Microbiological Induced Corrosion in Stainless Steel Piping: Mitigation Strategy

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OUTLINE

- What is MIC?
- MIC Causes
- Lessons Learned
MIC Facts and Numbers: In Industry

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$ corrosion</td>
<td>32%</td>
</tr>
<tr>
<td>corrosion in dead legs</td>
<td>16%</td>
</tr>
<tr>
<td>Microbiological corrosion</td>
<td>13%</td>
</tr>
<tr>
<td>corrosion of threaded items</td>
<td>11%</td>
</tr>
<tr>
<td>Erosion</td>
<td>8%</td>
</tr>
<tr>
<td>external corrosion</td>
<td>7%</td>
</tr>
<tr>
<td>velocity + CO$_2$</td>
<td>5%</td>
</tr>
<tr>
<td>mechanical corrosion failures</td>
<td>2%</td>
</tr>
<tr>
<td>corrosion + fabrication</td>
<td>3%</td>
</tr>
<tr>
<td>chemical attack</td>
<td>1%</td>
</tr>
<tr>
<td>corrosion fatigue</td>
<td>1%</td>
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</tbody>
</table>

Source: NACE Corrosion Survey
Microbiologically Induced Corrosion is the term used for the failure mode in which the corrosion is initiated, propagated and/or accelerated by micro-organisms like bacteria, algae, fungi, etc. MIC may occur in all fluids containing some water and nutrients for microorganisms.

What is MIC?

Schematic diagram of biofilm on an immersed metal surface

Schematic diagram of metabolic process on an immersed metal surface

Source:

a – MIC of stainless Steels, Report TN1621 Rolled Alloys.
b – MIC Control in Hydrostatic Testing, Presentation.
What is MIC?

The corrosion associated with MIC is usually pit corrosion.

Schematic for MIC pitting morphologies b

Source:
b – MIC Control in Hydrostatic Testing, Presentation.
MIC in Stainless Steel Piping

• Places where MIC can be found
  • Utility and water piping
  • Process Piping

• Studies concluded that the leaks were caused by MIC where bacteria was introduced via stagnant hydrotest water and ingress of solid contaminants
Inspection and Location Selection Criteria

- **High MIC susceptibility:**
  - Low points without drains and horizontal long runs.
  - Large Size Pipes
  - HAZ in Welds

  **Inspection at High Susceptibility areas:**
  - 10-20% RT to verify the MIC for all high susceptible cases. Incase RT shows indication 100% RT for welds.
  - GVI, RVI and Boroscopy where accessible.

- **Low MIC susceptibility:**
  - Vertical joints have very less susceptibility
Sample Inspection Findings

- Defect Definition: Localized Pitting
- Defect Location: Pipe to Pipe/Pipe to Elbow/ HAZ and Weld
- Material Definition: A312 TP 304/304L- Sch10S
- Diameter Range: 4-30 inch (Higher the diameter more susceptible)
MIC Samples

Source: Failure analysis reports by ARAMCO and AMCO
Causes were found:

- Improper Storage
- Design
- Inadequate flushing, draining and drying
- Improper preservation
- Non compliance with hydrostatic testing procedure
Corrective Actions

• Amended existing Hydrostatic Testing and Lay-Up procedure for emphasizing more stringent testing and control requirements
• Carried out extensive VT and RT inspections to investigate the extent of potential MIC locations
• Conducted inspection assessments for SS piping for remaining facilities under construction to validate system integrity
MIC Mitigation Approach

- Apply continuous monitoring and frequent inspection of SS piping systems with MIC risk
- Include use of effective biocides in hydrotest water
- Increase control of water quality
- Ensure adherence to hydrotest procedures
- Ensure adherence lay-up and preservation procedures
- Avoidance of stagnant or no-flow process systems
- Corrosion Management program to capture MIC monitoring and mitigation strategies
Thank You…

Any Questions…