

Microbiological Induced Corrosion in Stainless Steel Piping: Mitigation Strategy

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OUTLINE

- **What is MIC?**
- **MIC Causes**
- **Lessons Learned**

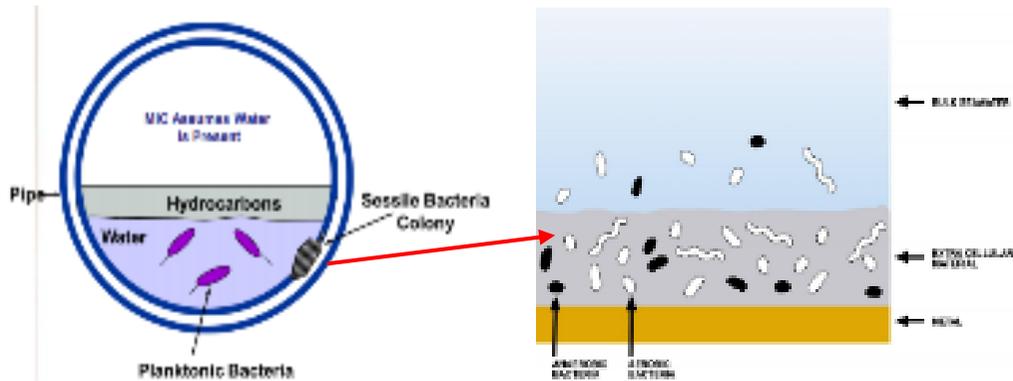
MIC Facts and Numbers: In Industry

CO ₂ corrosion	32%
corrosion in dead legs	16%
Microbiological corrosion	13%
corrosion of threaded items	11%
Erosion	8%
external corrosion	7%
velocity+CO ₂	5%
mechanical corrosion failures	2%
corrosion + fabrication	3%
chemical attack	1%
corrosion fatigue	1%

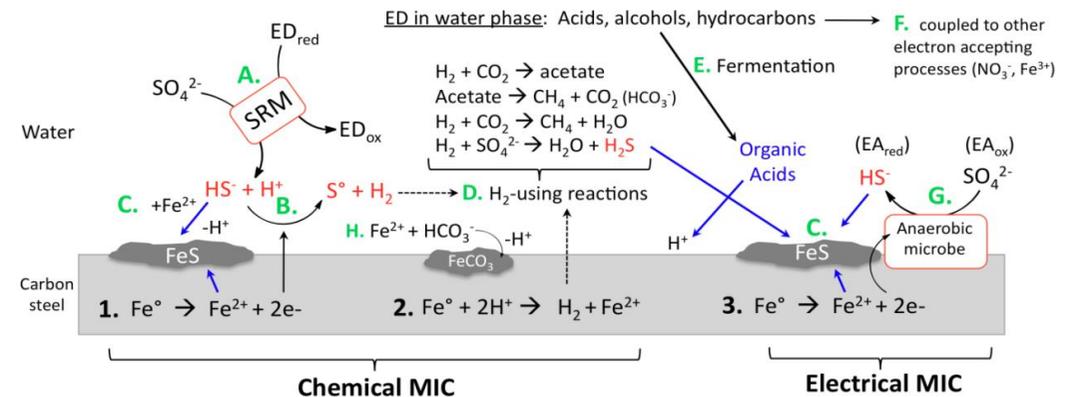
Source: NACE Corrosion Survey

What is MIC?

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



Schematic diagram of biofilm on an immersed metal surface ^a



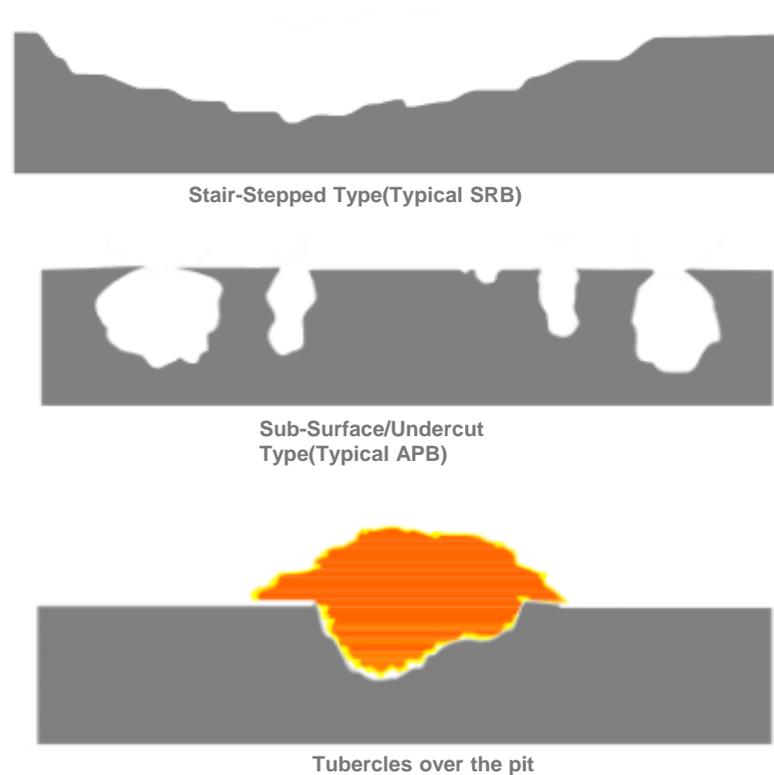
Schematic diagram of metabolic process on an immersed metal surface ^b

