Marine Atmosphere Stress Corrosion Cracking (SCC)

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Protecting People and the Environment

The Potential for SCC of Dry Storage Canisters

- Operational Experience: Examples of where chloride-induced SCC of austenitic SS components have occurred under ambient conditions.

- NRC Research: Indicates the potential for atmospheric SCC in dry storage canisters.

- NRC Licensing: How the potential for atmospheric SCC needs to be addressed by applicants during each licensing period (initial, renewal, extended).

The Potential for SCC of Dry Storage Canisters

Material

304, 304L, 316 or 316L austenitic stainless steel.

Tensile Stresses

Residual weld stresses.

Environment

Some ISFSIs are close to salt or brackish water.

Above ambient temperatures for long time periods.

Operational Experience with SCC

St. Lucie Unit 2 – April, 1999[a]

- Leaking of 304 SS piping in refueling water storage tank trench exposed to atmosphere
- ~16 years in service (Unit 2 commissioned 1983)
- Branched through-wall cracking initiated on pipe OD
- 24” diameter, ¼” wall piping, 30 psig at 120°F (49°C)
- Indications more severe at field welds

Turkey Point Unit 3 – April, 2005[b]

- Flaw in 304 SS spent fuel pool cooling line attributed to chloride-induced SCC
- Initiated on pipe OD, at base of a pit
- Piping housed in room with grating steel door open to outside
- Indication ½” from flange butt weld, near weld

a. LER 389-1999-003: “ECCS Suction Header Leaks Result in Both ECCS Trains Inoperable and TS 3.0.3 Entry,” ADAMS Legacy Library Accession Number 9905130085.

b. L-2005-168: “10 CFR 50.55a Request for Temporary Non-Code Repair,” ADAMS Main Library Accession Number ML052780060.

Operational Experience with SCC

Koeberg Units 1 and 2 (South Africa)

- Cracking in 304L piping connected to tank exposed to outdoor environment[a]
  - Extensive crack networks initiating from surface pits
- Cracks in 304L contaminated boric acid storage tanks[b]
  - Primarily in areas adjacent to welds
  - Water maintained between 7 and 40°C
  - <30 years in-service
  - Fabricated to ASME Code, Section III, Subsection NC

