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Internal SCC in Ethanol Pipelines

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Introduction

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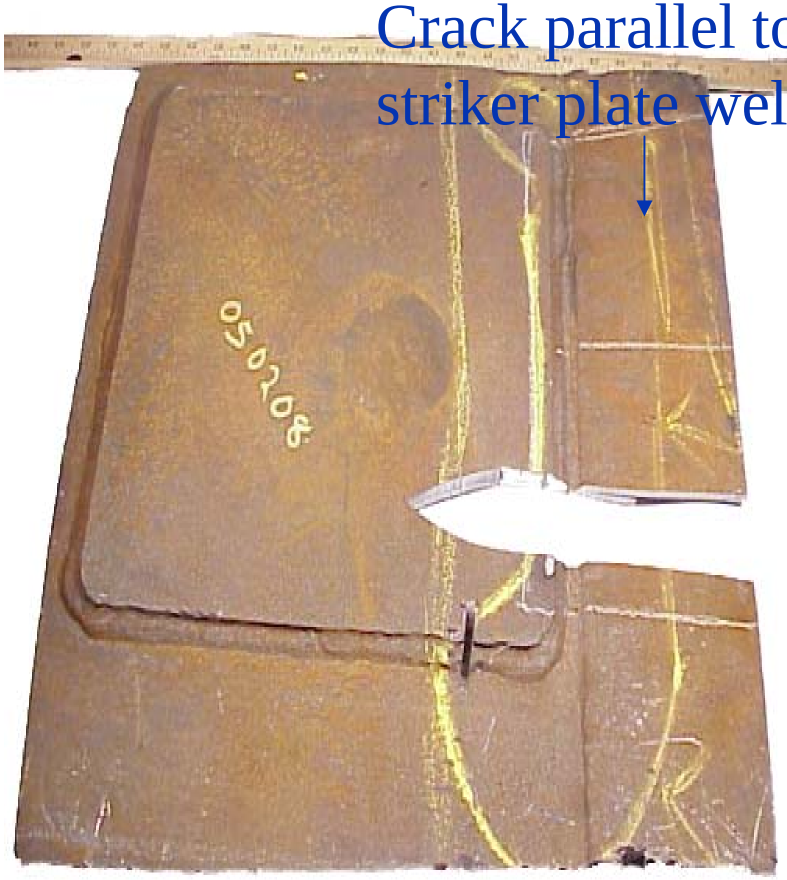
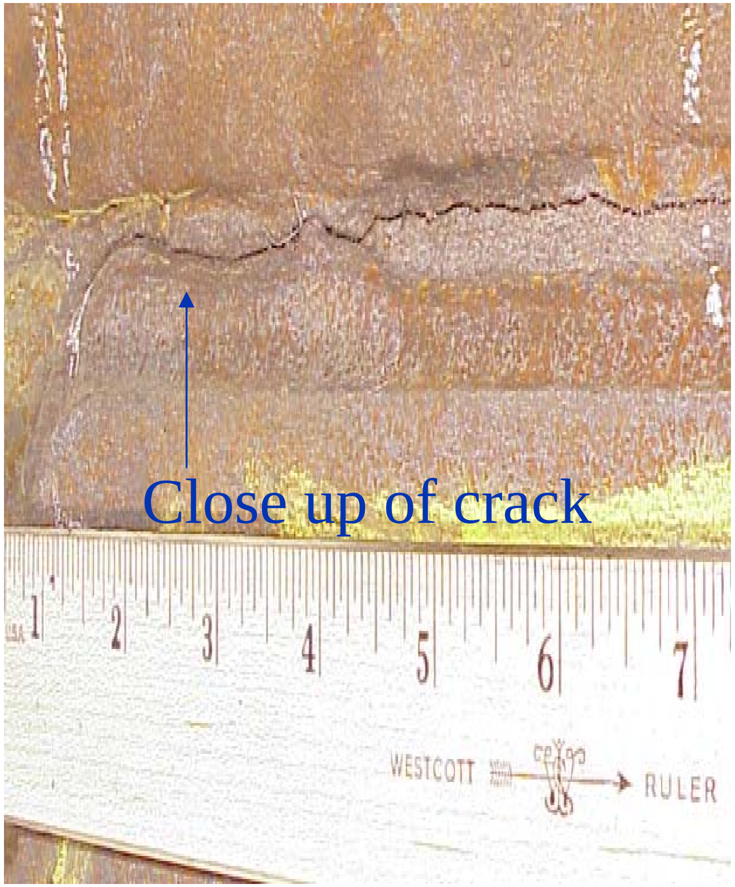
- Significant interest within pipeline industry in transporting fuel grade ethanol
  - Oxygenating agent for gasoline
  - Alternative fuel for motor vehicles
- Ethanol now transported to blending/distribution facilities
  - Tanker trucks
  - Rail cars
  - Barges
- Increased usage of ethanol has prompted the need for alternative, economical means of transporting ethanol
- Pipeline transportation is likely candidate but there are concerns with respect to corrosion / stress corrosion cracking

