CRIEPI's Studies on the SCC of the Canister for Spent Nuclear Fuel

Central Research Institute of Electric Power Industry

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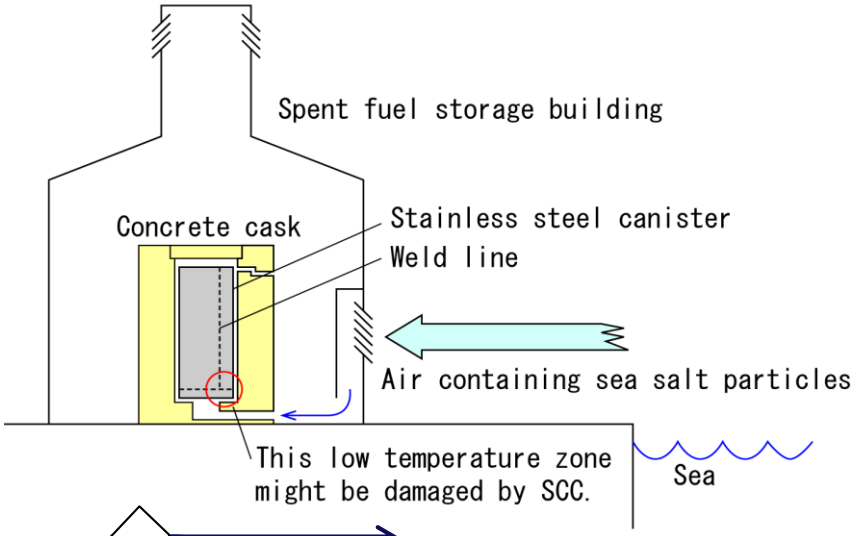
CRIEPI
Central Research Institute of Electric Power Industry

