

Spent Fuel Management in Japan and Key Issues on R&D Activities

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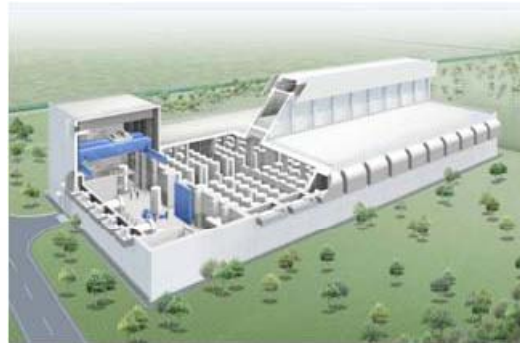
1646 Abiko, Abiko-Shi, Chiba 270-1194, Japan

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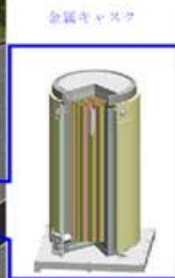
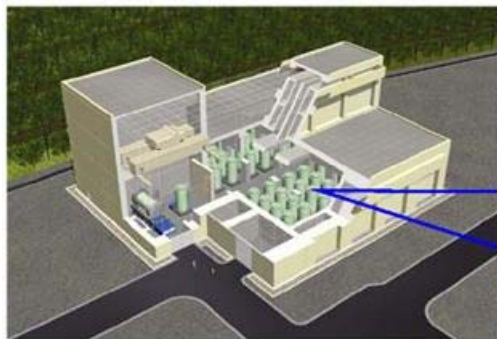
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Current Status of Dry Storage Facilities

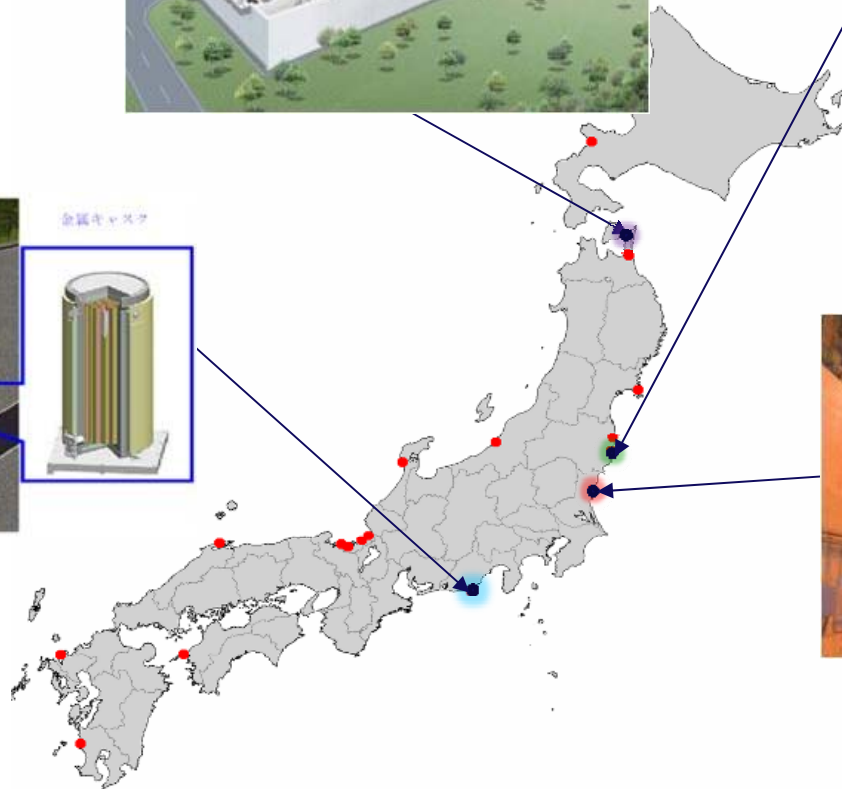
TEPCO and JAPCO, Mutsu
Storage away from reactor site
under Construction
(Max. 3000tU, 2013.10.-)



TEPCO, Fukushima-Dai-Ichi
under Restoration
1995-, 9BWR (74tU)