Background

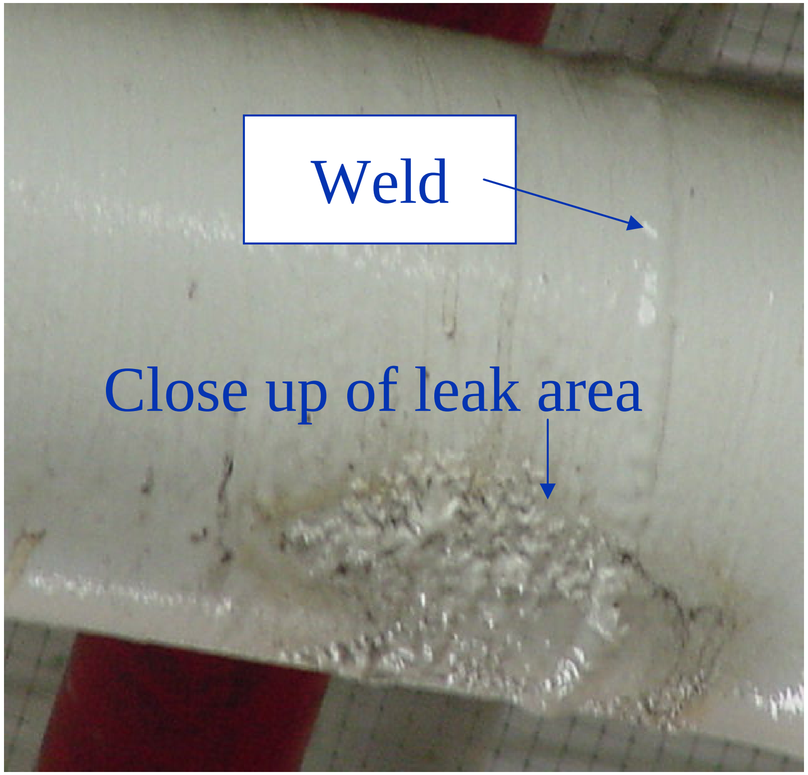
- Prior to shipment, ethanol is denatured & inhibited
  - Natural gasoline is most common denaturant
  - Octel DCI-11 is most common inhibitor for general corrosion
- At blending/distribution facilities, large tanks and piping facilities are used for blending operation and for storage
- SCC has been observed in carbon steels in contact with fuel grade ethanol
- Failures documented back to early 1990s
  - User terminals
  - Storage tanks
  - Loading/unloading racks
- No failures at ethanol producer sites nor after ethanol was blended with gasoline