SCC of the Canister



① *Stainless steel* — *Deposition of sea salt particles*

② *Deposition of sea salt particles*

③ *Deliquesce of sea salt*

④ *Rust* — *Pitting or crevice corrosion*

Criteria I

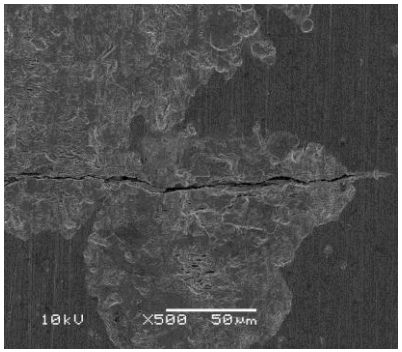
⑤ *Crack occurs around weld*

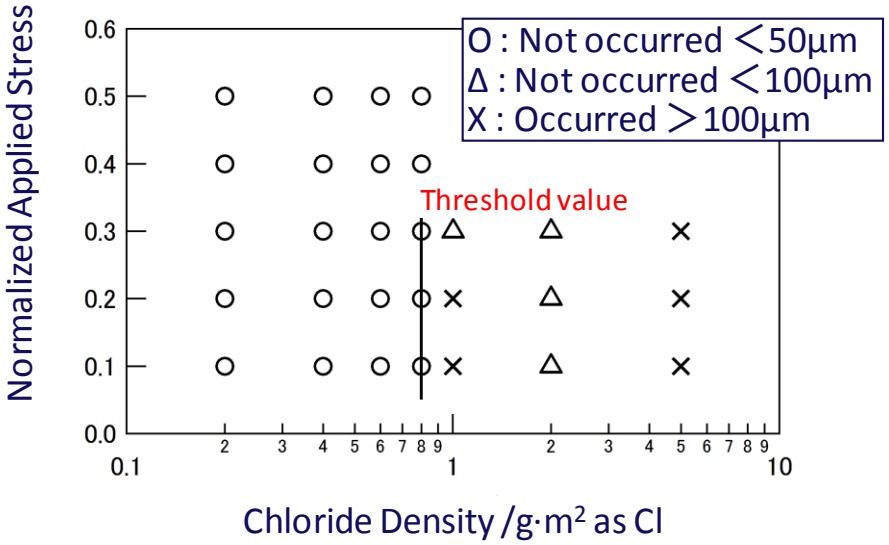
Criteria II

⑥ *Crack penetrates through the plate*

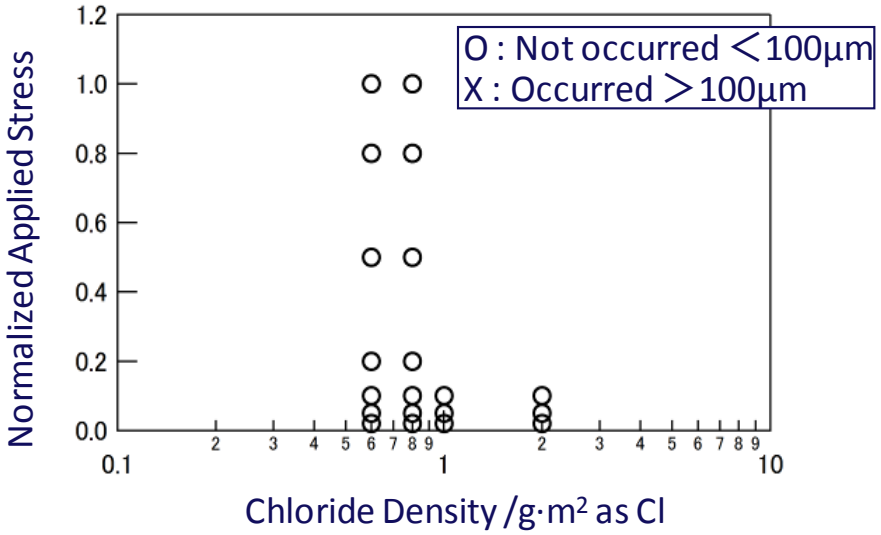
⑦ Loss of confinement

SCC Initiation Test with SUS304L





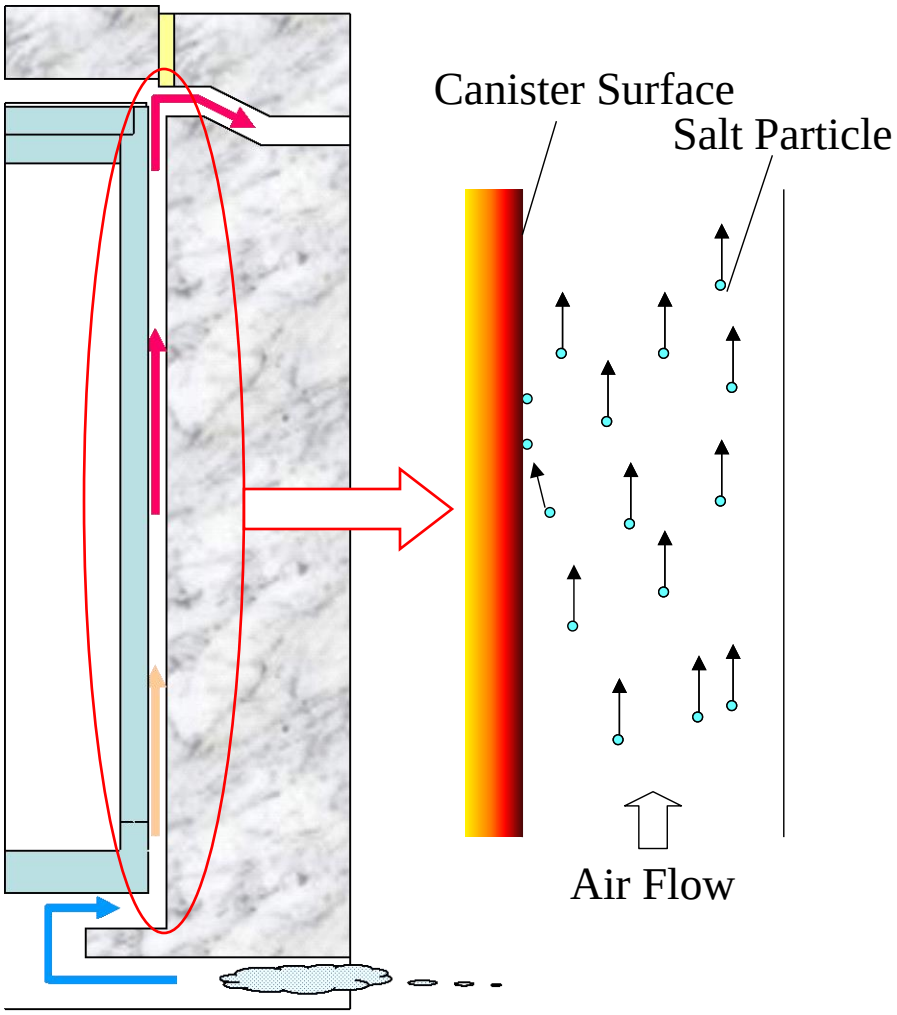
(Specimen A for 2000hr, Hardness 305Hv)



(Specimen B for 5000hr, Hardness 247Hv)

- Minimum amounts of salt for SCC initiation should be set to 0.8g/m^2 as Cl

Salt Deposition on the vertical Surface



(1) The temperature of the canister surface is hot.