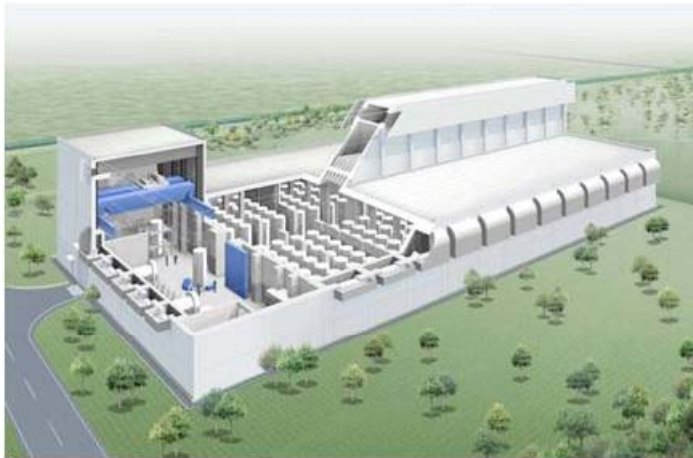
CEPCO, Hamaoka
At reactor storage
under Re-Design
(Max.700tU, 2016.?)



JAPCO, Tokai-Dai-Ni NPS
under Operation
2002-, 15BWR (160tU)

Storage away from reactor sites

- Recyclable-Fuel Storage Company (RFS)

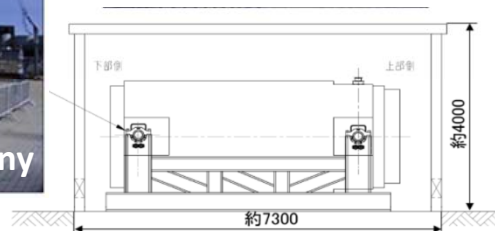
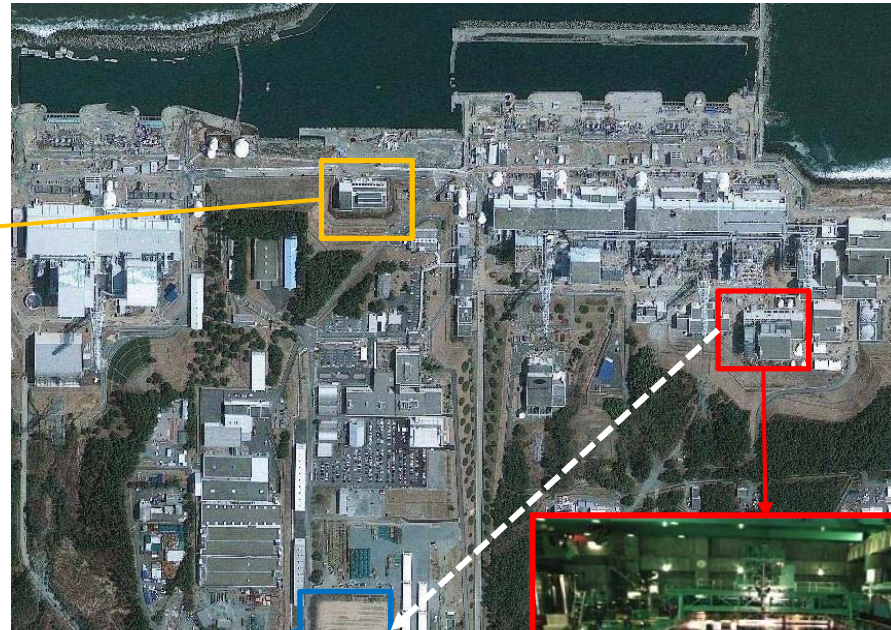


- * Final storage capacity : 5,000tU
(1st Phase : 3,000tU)
- * Storage period : 50 years

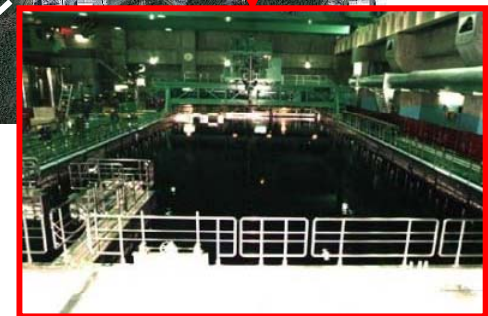
FY	2006	2007	2008	2009	2010	2011	2012-2013
Principal process for Mutsu Project			<i>Safety review</i>		<i>Commencement of construction work</i>	<i>Commencement of operation (2013.10.)</i>	
				<i>Approval of design and construction method</i>		<i>1 year stopped</i>	
				<i>Preparatory work for construction</i>		<i>Construction of building</i>	
						<i>Manufacturing of casks</i>	

Restoration Plan of Fukushima-Dai-Ichi Site

- Phase1 (Within 2 years) : Start of Removal from the SF Pool of Unit 4.
- Phase2 (Within 10 years) : Start of Removal of Fuel Debris from Reactors
- Phase3 (In 30~40years) : Decommissioning



Temporary Storage Equipment
(65 casks)



