Root cause analysis and successful modifications to eliminate hot spots in SRU at MOL’s Danube Refinery

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Residue Processing Area
Danube Refinery, MOL
SRU units

<table>
<thead>
<tr>
<th></th>
<th>SRU4</th>
<th>SRU5</th>
<th>SRU6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>85 t/d</td>
<td>90 t/d</td>
<td>90 t/d</td>
</tr>
<tr>
<td>Feed</td>
<td>AAG: amine acid gas</td>
<td>AAG: amine acid gas</td>
<td>AAG: amine acid gas</td>
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<tr>
<td></td>
<td>SWS: Sour water stripper gas</td>
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</tr>
<tr>
<td>Steam pressure</td>
<td>18 (14) barg</td>
<td>52 (45) barg</td>
<td>52 (45) barg</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>~180°C</td>
<td>263°C</td>
<td>263°C</td>
</tr>
</tbody>
</table>

SRU1,2,4,7 units had shown no problems with bundle walls
SRU3,5,6 units developed serious problems within short operation times
Timeline

SRU5 Check-up: no problem
SRU5 Water flooding
• Bundle replacement
SRU5 Check-up: broken ferrules

SRU6 Startup
SRU6 Water flooding
• Bundle replacement
SRU6 Check-up: broken ferrules

Damage details: SRU5 unit

- Refractory wall separated from bundle wall
- Large percentage of ceramic ferrules were broken or cracked
- Outlet bundle wall intact
- Refractory wall support pins corroded away
- Bundle wall and tube weldings corroded
- Tube endings funnelled in, thinned around the ending
- More than 57 leaking welding
Repairs of SRU5 unit (2008)

- Bundle lining was replaced according original design
- Inlet side bundle wall was replaced
- Ceramic ferrules and refractory wall were replaced according original design
- Refractory wall support pins were modified
Damage details: SRU6 unit (2011)

- Refractory wall separated from bundle wall
- Large percentage of ceramic ferrules were broken or cracked
- Refractory wall support pins burned away
- Outlet bundle wall was intact
- Bundle wall and line endings were corroded
- Tube inlets were funnelled, thinned around the weldings
- More than 75 inlets leaked at low pressure testing, replacement needed
Damage investigation

Possible damage mechanism:

• High temperature S-corrosion damages overheated areas like bundle wall and tube inlets and weldings (high prob.)
• Acid dew corrosion during S/U and S/D. (low prob.)

Possible counteractions

• Cr alloy materials instead of carbon steel
• Reducing surface temperature
  • Lower bundle wall thickness
  • Reduced welding distance from feed water
• Prevent ferrule and refractory wall cracks, protecting the less cooled areas from high S gases
Repairs and modifications: SRU6 unit (2011)

- Bundle lining replaced according original design
- Tube ending welds were modified for better cooling
- Ceramic ferrules were changed to more robust type, refractory wall remained original design
- 2012: Ferrules were coated with thick heat-resistant fibre insulation to avoid stress fractures due to wall movements
Internal benchmark: Ferrule + Refractory types

**Similarities:**
- Fix bundle
- Concrete refractory + ceramic ferrules over the bundle wall
- Boiler material quality
- Processing capacity (90 t/d)

**Differences**
- Inlet side bundle wall thickness

**Modifications:**
- Additional 5 mm fibre insulation between bundle and refractory walls
- Stronger ferrules and wall support pins, weldings

**Results**
- Cracked ferrules within a few years of operation
- Beginning or leaking corrosion and funneling
Internal Benchmark: Block ferrules and Other protections

Similarities:
- Fix bundle
- Boiler material quality
- 30 mm bundle walls

Differences
- Tube size and number
- Waterside pressure
- Heat distributor wall

Modifications
- Replacements of ferrules to block type in 2 units

Results
- No breaking or corrosion
Summary

Damage mechanism:
• High temperature S-corrosion at hot parts of the inlet side tube endings

Suggestions:
• Thin bundle wall
• Corner of half V welds at tube endings
• Block type ferrules instead of tubular ferrule+refractory wall
• Fibre insulation coated ferrules
• Heat distributor wall (optional)
Results

2 SRU unit modified during 2014-2015

Modifications:
• Bundle wall replaced (35 mm)
• Bundle lines replaced
• Tube weldings: corner welds
• Refractory+ferrules replaced by block type ferrules
• Heat distributor wall deemed unnecessary.

Testing:
• 2017 check-up found 2 cracked ferrule after extreme testing