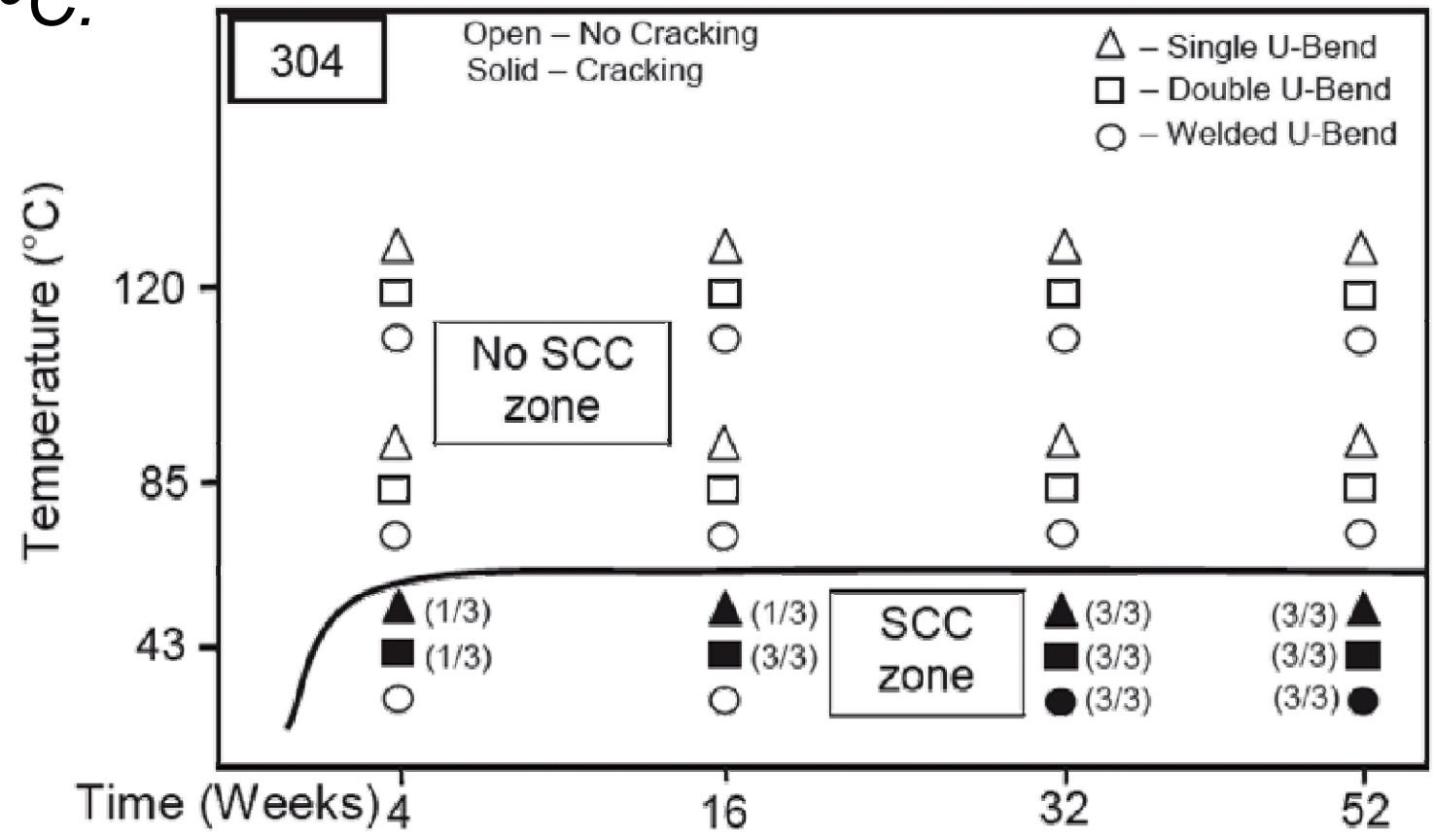
a. M. van Dalen, C. Wicker, G. Wilson, "Non Destructive Testing of Materials Subject to Atmospheric Stress Corrosion Cracking," 17th World Conference on Nondestructive Testing, Shanghai, China, 2008.

b. D. Alexander, P. Doubell, C. Wicker, "Degradation of Safety Injection System and Containment Spray Piping and Tank Fracture Toughness Analysis. Fontevraud 7, Sept 26 – 30, 2010.