Cracked Bottom Plate - Tank

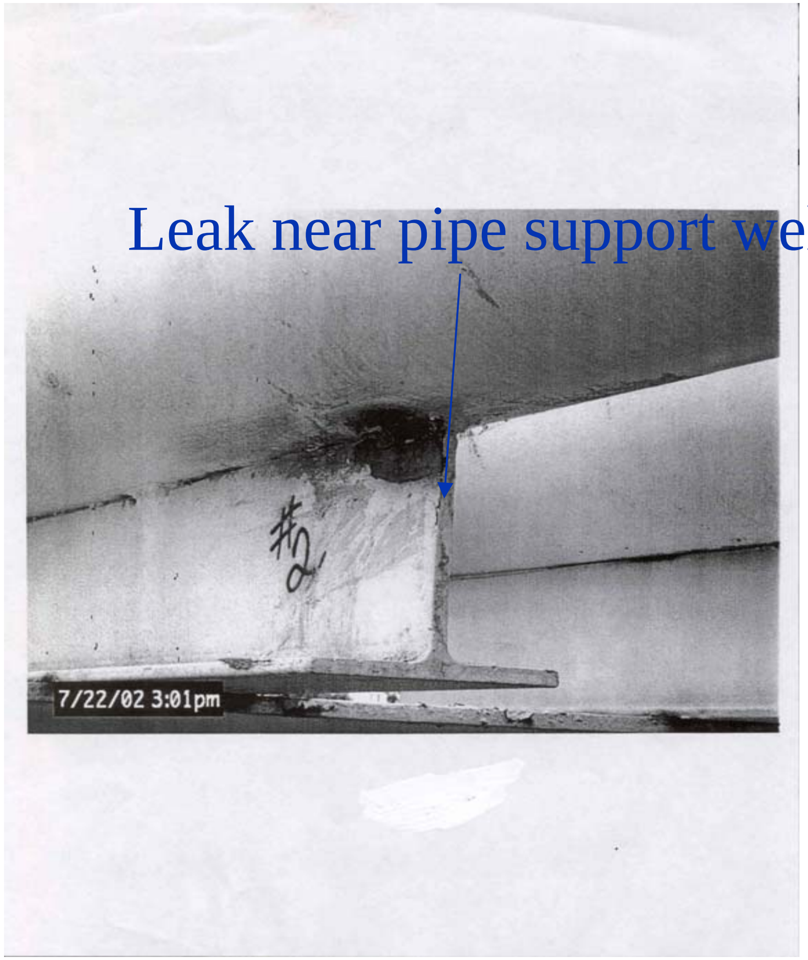


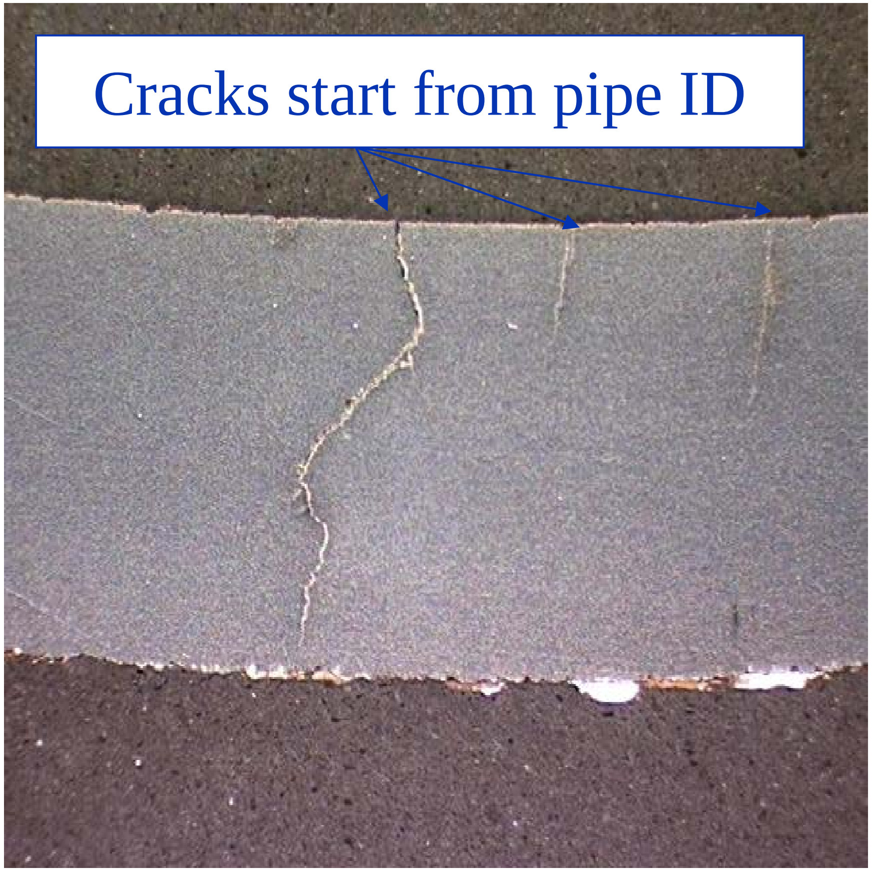


Piping Failures in Terminals



Piping Failures (Cont'd)





Background

- API Technical Report [939-D (2003)] provides a review and summary of ethanol SCC of carbon steel
  - Published literature
  - Service experience
- All occurrences of SCC were in first major hold point or downstream
  - Fuel ethanol distribution terminal
  - Subsequent gas blending or distribution terminals
- Majority of cracking found at welds
  - In base metal and HAZ of welds
  - Primary stress leading to SCC is residual welding stresses
- No cases reported in:
  - Manufacturer facilities or other transport facilities directly following blending
    - Tanker trucks
    - Railroad cars
    - Barges