Future Strategy

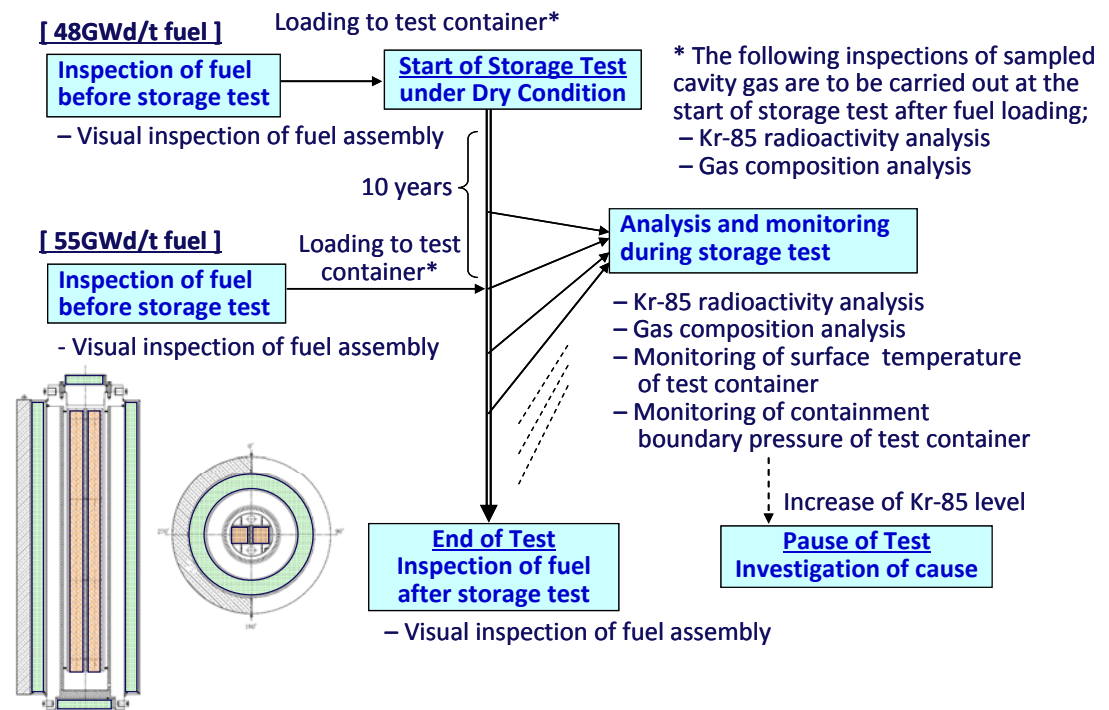
- After Fukushima accident
 - Unit 1 to 4 at the TEPCO Fukushima Dai-ichi NPS have moved to the decommissioning stage
 - Launch Nuclear Regulation Authority (NRA) (2012.Sep.)
 - Strengthen Accident Management
 - Amendment of Nuclear Reactor Regulation Law (Mid of 2013.)
 - Only two NPSs could restart by now
 - The others will possibly after the amendment of Law, depends on back-fit procedures (Seismic, Tsunami, Fire etc.)
 - Possible Options for Spent Fuel management under consideration in terms of Safety, Economy, Effective use of Energy Resources, Non-proliferation, Security, Wastes

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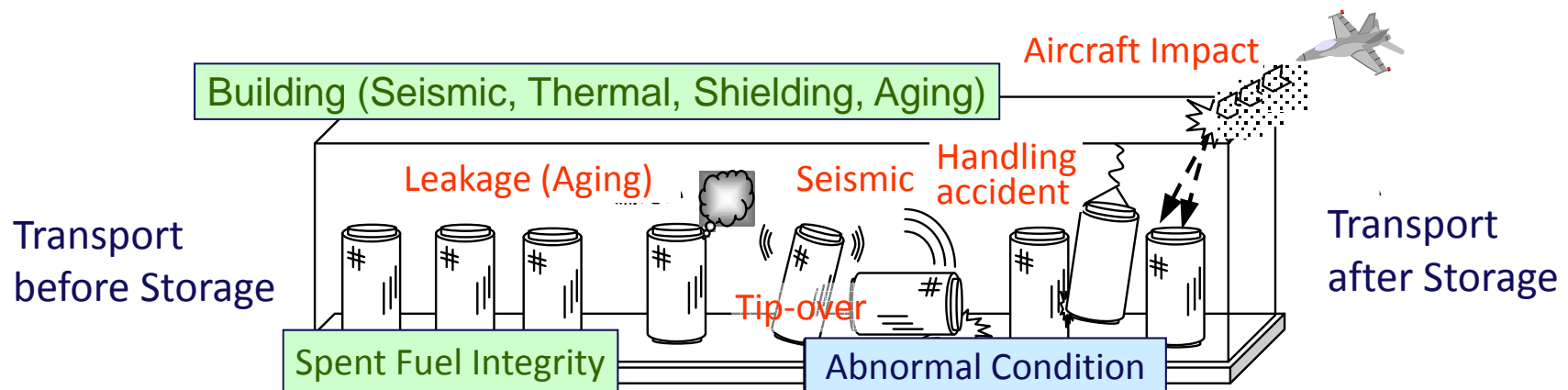
Demonstration Test Program for Long-term Dry Storage of PWR Spent Fuel