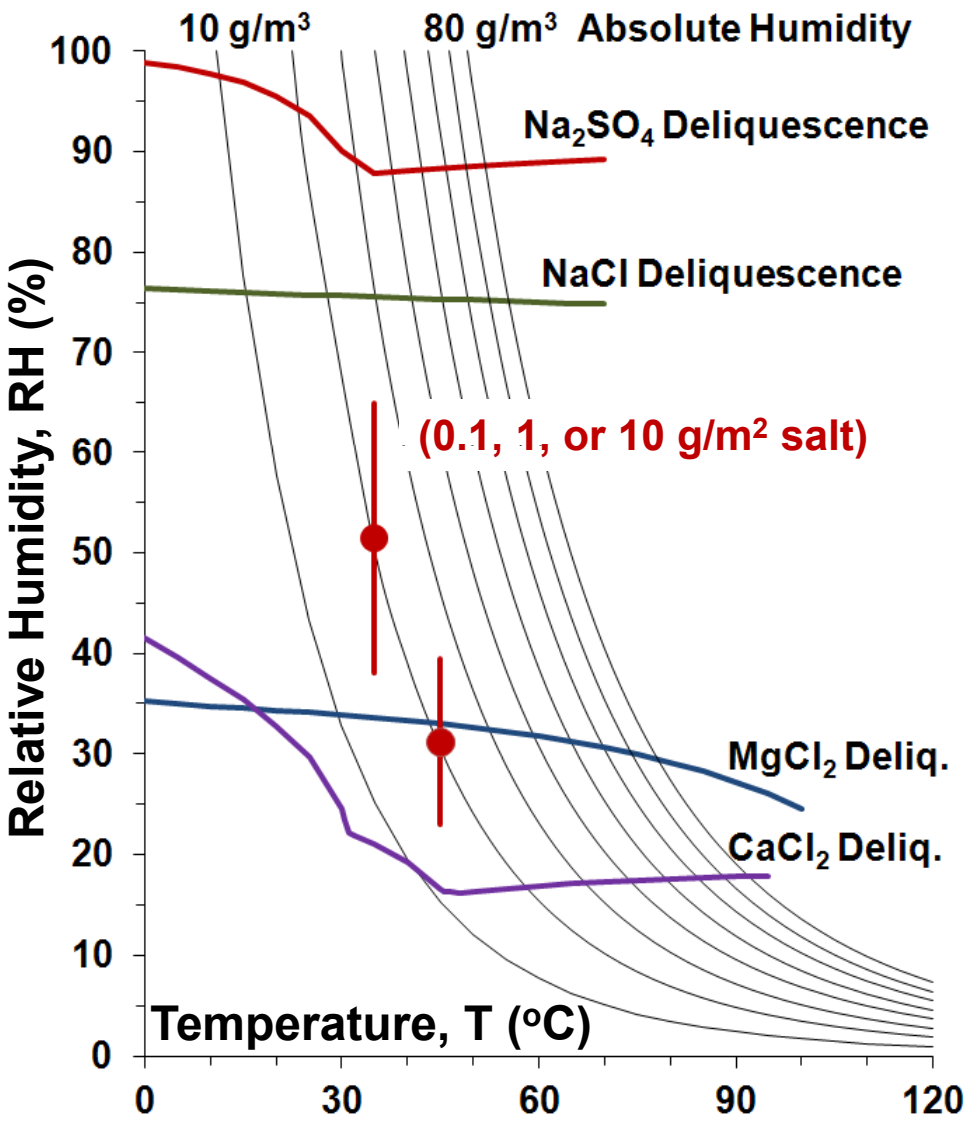
NUREG/CR-7030 Testing

NUREG/CR-7030 determined that SCC can occur under bounding conditions in a salt fog test.

All tested samples (304, 304L, and 316) cracked at 43°C.