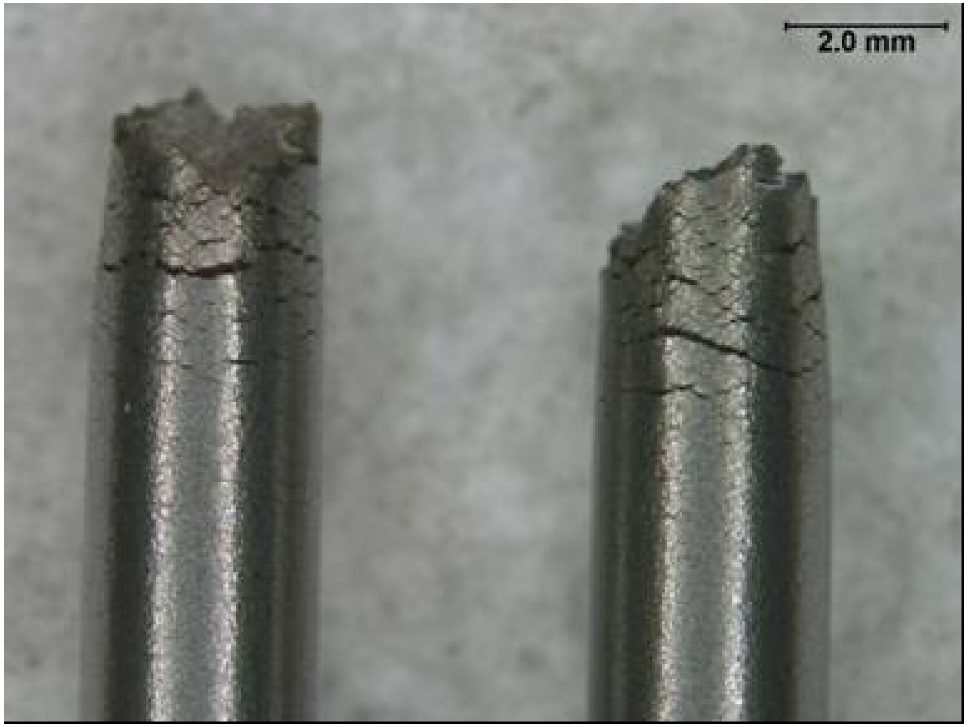
Prior Research Results

- PRCI and API funded research on the roles of chemistry and steel properties on ethanol SCC
  - Fuel grade ethanol that meets ASTM standards is a potent cracking agent
  - Dissolved oxygen concentration is a primary contributing factor in cracking
    - Reflected in potential dependence of cracking
  - Chloride was found to exacerbate cracking and affect cracking mode
    - Intergranular SCC with low Cl (<1 ppm)
    - Transgranular SCC with high Cl (>35 ppm)
  - Testing was inconclusive with respect to relative susceptibility of different line pipe steels

Prior Research Results

- Factors having some effect
  - Coupling to corroded steel
  - Presence of methanol
- Factors that had a minimal effect on SCC
  - Type of Denaturant
  - Acidity within specifications
  - Water content from 170 ppm to 2%
  - One standard inhibitor for general corrosion (Octel DCI-11)

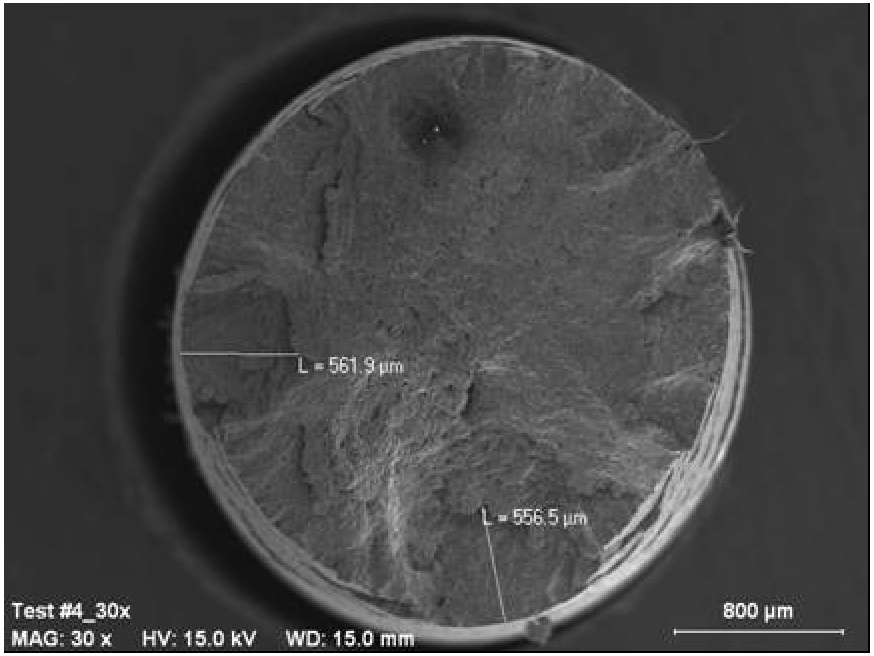
Slow Strain Rate Test Results



Severe SCC

(Aerated Simulated FGE)