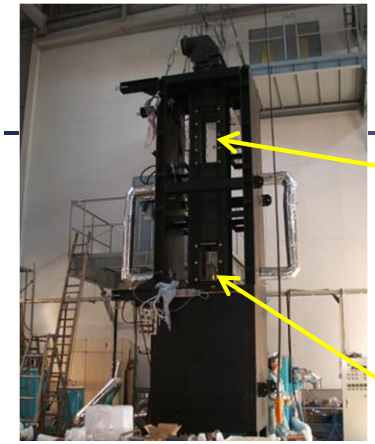
(2) The surface of the deposition is vertical.

(3) The cooling air including the sea salt particles goes upward in parallel with the canister surface.

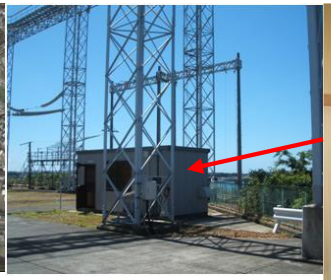
(4) The concrete cask is placed in a building and the canister surface is not exposed to wind and rain.

(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.

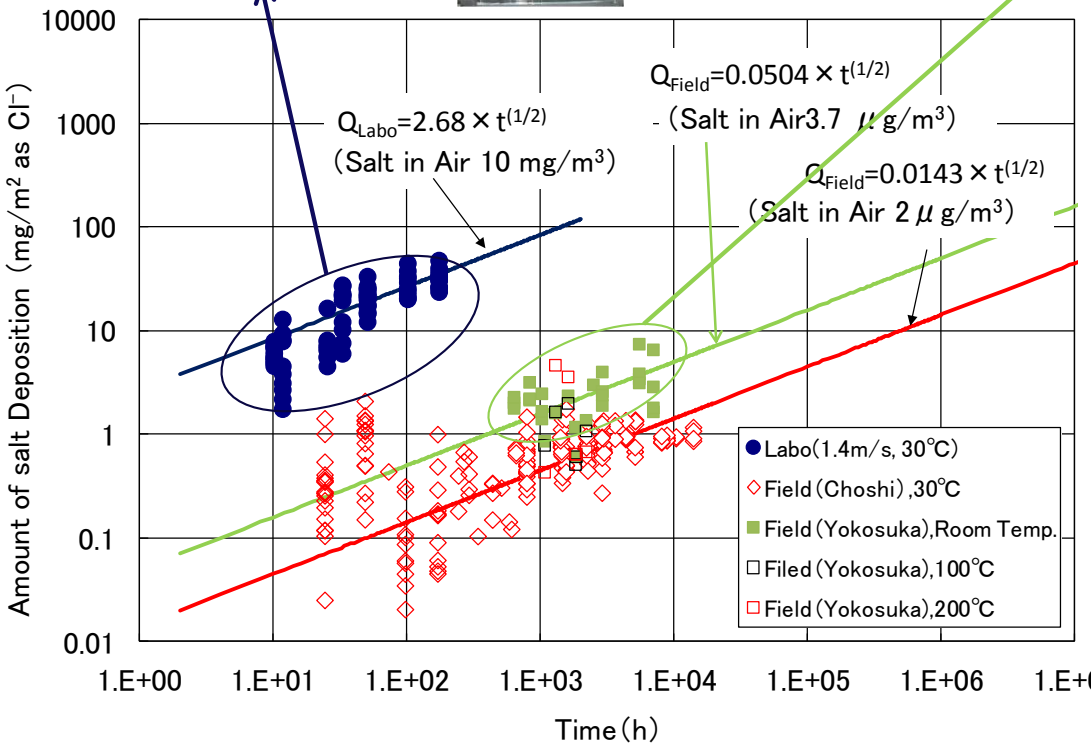
Salt Deposition Test on the Metal Surface

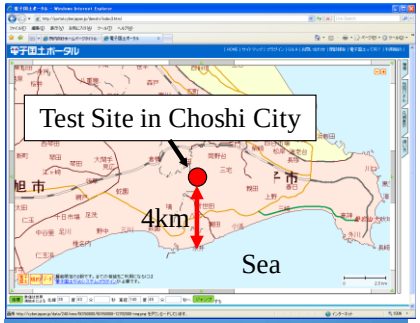


Laboratory Test



Field Test (Yokosuka)

