
<td>Valve body</td>
<td>175.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bonnet</td>
<td>163.5</td>
<td>-</td>
</tr>
<tr>
<td>Low temperature minus 10°C</td>
<td>Valve body</td>
<td>102.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bonnet</td>
<td>85</td>
<td>-</td>
</tr>
<tr>
<td>Low temperature plus 20°C</td>
<td>Valve body</td>
<td>107</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bonnet</td>
<td>94</td>
<td>-</td>
</tr>
<tr>
<td>Low temperature – 10°C + 20°C</td>
<td>Valve body</td>
<td>-</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Bonnet</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Low - High temperature</td>
<td>Valve body</td>
<td>-</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Bonnet</td>
<td>-</td>
<td>74</td>
</tr>
</tbody>
</table>

**Note:**

<table>
<thead>
<tr>
<th>Valve Temperature</th>
<th>Low Temperature Case</th>
<th>High Temperature Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Side</td>
<td>114.4 °C</td>
<td>415 °C</td>
</tr>
<tr>
<td>Bonnet</td>
<td>73 °C</td>
<td>402 °C</td>
</tr>
<tr>
<td>East Side</td>
<td>70.6 °C</td>
<td>412 °C</td>
</tr>
</tbody>
</table>
Assessment Result

Failure Assessment Diagram

Stress Intensity Ratio, $K_r$

Load Ratio, $L_r$

- Failure Assessment Diagram
- Assessment point for body flaw, Low temperature case
- Safe
- Un-safe

$a = 31.8$ mm, $2c = 170$ mm

$a = 16.0$ mm, $2c = 130$ mm
Assessment Result

- Critical flaw - Low Temp Pm = 130 MPa, wall thickness 60 mm, Location A4
- Body flaw a = 31.8 mm 2c = 170 mm
Assessment Result

Crack Critical Value for Bonnet

- Critical flaw Low Temp $P_m = 127$ MPa, wall thickness 35.7 mm, Bonnet
- Re-categorised body flaw $a = 16$ mm, $2c = 130$ mm
## Assessment Result

### Crack Growth Analysis

<table>
<thead>
<tr>
<th>Case</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack on Body</td>
<td></td>
</tr>
<tr>
<td>➢ Low Temperature Case –10 °C + 20 °C</td>
<td>No crack growth</td>
</tr>
<tr>
<td>➢ Swing between low and high Temperature Case</td>
<td>Crack growth occurred</td>
</tr>
<tr>
<td>Crack on Bonnet</td>
<td></td>
</tr>
<tr>
<td>➢ Low Temperature Case –10 °C + 20 °C</td>
<td>No crack growth</td>
</tr>
<tr>
<td>➢ Swing between low and high Temperature Case</td>
<td>Crack growth occurred</td>
</tr>
</tbody>
</table>
Assessment Result

Crack Growth Analysis - Body

Swing between low and high temperature case
Assessment Result

Crack Growth Analysis - Bonnet

Swing between low and high temperature case

Flaw height, a (mm) and length, 2c (mm)

Number of years in continued operation
The 170 mm long flaw located at the valve body had a semi-elliptical shape with a maximum height of 31.8 mm.

The equivalent flaw size on bonnet was determined to be 16 mm high and 130 mm long.

Valve body flaws are in the safe region of the API 579 Level 3B failure assessment diagram.

Crack growth analysis showed that the crack on valve not likely to grow if the valve experiences limited temperature cycling (between 10 °C below to 20 °C above the low temperature case) but sub-critical growth of the body crack will occur if the valve experiences temperature cycling between the low and the high temperature case.

Close monitoring of temperature has been conducted to prevent any temperature swing beyond lower temperature case.
Thank you