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:

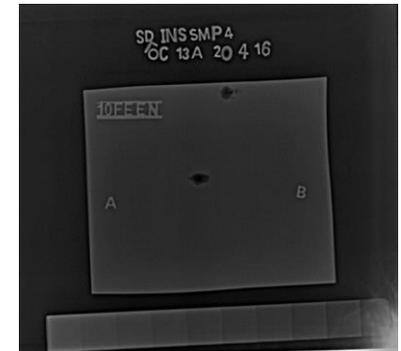
- Low points without drains and horizontal long runs.
- Large Size Pipes
- HAZ in Welds

Inspection at High Susceptibility areas:

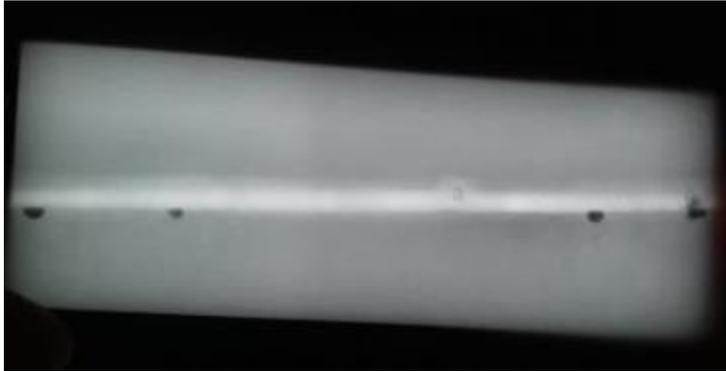
- ✓ 10-20% RT to verify the MIC for all high susceptible cases. In case RT shows indication 100% RT for welds.
- ✓ GVI, RVI and Boroscopy where accessible.

▪ Low MIC susceptibility:

- Vertical joints have very less susceptibility



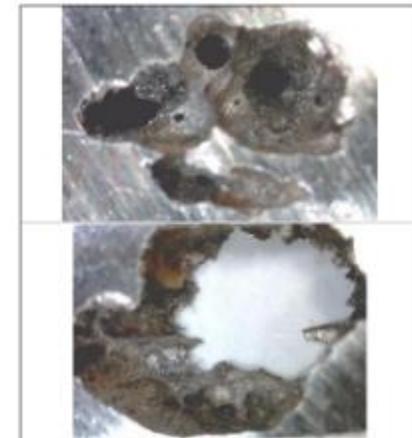
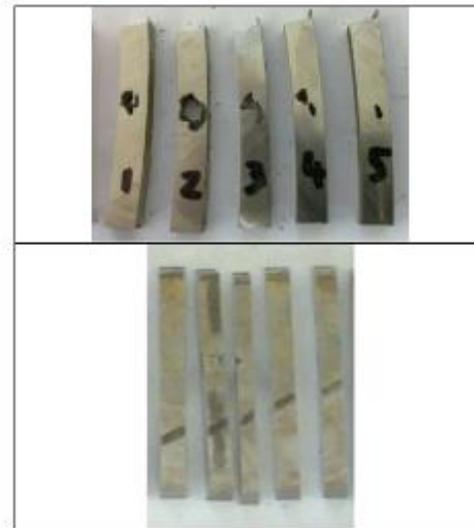
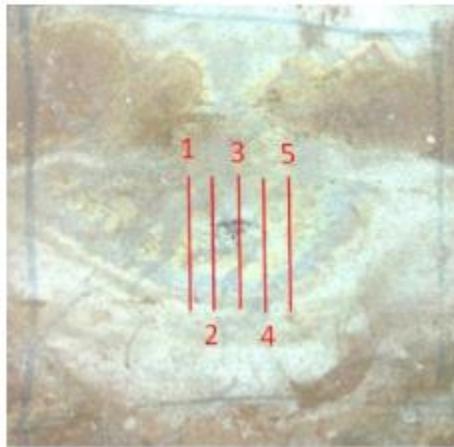
Sample Inspection Findings



- 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)



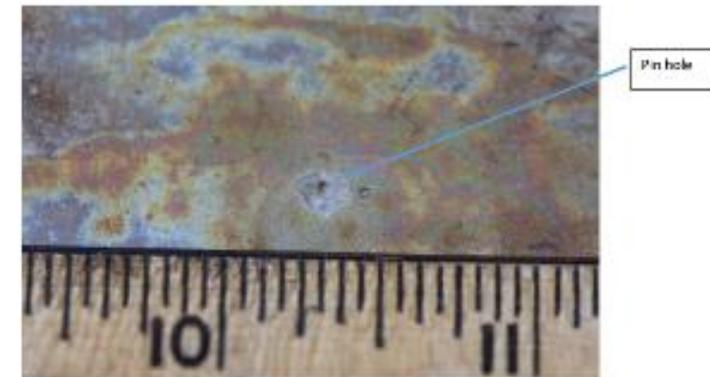
MIC Samples



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
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Thank You...



Any Questions...