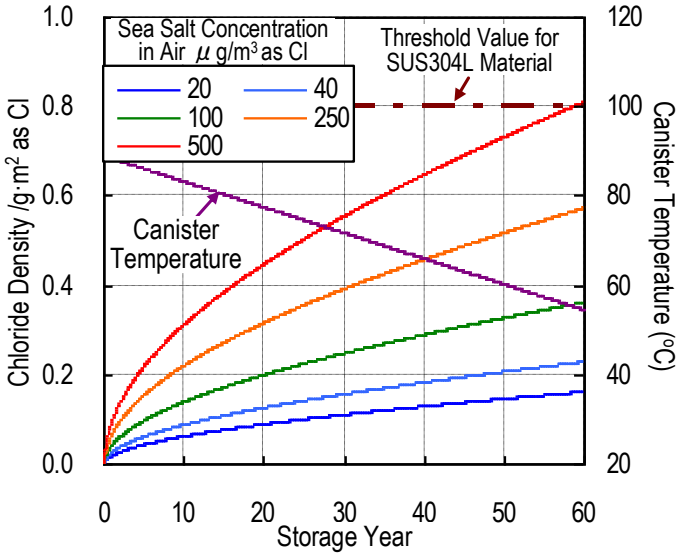




Field Test (Choshi)

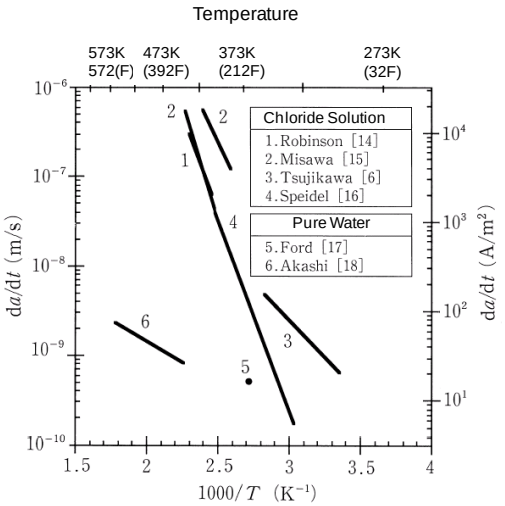
Prevention of the Initiation of SCC

- Estimation of Deposition rate at High Temperature MPC
  - Salt Deposition Tests : Laboratory and Field
  - Temperature Dependence of the Salt Deposition rate
- Temperature decay of the canister over time
  - Performance Data with Full-Scale Demo Test
- Prevention of the Initiation of SCC
  - more than 50years under an airborne salt concentration of 100μg/m^3