Slow Strain Rate Test Results



Aerated SFGE

SCC Crack Depth Measurements

Slow Strain Rate Test Results

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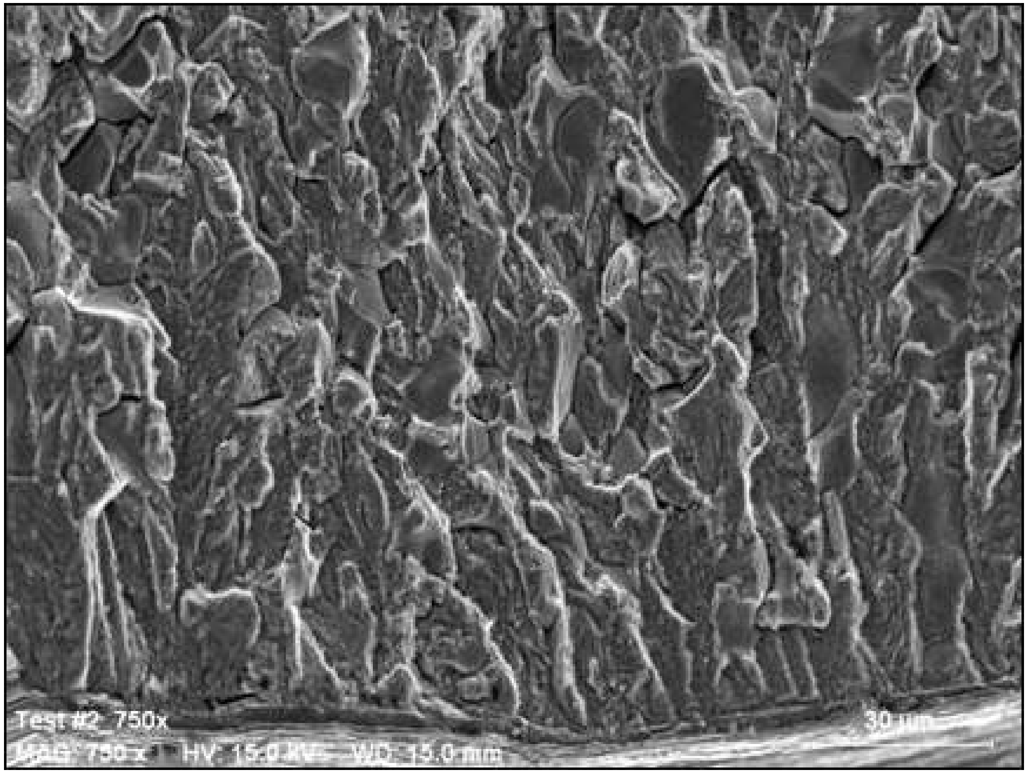

Mixed mode SCC in aerated SFGE

Recent PRCI Research Findings

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- Limited success with constant load tests in laboratory
- SSR test technique very effective for evaluating environmental effects
- Corrosion potential generally good cracking indicator
- SCC mitigation
  - One inhibitor and one oxygen scavenger identified in recent PRCI research
    - Di-ethanol amine (DEA)
    - Hydrazine
  - Three non chemical means of oxygen scavenging identified
    - Mechanical deaeration
    - Corrosion reactions (steel wool)
    - Nitrogen deaeration
- E-85 fuel potent cracking agent
- Batching with diesel fuel not shown to inhibit SCC in SSR tests