Ongoing EST Research Program at CWRNRA



Determine salt concentration limit for SCC

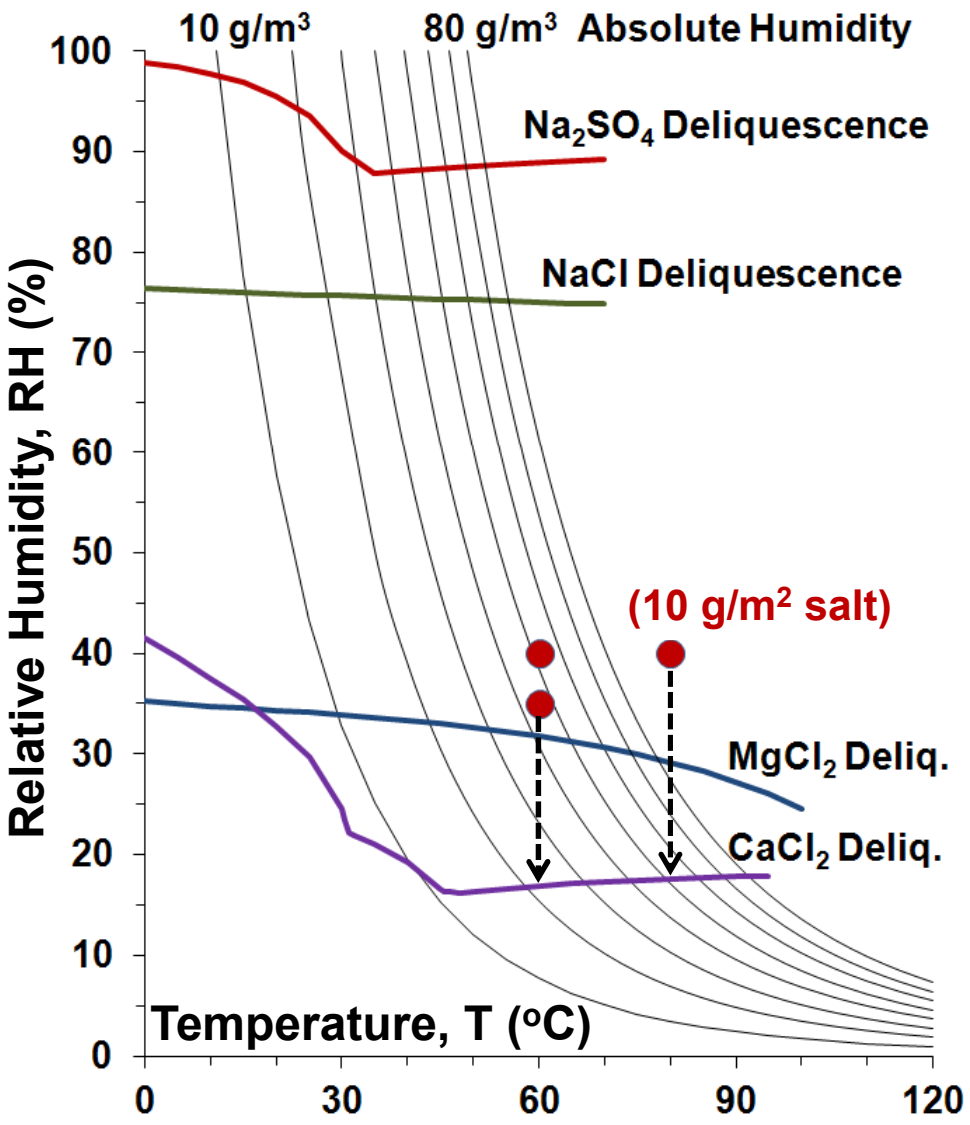
- Within 3 months, as-received and sensitized specimens with 1 or 10 g/m^2 salt showed intergranular cracking.

- No welded specimens have cracked yet, but there may be interdendritic attack (signs of pre-cracking).

- Some specimens with 0.1 g/m^2 salt at 35°C show minor pitting.

- Cracking earlier and is more extensive for specimens at 35°C compared to 45°C.

Ongoing EST Research Program at CWRNRA



Determine upper temperature limit for SCC

U-bend specimens coated with 10 g/m^2 salt.

- 60°C and 40% RH. Cracking occurred.
- 80°C and 40% RH. Cracking may be occurring.
- 60°C and 35% RH. Testing underway.

Deliquescence of sea salt is near that of $MgCl_2$

Safety Issues
Initial Licensing, Renewal, EST

- Loss of confinement integrity
  - Loss of helium and radionuclides
  - Oxidation and/or splitting of fuel cladding
  - Concern during retrieval and transfer of fuel

- Failure times and likelihoods are unknown
  - Relevant examples of chloride-induced SCC in austenitic SS are known
  - No direct monitoring of canister integrity
  - Further assessment of canisters is needed

The View Ahead

- Operational experience shows SCC of austenitic SS components caused by atmospheric chloride exposure.

- NRC research programs indicate the potential for atmospheric SCC in dry storage canisters. This potential needs to be addressed during each licensing period (initial, renewal, extended).

- Industry should provide the necessary information for the actual conditions of canisters in the field and may need to develop qualified procedures and acceptance criteria for SCC on dry storage canisters

- The onus is on licensees to provide the licensing and safety bases for safe operation of canister systems operating in potential chloride environments. NRC expects licensees to address this issue in a timely manner. NRC is, in parallel, conducting research to inform our evaluations of the technical bases and approaches developed by industry.

Questions and Answers