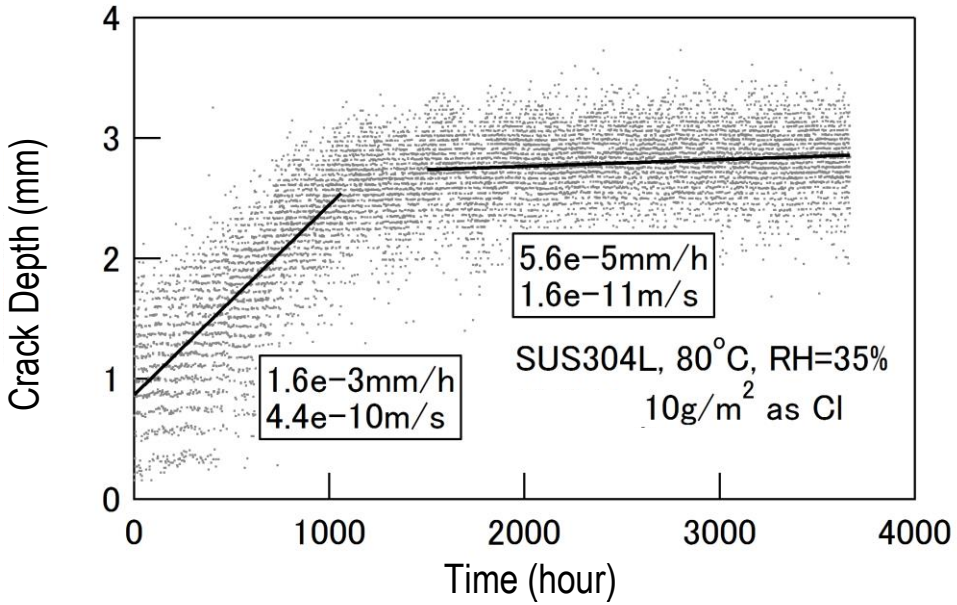


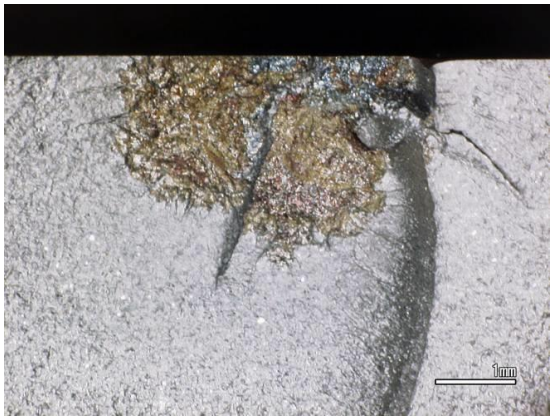
Evaluation of Crack Growth

- *4 Point Bending Test*
  - *Type 304 stainless steel, 80°C, 35%RH, 270MPa*
  - *About 10g/m² as Cl of sea salt*
  - *RDCPD (Reverse Direct Current Potential Drop) method*
  - *Potential drop data was converted to crack depth, assuming half elliptical crack propagated*
- *Crack Growth Rate as 2x10⁻¹¹m/s*



Crack Growth Rate in the literature (S30403)

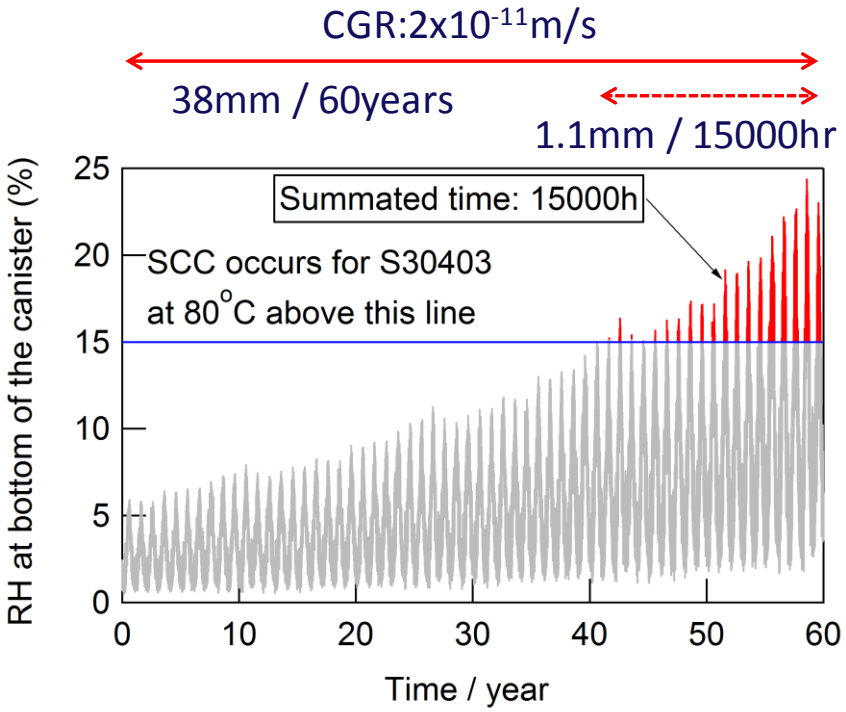




(S30403 stainless steel, 80°C, 35%RH, 270MPa, about 10g/m² as Cl of sea salt)

Crack Growth Depth (CGD) Control

- Humid Period in which the relative humidity exceeds 15% would be approximately 15,000 hours during a 60 year storage period crack growth test
- Consequently, the estimated crack propagation value during this period is only 1.1mm.



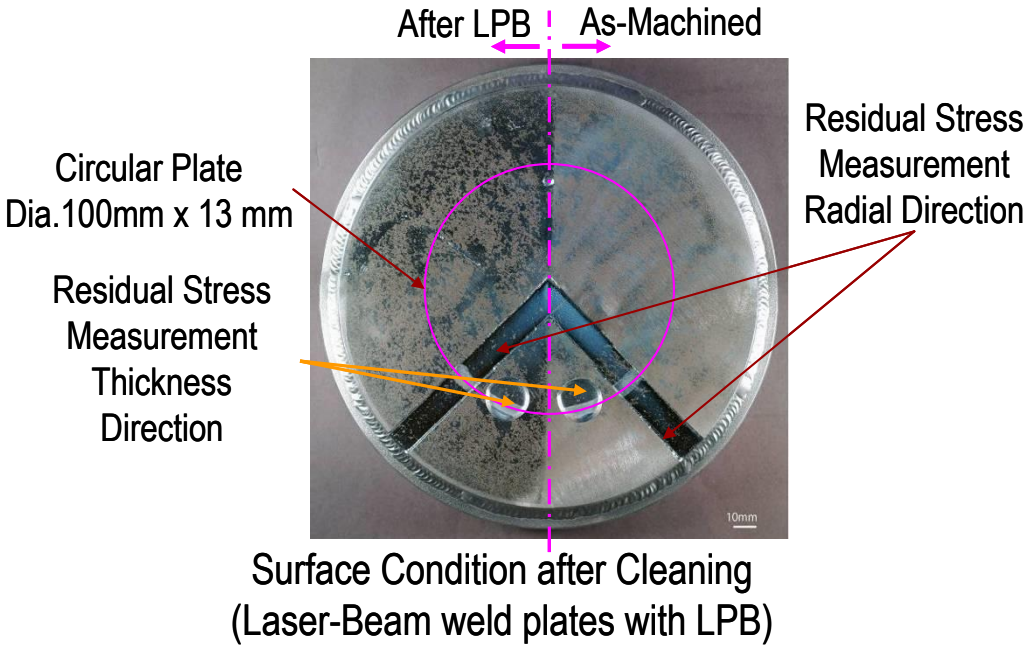
[Crack Growth Test Result]

