U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

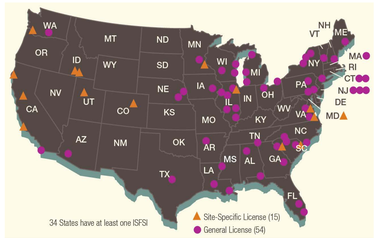
RIC 2014

Office of Nuclear Regulatory Research

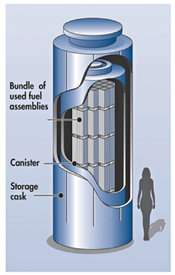
NRC Testing and Analyses on Stress-Corrosion Cracking of Dry Cask Storage System Canister Materials

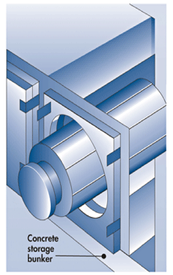
Overview

- Spent nuclear fuel is kept at dry storage facilities throughout the United States.
- Many dry cask storage systems consist of a welded austenitic stainless steel canister inside a shielding or overpack structure.
- The shielding structure is externally vented to allow airflow for cooling. Particulates or other airborne atmospheric species could deposit on the canister.
- The NRC has evaluated the potential for atmospheric species, such as chlorides in marine environments, to cause stress-corrosion cracking (SCC) of the austenitic stainless steel canisters.
- The NRC Office of Nuclear Regulatory Research sponsored a research program at Center for Nuclear Waste Regulatory Analyses to evaluate parameters that could affect SCC susceptibility, such as temperature, humidity, salt concentration, and stress level.



Licensed Spent Fuel Storage Facilities in the United States





Typical Dry Cask Storage System Designs

Photograph of Vertically-Oriented Cask Systems

SCC Testing

- SCC is thought to occur in conditions of high relative humidity (RH) when salt or other species can deliquesce, or absorb moisture from the air to form a corrosive brine.
- Sensitized and as-received Type 304 stainless steel U-bend and C-ring specimens were deposited with different quantities of sea salt and exposed to various temperatures between 27 and 80°C [81 and 176 °F] and RH between 10 and 90%.

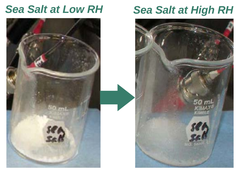
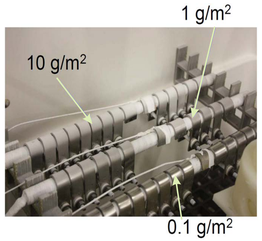


Illustration of Sea Salt Deliquescence

Sea Salt Composition (Weight Percent)				
NaCl	$MgCl_2$	Na_2SO_4	$CaCl_2$	Others
58.5	26.5	9.8	2.8	2.4



U-bend Specimens Deposited with Different Sea Salt Quantities, Specimen Strain ~14%

C-ring Specimens, Specimen Strain ~0.4 – 1.5%

Effect of Salt Concentration

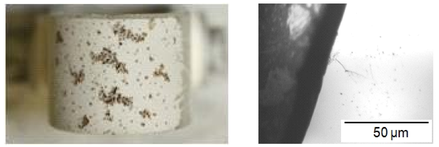
- U-bend specimens with surface salt concentrations of 0.1, 1.0, and 10 g/m^2 were cycled 4x/day between 10 and 30 g/m^3 absolute humidity (AH) at various temperatures between 27 and 60 °C [81 and 140 °F].
- SCC initiation was seen at salt concentration as low as 0.1 g/m^2.

Pitting on Specimens at (Top) 10 g/m^2, (Middle) 1 g/m^2, and (Bottom) 0.1 g/m^2 Sea Salt

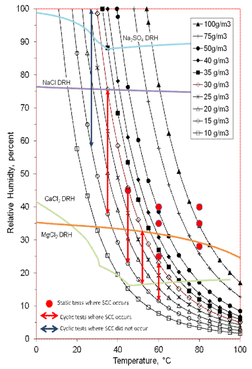
Cracking on Specimen at 45 °C [113 °F] at 0.1 g/m^2 Sea Salt

Effect of Temperature

- Cyclic or static humidity tests were performed at temperatures up to 80 °C [176 °F].
- SCC was observed when the RH was above about 25%.
- Susceptibility appears to increase with decreasing temperature because RH is higher for given absolute humidity.

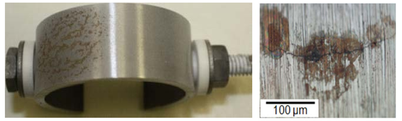


Specimens at 80 °C [176 °F] and 35% RH



Effect of Strain

- C-ring specimens were strained to 0.4 or 1.5%, deposited with 1 or 10 g/m^2 of sea salt, and exposed at 35, 45, and 52 °C [95, 113, and 126 °F] .
- SCC was seen on some specimens with as low as 0.4% strain.



Specimen with 0.4% Strain and 1 g/m^2 Sea Salt Exposed at 52°C [126 °F]

Summary

- Austenitic stainless steel may be susceptible to SCC caused by deliquescence of chloride-rich salt. The salt chemistry will affect the degree of susceptibly.
- For tests with Type 304 stainless steel and simulated sea salt, SCC was observed at RH above about 25% at temperatures of 80 °C [176 °F] and lower.
- SCC initiation was observed at sea salt surface concentration as low as 0.1 g/m^2 or specimen strain as low as 0.4%.

Caution: The NRC does not use modification code stickers. You must not scan or use a QR code if it appears to be manipulated or modified in any way or appears not to be part of the original printing of the material.