Recent PRCI Research Findings

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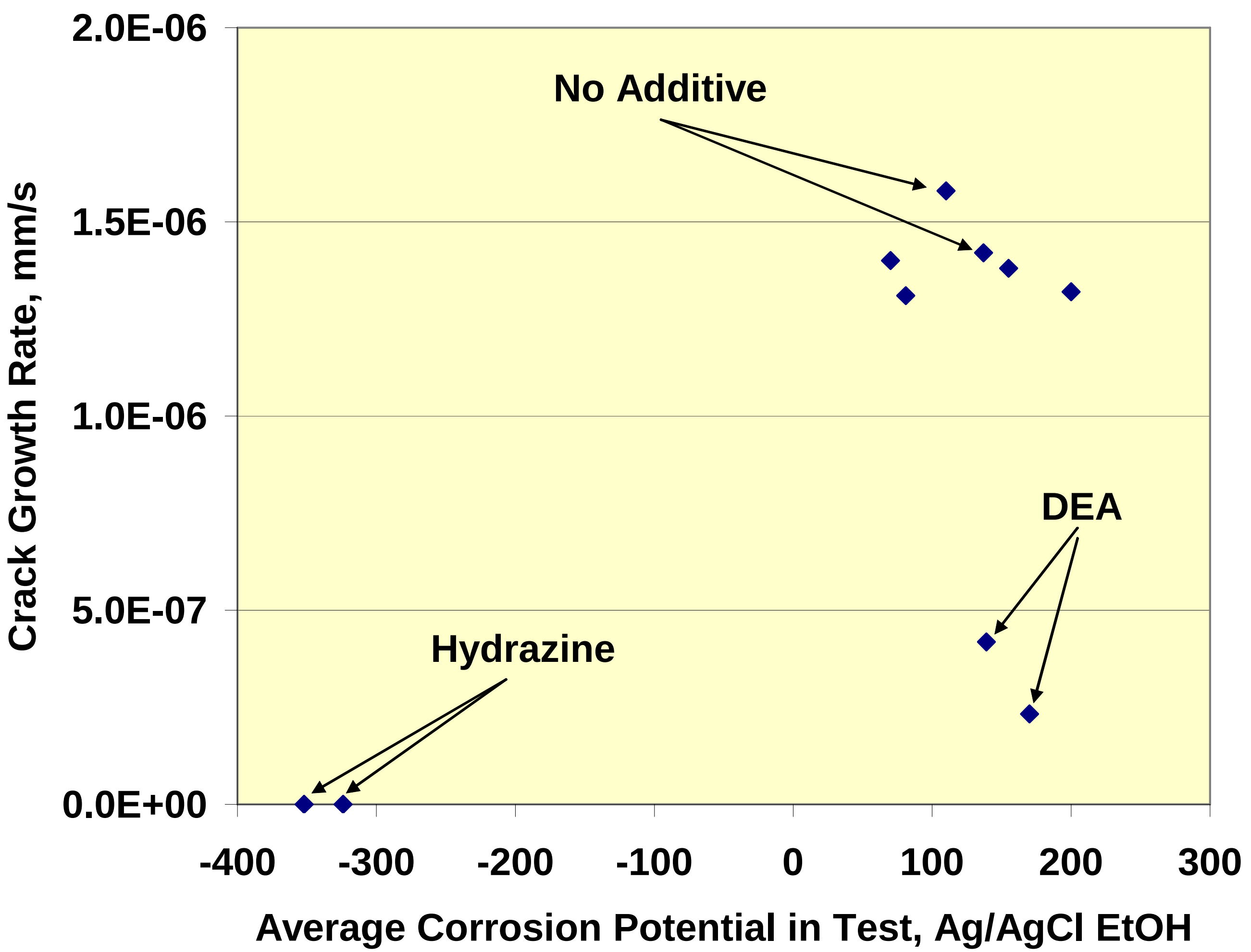