Countermeasure for SCC

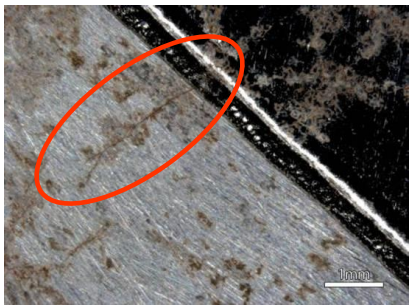
Method	Example
Decrease residual stress	Laser welding
Stress relaxation	Annealing
Apply compression stress	Shot peening, Ball-burnishing
Use high-Cr, high-Mo material	Duplex stainless steel, Super austenitic stainless steel
Use SCC free material	Titanium, Ferrite Steel
Isolate from chloride	Painting, Corrosion resistant plating
Decrease salt deposition	Sea salt particle collection, Washing
Keep salt dry	Keep surface temperature high
Design standard	Threshold salt density, etc.
Operational standard	Crack growth evaluation

SCC Test using Small Scale Test Model with Surface Treatment

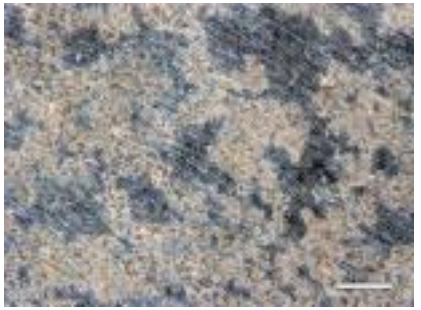
- Salt Concentration on the surface
  - $10g/m^2$ as Cl over 10 times of threshold chloride density for SCC initiation of S30403 stainless steel
  - 80˚C with RH=35% over 1000 hours
  - SCC initiation was not observed on the treated surface.



Surface Condition after Cleaning
(Laser-Beam weld plates with LPB)



Non-Treated surface
(SCC occurrence)

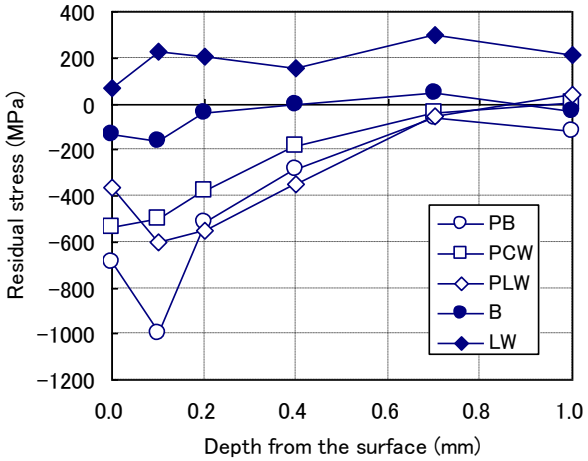


Treated surface by LPB
(only corrosion)

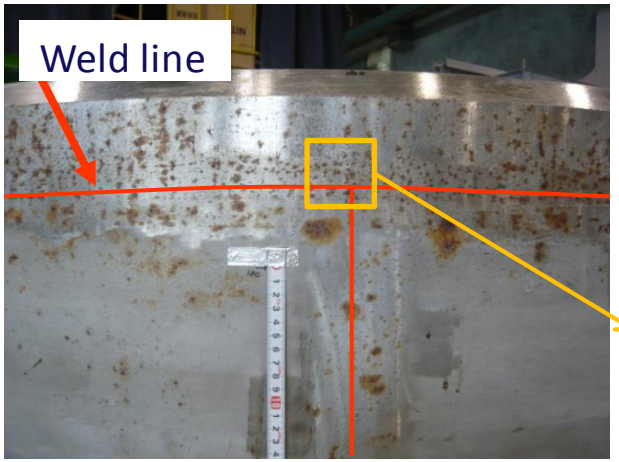
[Corrosion Test Results]