- Nuclear Safety Commission requested utilities to accumulate knowledge and experience on long-term integrity of spent fuels during dry storage
 - 2 AR storage facilities of BWR SFs have been already operating.
 - No dry storage experience for PWR SFs
- Test Program by PWR Utilities
 - Loading 2 PWR SFs (48 and 55GWd/t)
 - Periodically analysis
 - ^{85}Kr
 - Gas Composition
 - Monitoring during storage
 - Surface temperature
 - Boundary Pressure
 - License Approval
 - Manufacture started



Specific R&D Activities for Dry Storage

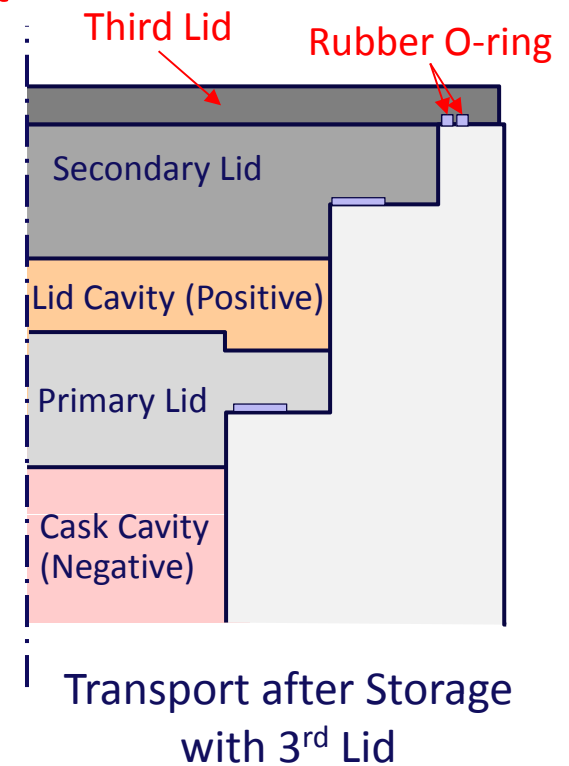
- Dry Storage with Metal Cask
 - Construction materials and components for ISF
 - Leak-tightness during Normal Transport Condition before and after Storage
 - Confinement Performance of the Lid Structure against Drop Accident and Airplane Crash
 - Seismic Stability during Storage in a Vertical position
 - Monitoring Technology for Cask Confinement
 - Life Time of Confinement Performance of the Metal Gasket



Safety Review Guideline of Former Nuclear Safety Commission

- Item #4 Confinement of radioactive material
 - Term3 Additional Lid Structure to repair the confinement performance
 - Transport after storage : **Use of 3rd Lid**
 - **Basic Design Criteria for Sub-Criticality in Transport**

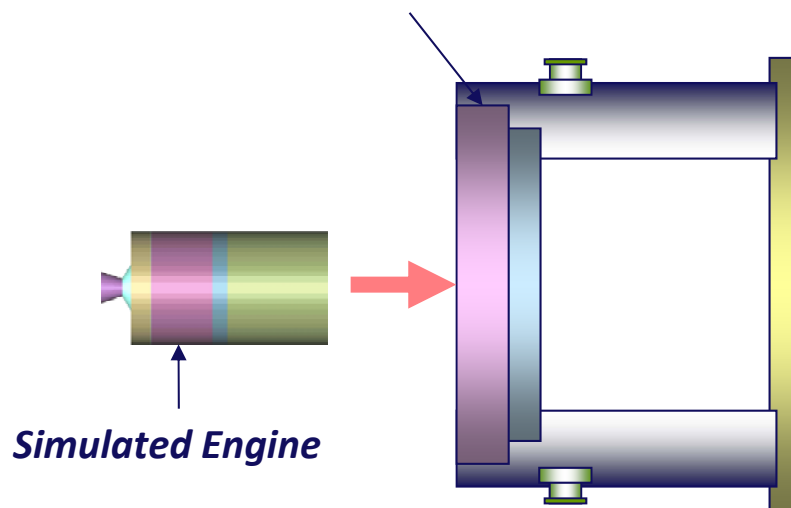
Lid	Confinement	Water Exclusion
Primary	Not expected	Not expected
Secondary	Not expected	Expected
Third	Expected	Expected



