Stress Corrosion Cracking of Stainless Steel - Where Next?

David Alley

6 June 2013
Agenda

• Introduction
• Common Knowledge
• Interesting Events
• Potential Lessons
• Where to look next?
Introduction

• Will consider 300 series stainless
  – Environmental conditions leading to cracking
  – Cracking morphology
Common Knowledge
Common Knowledge

• Cracking environments
  – Chlorides (halides)
    • Maybe others (sulfates)
  – Oxygen needed
  – Temperature > 140°F
  – BWR normal water chemistry
    • Very low chlorides if any
  – Grade makes little difference in Cl⁻ cracking
  – Cold work makes cracking worse
Common Knowledge

• Cracking morphology
  – Sensitized
    • Intergranular cracking
  – Unsensitized
    • Normally transgranular cracking
Common Knowledge
Interesting Events
Interesting Events

• Canopy Seal Welds
• CRDM Seal Housing J Groove Welds
• CRDM Housing Welds 3 and 5
• Refueling Water Storage Tanks
• Reactor Vessel Leak Off Lines
• OD Pipe/Vessel Cracking
Canopy Seal Welds

- 5 Plants
- Base metal and weld
  - 304/308/309
- Transgranular
- Cl\(^-\) verified
- High oxygen assumed
- Various housing types
- High stress
CRDM Seal Housing

- One Plant
- Rack and Pinion Housing
- Multiple failures
- 304 and 347
- Transgranular
- Lower temperature
- Low flow area
- Cl\(^-\), O\(_2\) assumed
CRDM Housing Weld 3 and 5
CRDM Housing Weld 3 and 5

- Two plants
- Three failure occurrences
- Rack and Pinion Housings
- 40 + housings replaced
- 316, 347, 348
- $\text{Cl}^-, \text{O}_2$ assumed

- One dead leg
- One low flow
- Transgranular
  - Beach marks
- One instance
  - Manufacturing issues
    - Affected stresses
    - Voids at crack initiation
    - $\text{F}^-$ containing flux?
CRDM Housing Weld 3 and 5

Void at crack initiation

Beach Mark
Refueling Water Storage Tank

- Chloride SCC
- OD originated
- Temp probably < 140°F
Reactor Vessel Leak Off Lines

• Both OD and ID cracking
• ID cracking
  – At “water level” in line
  – Oxygen and Chlorides assumed
• OD cracking
  – Lines used as handrails
    • Chlorides from sweaty skin
• Not necessarily at welds
OD Pipe/Vessel Cracking

- Chlorides in air
- Chlorides on hands
- Not necessarily at welds
  - Info Notice IN-2011-04
- Can occur below dew point (Hygroscopic)
- Temperature < 140°F
- Dry Cask storage
  - Info Notice IN-2012-20
Potential Lessons
Potential Lessons

• Sweaty hands cause cracking
• Cl\(^-\) deposition from the air causes cracking
• Cracking will occur < 140\(^\circ\)F in air environments
• Cracking not limited to welds
• Stresses/strains including weld residual stress and cold work accelerate cracking
• Temperature accelerates cracking
Potential Lessons

• Cracking occurs in PWRs
  – Dead legs help but not required
  – Reduced flow, $O_2$, contaminants required?

• Attempts to call a location or environment “special” have fared poorly in light of history
Where to Look Next?
Where to Look Next?

• All CRDM housings (not just rack and pinion)?
  – All welds (not just pressure boundary welds)?
  – Base material?

• Vessel internals out of main flow?

• Dead leg piping (especially if $O_2$ enters during outages)?
Where to Look Next?

• Outdoor stainless material
  – Near coastlines etc.? 
  – Exposed to dicing salts? 
  – Exposed to saline groundwater? 
  – Below 140°F? 
  – Welded with F⁻ containing flux?