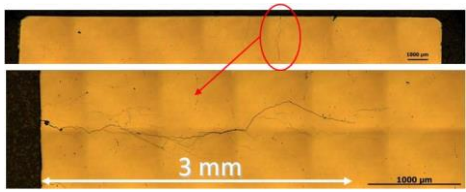
SCC Test using Mock-up MPC Model

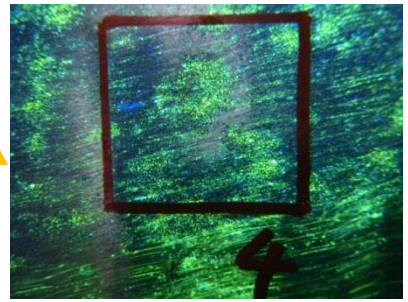
- Verify the effectiveness of the surface treatment technique
  - MPC with full-scale diameter (1,836mm) and wall thickness (12.7mm)
  - Half of the weld lines were treated by SP (Shot Peening)
  - 4g/m^3 as Cl , 80˚C with RH=35% over 2000 hours
  - As the indication of the existence of the SCC was not visible due to the rust
  - At the suspicious areas selected by PT, SCC initiation was detected only on the as-weld surface (measured crack depth: 3mm) by SEM observation .



[Measured Residual Radial Stress Distributions in the Mock-up MPC]



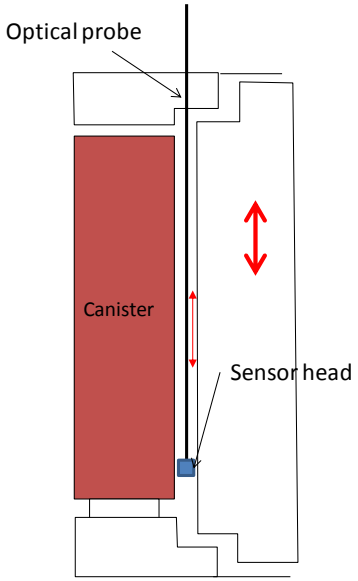


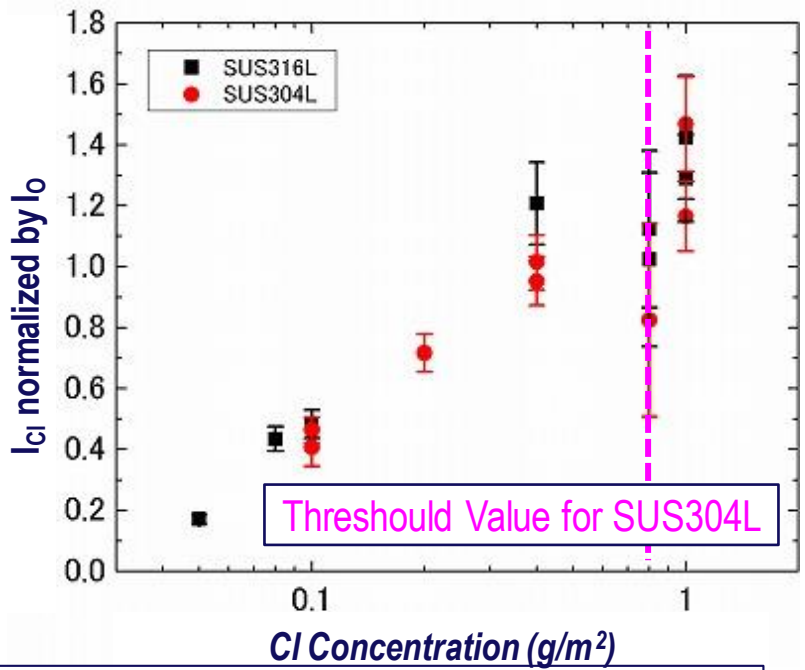


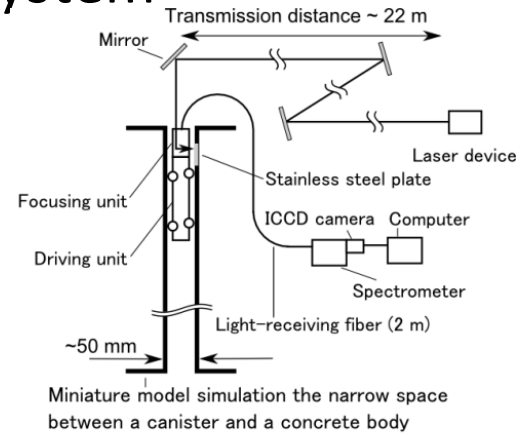
[Typical Indication detected in PT]