Demonstrative Tests for Confinement Performance of the Lid Structure

- Accident Management for the ISF
 - Evaluation of the effect of the lid structure behavior on confinement by airplane crash

Full Scale Model of Cask Lid



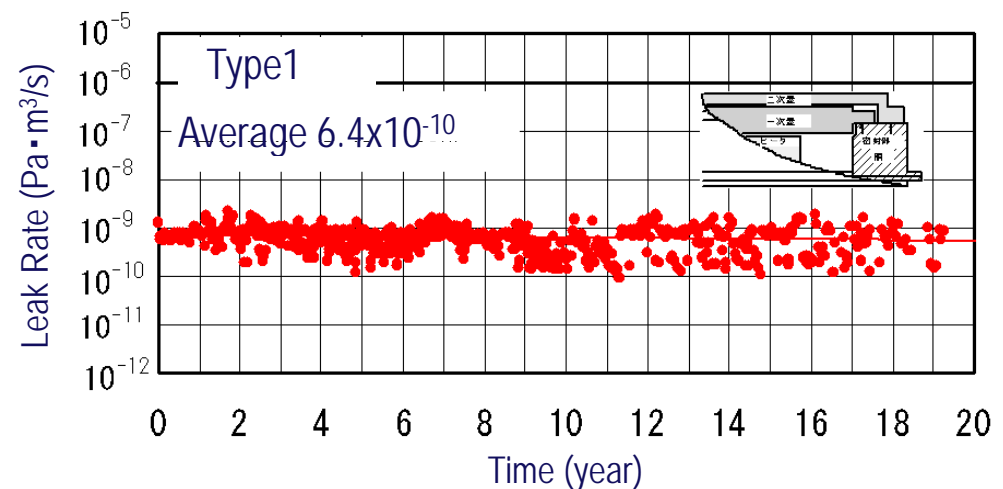
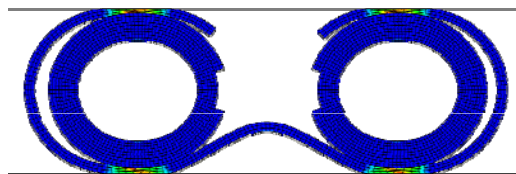
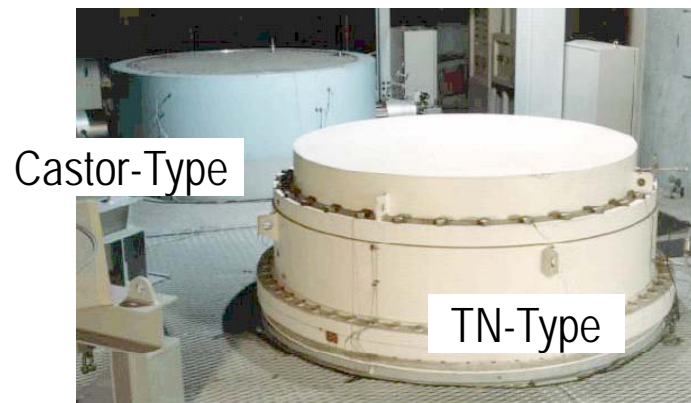
Vertical crash test of full scale model cask lid crashed by a simulated engine (Nov. 2008)



This study was carried out under a contract from Secretariat of NRA (the Japanese Government).

Confinement performance for the subsequent storage

- Lifetime of confinement performance of the metallic gasket
 - Life time of confinement performance of the metallic gasket
 - Assessed by experimental data of two full-scale cask lids & analysis
 - Tests continuing for more than 19 years under accelerated condition (Gasket temp. = 140, 130 °C const.)
 - Equivalent storage period : more than 60 years extrapolated by LMP (C=16) (Actual condition : Gasket temp. decrease)



