Sea Salt Deposition on the Canister Surface of Concrete Cask

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ISSF2010 in CRIEPI (Komae)
Background

Location of nuclear power plants in Japan

Mutsu
Fukushima Daiichi NPP
Tokai No.2 NPP

Transport of the sea salt particle

Concrete Cask

Storage Facility
Natural Cooling
Concrete Overpack
Canister
Sea Salt Particle

Wind
Sea

Sea Salt Particle

Concrete Cask

Welding of Lids
Welding of Bottom Part

Exhaust Air
98°C

Inlet Air
33°C
0.8 ~ 1 m/s

Temperature (℃)
Height (mm)

22.6kW
16kW
10kW
Bottom of the Canister
Top of the Canister

Location of nuclear power plants in Japan
Stress Corrosion Cracking

Environment

Stress

Material

Stainless steel

Deposition of sea salt particles

Deliquesce of sea salt

Rust

Pitting or crevice corrosion

Crack occurs around weld

Residual stress of Weldment
Specify the storage system
- Facility (Structure, Salt intrusion rate)
- Cask (Structure, Material, Spent fuel)

(a) Salt density critical to initiate SCC
(b) Salt density that deposit on canister

(a) > (b) No

- Decrease the salt deposition
- Utilize corrosion resistive material

Yes

Completion
Objectives

- To Evaluate the amount of deposition on the canister surface during the interim storage
- To obtain the experimental data of the deposition on the metal surface
State of the Art

CRIEPI in Yokosuka

(Distance from the seashore 50m)

Equivalent Salt Deposit Density (mg/cm²)

0.01 0.1 1 10 (g/m²)

Measurement Data of Salt Deposition on the bridge piers

Distance from the sea (m)
State of the Art

1 mdd = 1 mg/dm²/day = 0.1 g/m²/day

Measurement Data of Salt Deposition by Gauze Method (May 2004 - April 2005)
(1) The temperature of the canister surface is hot.
(2) The surface of the deposition is vertical.
(3) The cooling air including the sea salt particles goes upward in parallel with the canister surface.
(4) The concrete cask is placed in a building and the canister surface is not exposed to wind and rain.
(5) Because the radiation dose is very high near the canister surface and the gap between the canister surface and the concrete container is very narrow, it is difficult to measure the amount of the deposition and check the surface condition.
Chloride Deposition Velocity Test (Test equipment)

- Cross Section of the Wind Tunnel: 400 × 400mm
- Test Piece
  - Size of the Piece: 75 × 75 × 2mm
  - Number: 10
- Nozzle
- Blower
  - 6m
Particle Observation in the Wind Tunnel (Immersion Method)

Size of Salt Particle: 31μm (Test)  
~30μm (Measurement near the Sea)

Salt Concentration in the Air: ~16mg/m³ as NaCl (Test)  
~60μg/m³ (Measurement near the Sea)
Result of Chloride Deposition Velocity Test (1)

- **Horizontal Position**
  - Gravitational Settling
  - Boundary Layer
  - Cold Plate
  - Hot Plate

- **Vertical Position**

The graph shows the deposition of the salt (mg/m² as Cl⁻) over time (hour) for various conditions:
- Horizontal, Temp. of Specimen: 30°C, Vair: 1.4 m/s
- Horizontal, Temp. of Specimen: 100°C, Vair: 1.4 m/s
- Vertical, Position: 1, Vair: 1.4 m/s
- Vertical, Position: 2, Vair: 1.4 m/s
- Vertical, Temp. of Specimen: 30°C, Vair: 0.85 m/s
- Vertical, Temp. of Specimen: 100°C, Vair: 0.85 m/s
- Vertical, Temp. of Specimen: 30°C, Vair: 0.3 m/s
- Vertical, Temp. of Specimen: 100°C, Vair: 0.3 m/s

The graph includes data points for different conditions, with symbols indicating the specific conditions and time points.
Result of Chloride Deposition Velocity Test (2)

Effect of the Temperature of the Specimen

Q_{200}: Deposition of the Salt at 200°C
Q_{100}: Deposition of the Salt at 100°C
Q_{30}: Deposition of the Salt at 30°C

Q_{200} < Q_{100} < Q_{30}

Effect of the Air Velocity

Q_{1.4}: Deposition of the Salt at 1.4 m/s
Q_{0.85}: Deposition of the Salt at 0.85 m/s
Q_{0.3}: Deposition of the Salt at 0.3 m/s

Q_{0.3} < Q_{0.85} < Q_{1.4}
Test Equipment for the Field Test in Choshi

Test Site in Choshi City

Test Equipment for the Field Test in Choshi

Japan Weathering Test Center (Choshi Site)
Test Equipment for the Field Test in Choshi

Wind Tunnel

Test Piece with Heater

Air Inlet of Test House

Salt Deposition (mg/m² as Cl) vs. Time (h)

0 2000 4000 6000 8000 10000 12000 14000

0 10 20 30 40 50 60 70 80

0 2000 4000 6000 8000 10000 12000 14000

Time (h)
Comparison between Laboratory data and Field Data

\[ Q_{in} = 5.07 \sqrt{t} \]

(30°C, 10 mg/m\(^3\))

\[ Q_{out} = 0.0892\sqrt{t} \]

(30°C, 2 μg/m\(^3\))
Transport Phenomena of Sea Salt Particle in Nature
Measurement Data of the Deposition by Gauze Method:
13.1 mdd as NaCl (Average of August)

This is not the concentration of sea salt in air.
Development of Measurement Device

Sea salt in air dissolves in this part.

Air Pump

Air Flow

Water including the sea salt

Water Pump

Electrical Conductivity Sensor

Graph showing Electrical Conductivity (mS/m) over Time (h)

- Y-axis: Electrical Conductivity (mS/m)
- X-axis: Time (h)

Graph data shows the increase and decrease of electrical conductivity over time.
Calculation Method of Concentration of Sea Salt in Air

\[
C'(x, y, z, s, H) = \frac{Q(H)}{2\pi U \sigma_y \sigma_z} \exp\left\{ - \frac{(y-s)^2}{2\sigma_y^2} \right\} \times \exp\left\{ - \frac{(H-z-V_s \frac{x}{U})^2}{2\sigma_z^2} \right\} + \exp\left\{ - \frac{(H+z-V_s \frac{x}{U})^2}{2\sigma_z^2} \right\}
\]

Number Density \( \theta_0 \) (1/m^3)

<table>
<thead>
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<th>Diameter (( \mu \text{m} ))</th>
<th>Number Density ( \theta_0 ) (1/m^3)</th>
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<tbody>
<tr>
<td>Size1</td>
<td>4.06 ( \times 10^4 )</td>
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<td>5.96 ( \times 10^4 )</td>
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<td>Size7</td>
<td>40.6 ( \times 10^4 )</td>
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</tbody>
</table>
Example of the Calculation Result

Concentration of Sea Salt in Air (g/m$^3$ as NaCl)

Amount of Sea Salt going through the gauze Area (g as NaCl)
Summary

- We obtained the experimental data concerning the amount of deposition on the metal surface in the laboratory and field test.
- To evaluate the amount of deposition on the canister surface during the interim storage, it is necessary to know the concentration of sea salt in air. We developed the measurement device and the calculation method.