Monitoring salt concentration by LIBS

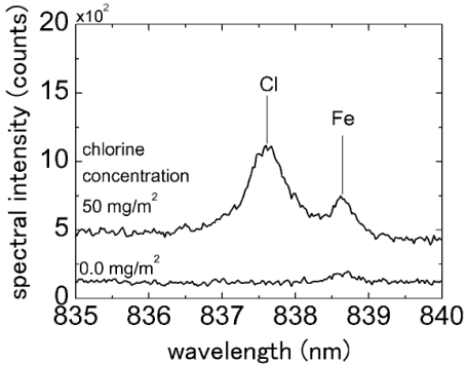
- Inspection of the occurrence of SCC
  - Evaluation of the deposition of chloride attached on canister during storage
  - Development of the laser measurement system







Miniature model simulation the narrow space between a canister and a concrete body

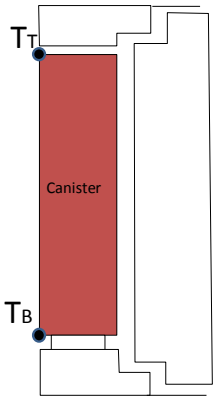


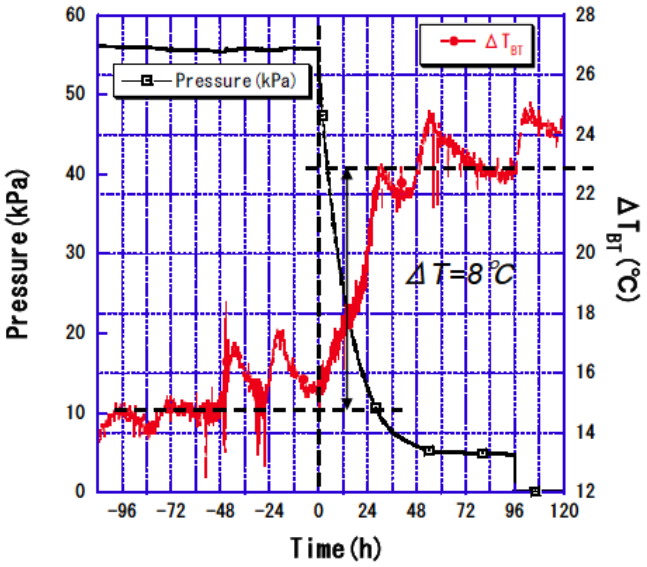
LIBS results of open pass transmission of laser light

[1] S. Eto *et al*., Spectrochim. Acta B. 87 (2013) 74-80.
[2] S. Eto *et al*., Proc. EMSLIBS2013, Bari, Italy, Sep. 16–20, 2013, (2013) P_023.

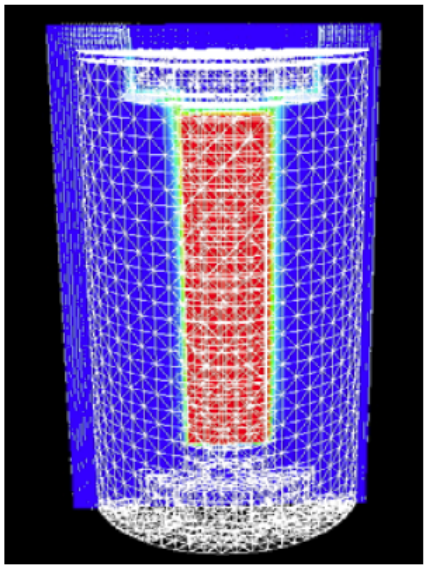
Monitoring Technology for Canister Confinement

- Monitoring of the occurrence of the loss of the canister containment
  - Evaluation of the loss of the canister containment during storage
  - He leak detecting method using by $\Delta T_{BT} = (T_{center\ of\ biottom} - T_{center\ of\ top})$
  - ΔT_{BT} is yielded due to the change in the inner pressure and temperature profile resulting from the reduction of Helium convection in the canister
  - Develop the monitoring system based on the thermal-hydraulic calculation





ΔT_{BT} and Pressure



Development of TH Model

Ref: H.Takeda, Development of the detecting method of helium gas leak from canister, Nuclear Engineering and Design 238 (2008)

Summary

The items which the CRIEPI is continuing to study is as follows;

- Critical value of initiation of SCC
- Countermeasure technology for SCC
- Inspection technology for salt deposition by LIBS
- Monitoring technology for canister confinement
- Preparation of revision of JSME code