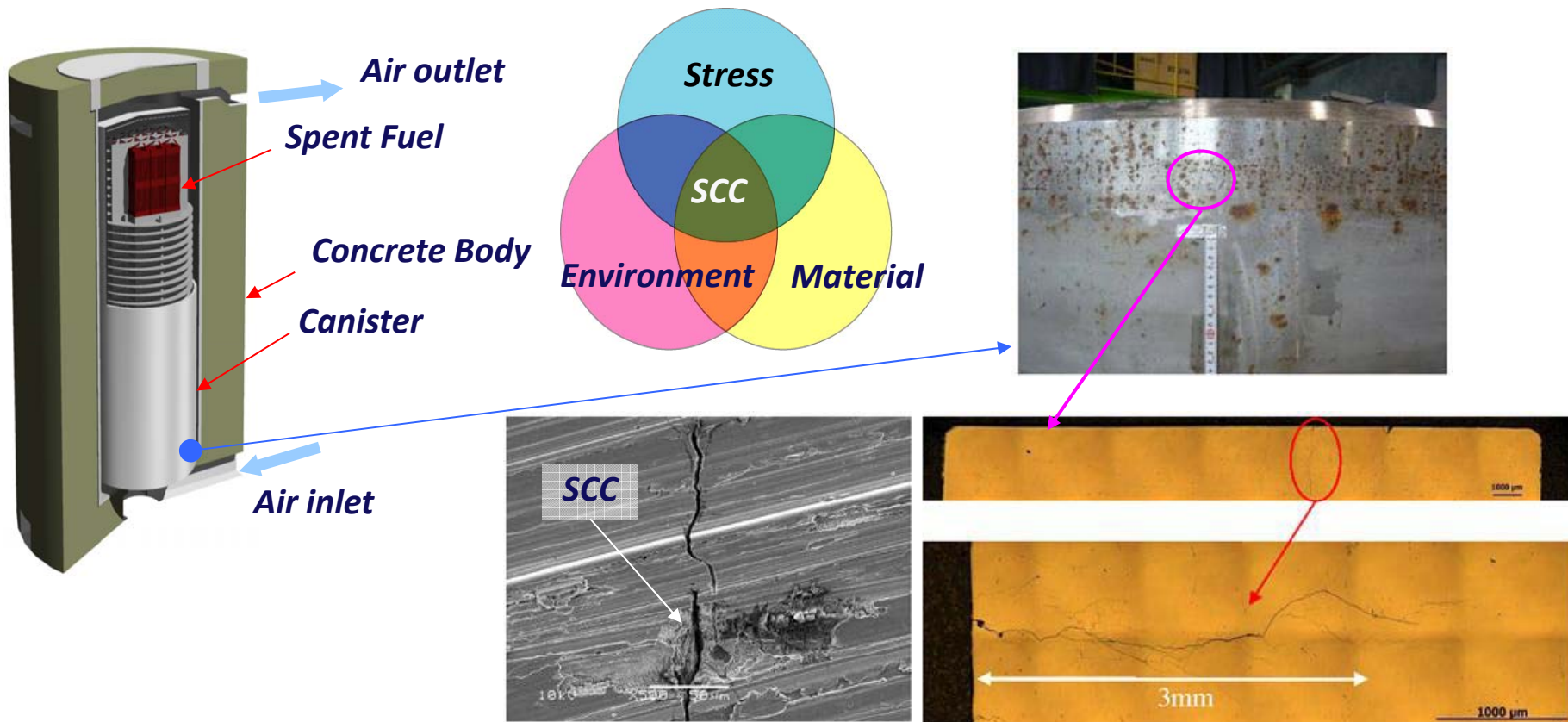
This study was carried out under a contract from Secretariat of NRA (the Japanese Government).

R&D Study for Interim Storage in CRIEPI

- Dry Storage with Concrete Cask
 - Construction materials and components for ISF
 - Containment performance of the welded lid structure under hypothetical drop condition
 - Clarification of the condition of SCC for the stainless steel canister
 - Temperature Profile of Canister
 - Inspection Technology for Canister Surface
 - Inspection of the occurrence of SCC
 - Monitoring Technology for Canister Confinement
 - Monitoring of the occurrence of the loss of the canister containment

Necessity of SCC Prevention of Canister

- SCC for the stainless steel canister
 - Evaluation and Verification of long term reliability of the stainless steel canister under SCC environment

