Best Practice
Corrosion/Erosion Monitoring
and
Critical Process Indicators
Salton Sea KGRA

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Salton Sea Geothermal Fluids

- Hot (>500°F)
- High chloride content (>10%)
- High total dissolved solids (>25%) with high scaling tendency
- Noncondensible gases (ammonia, carbon dioxide, hydrogen sulfide)
- Corrosion rates:
  - can exceed 300 mils per year for carbon steel
  - much higher corrosion rates if aerated or acidified brine
## Material of construction

<table>
<thead>
<tr>
<th>Material</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium Grade 29</td>
<td>Production Wells</td>
</tr>
<tr>
<td>Inconel 625 (58% Ni, 23% Cr), Inconel 825</td>
<td>Vessel</td>
</tr>
<tr>
<td>2507 Duplex Stainless Steel (25% Cr, 7% Ni, 4% Mo), 2205</td>
<td>Piping</td>
</tr>
<tr>
<td>2507 Duplex Stainless Steel</td>
<td>Injection Wells</td>
</tr>
<tr>
<td>316L Stainless Steel</td>
<td>Condensate/NCG</td>
</tr>
<tr>
<td>Cement Lined</td>
<td>Injection line</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>Non-aerated brine tank</td>
</tr>
</tbody>
</table>
Monitoring is essential for safe and sustained operation

<table>
<thead>
<tr>
<th>Degradation Mechanism</th>
<th>Inspection Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>General corrosion/erosion</td>
<td>Ultrasonic Thickness Testing (UT)</td>
</tr>
<tr>
<td>Pitting or “bear claw” corrosion</td>
<td>Visual, B scan or C scan UT</td>
</tr>
<tr>
<td>Stress Corrosion Cracking (SCC)</td>
<td>Visual, Dye Pen, Magnetic Particle Inspection, Shear wave UT</td>
</tr>
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</table>
## Process Indicators

<table>
<thead>
<tr>
<th>Process Indicator</th>
<th>Potential Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical monitoring:</td>
<td>Higher potential for stress corrosion cracking (SCC) and</td>
</tr>
<tr>
<td>- increase in chloride/silica in steam</td>
<td>corrosion</td>
</tr>
<tr>
<td>- decrease of pH in condensate</td>
<td></td>
</tr>
<tr>
<td>Pressure change vs. time</td>
<td>Scaling or erosion</td>
</tr>
<tr>
<td>Log book of upset conditions</td>
<td>Target inspection</td>
</tr>
</tbody>
</table>
Degradation type, knowledge of service and risk of failure drives inspection

- **Major Overhaul Inspection**
  - Visual, pictures and thickness measurements at all process changes
  - Additional inspection if there is a potential to crack

- **More Frequent Inspections if:**
  - New plant; one year after start-up
  - Poor understanding of degradation mechanism
  - Process parameters outside design

- **Sustained Inspection**
  - Baseline prior to start-up
  - Same location for each major overhaul inspection
  - Evaluate corrosion rate (mils per year) changes over life of project
Corrosion

- Example of selected inspection locations and frequency

- Accelerated corrosion of weld zones in alloys
Turbulence

increased turbulence/velocity

mixed fluids

Scale down stream of brine injection pump

Flow Direction
Scale does not adhere to alloys. Easy to remove and clean.
Well Casing Pressure Test

Video Camera

Multiple Finger Caliper
Massive pitting in HP steam line from wash water impurities

Weld failure on steam vessel internals
UT Inspection Matrix – Carbon Steel

Evidence of changes in physical and chemical depositional environment
Materials of construction can mitigate impacts
Monitoring is critical to sustained operation
Anticipated degradation process and risk of failure directs frequency and inspection technique
Discussion

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