Recent PRCI Research Findings

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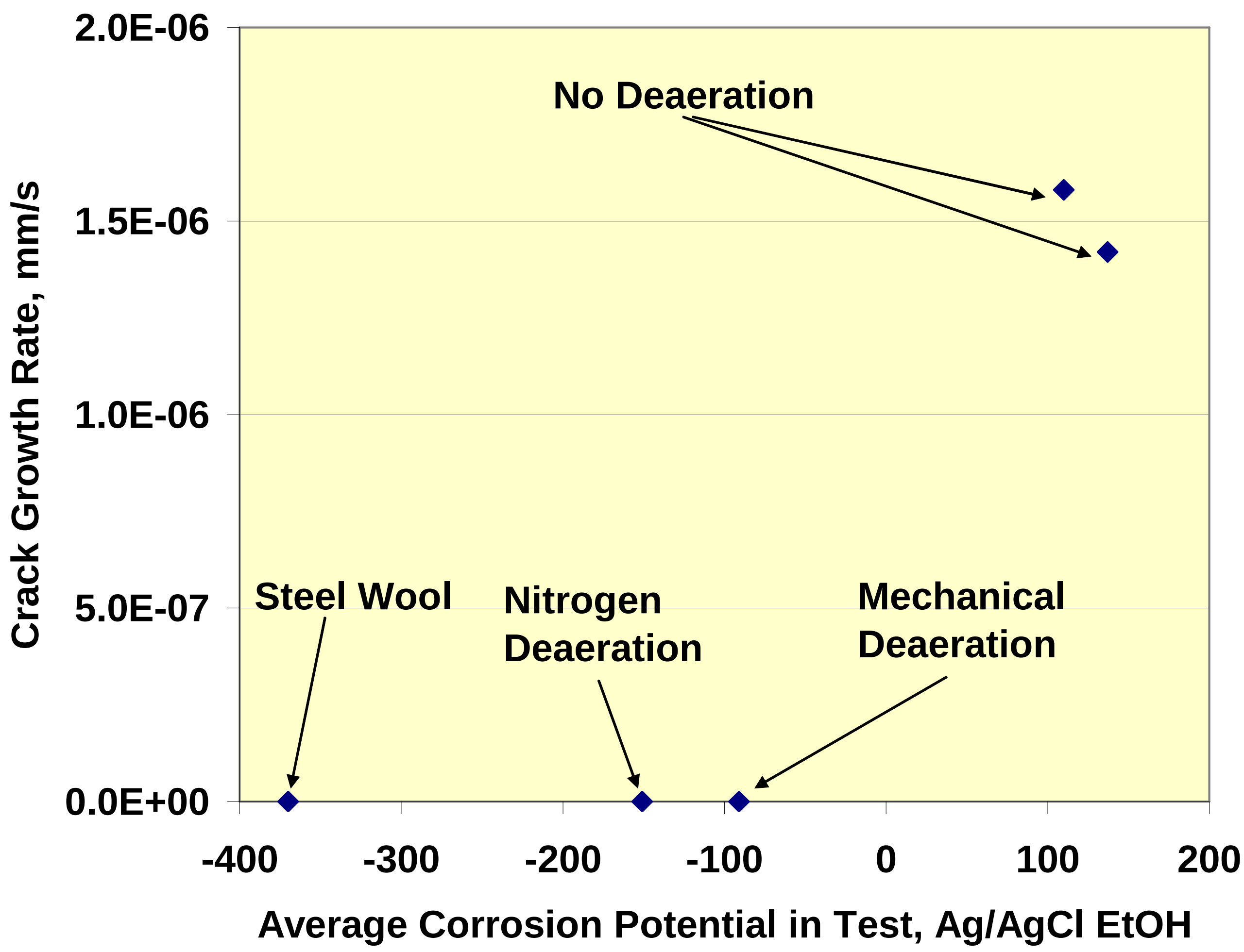

Other Recent Research Findings

- SCC potency of ethanol-gasoline blends decreases with increasing gasoline concentration
- SCC potency of FGE decreases with decreasing oxygen concentration
- Considerable variability in potency of actual FGE
- Evidence that FGE contains natural inhibitors that degrade with time

Objectives of New Research Programs

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- PRCI SCC 4-4
  - Identify FGE blends that can be transported in pipelines
    - Case 1 – Blends that do not require significant modifications of systems and operations
    - Case 2 – Blends that require significant modifications but can be transported in existing systems
    - Case 3 – Blends that require specially designed systems
  - Characterize the time to initiation of SCC in a range of potent FGE environments
    - Identify operating and batching practices that prevent SCC initiation and growth

Objectives of New Research Programs

- PRCI SCC 4-3
  - Design laboratory experimental procedures to better implement various mitigation strategies
    - Inhibitors
    - Oxygen scavengers
    - Other methods of oxygen scavenging
  - Estimate the types and concentrations of chemical treatment required for effective performance.
  - Establish protocols for non-chemical treatment methods
    - Volumes and flow rates for gaseous deaeration
    - Vacuum-time behavior for vacuum deaeration
  - Assess cost effectiveness of scale-up of mitigation methods
  - Assess end-user acceptance of mitigation methods and implications of post transportation issues
  - Develop field procedures to establish effectiveness of mitigation methods

Questions?

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