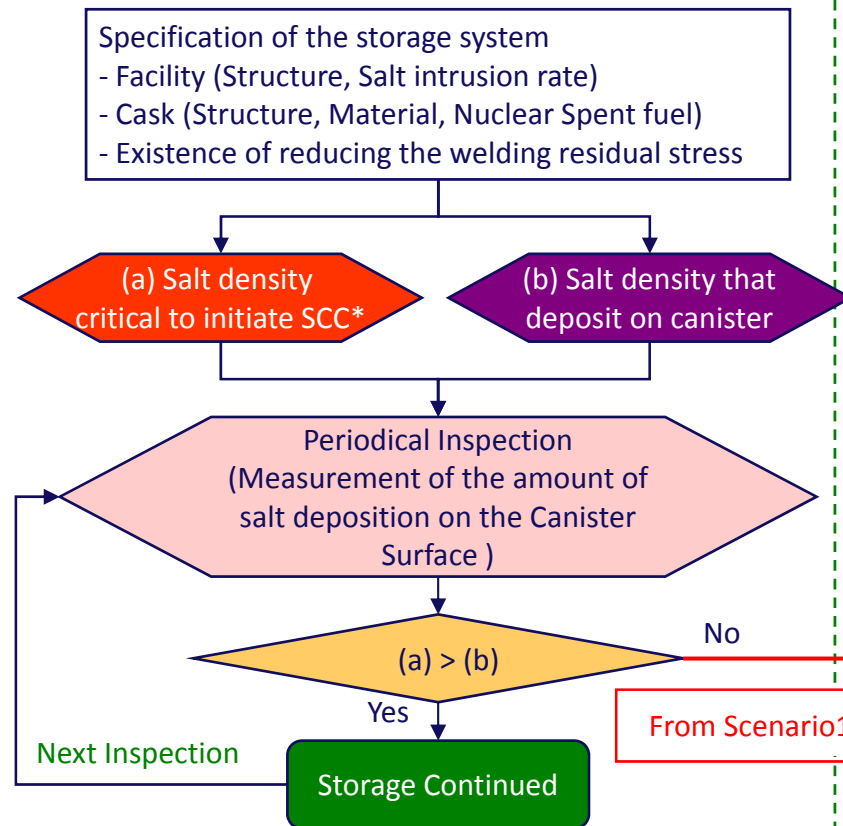


Methodology of the SCC Evaluation

Criteria I : Evaluation Flow Based on Critical Salt Concentration on the Canister Surface

Fundamental : Prevention of the Initiation of SCC

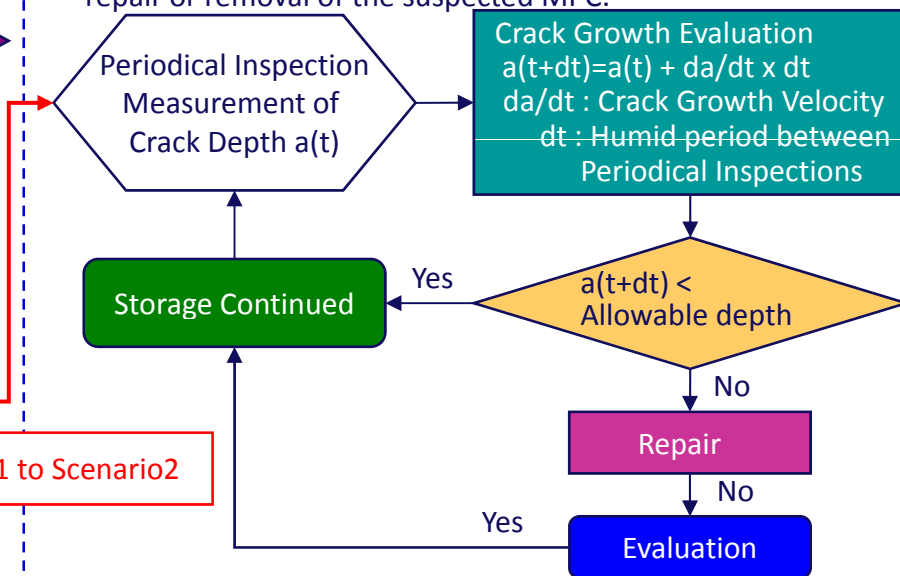
Methodology : The initiation of SCC will not occur if the chloride density on the canister surface does not exceed a allowable value



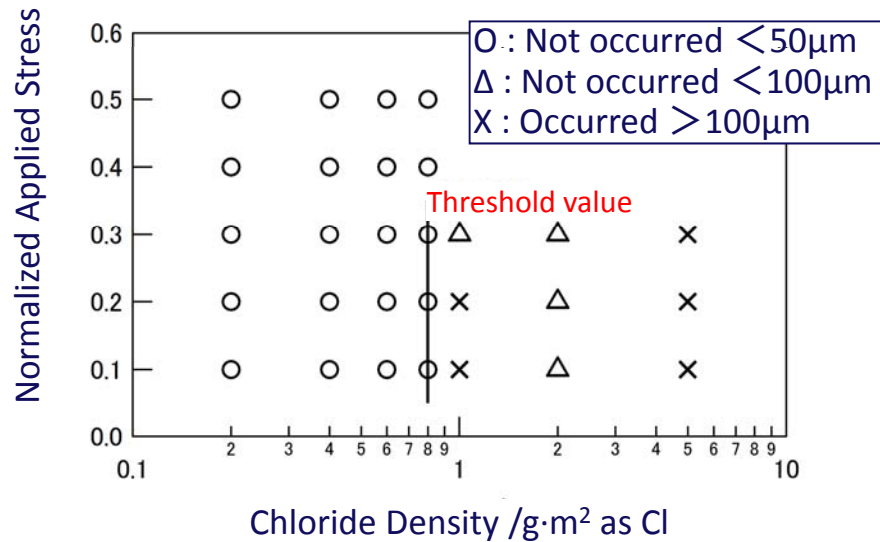
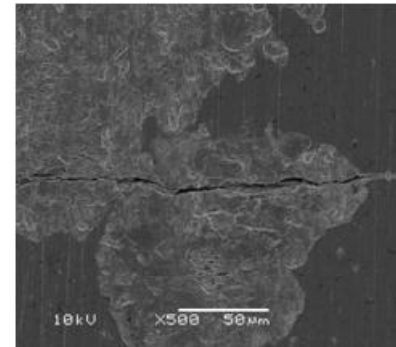
Criteria II : Evaluation Flow Based on Crack Growth Depth (CGD) Control

Fundamental : If the chloride density on the canister surface exceeds a critical value and the initiation of SCC is detected, the CGD should be controlled below an allowable value (including the case of the specified site where Scenario 1 is not applicable.)

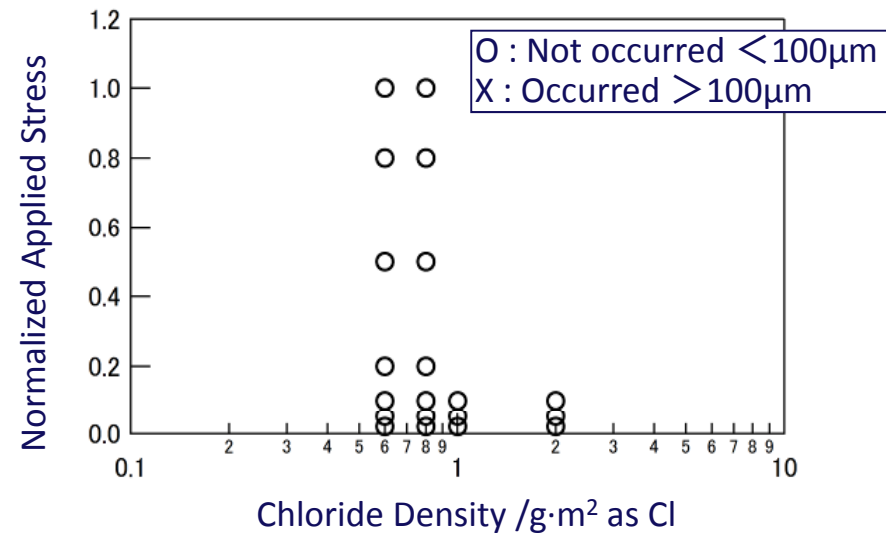
Methodology : CGD on the canister surface should be measured. Storage might be continued by the confirmation that the estimated CDG in the next periodical inspection would be below an allowable value. In case that the estimated CGD exceeds an allowable value, storage could be continued by repair or removal of the suspected MPC.



SCC Initiation Test with UNS S30403 SS



(Specimen A for 2000hr, Hardness 305Hv)

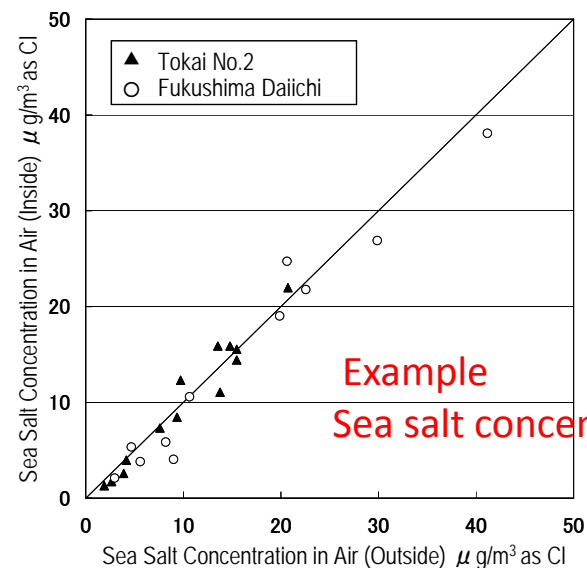
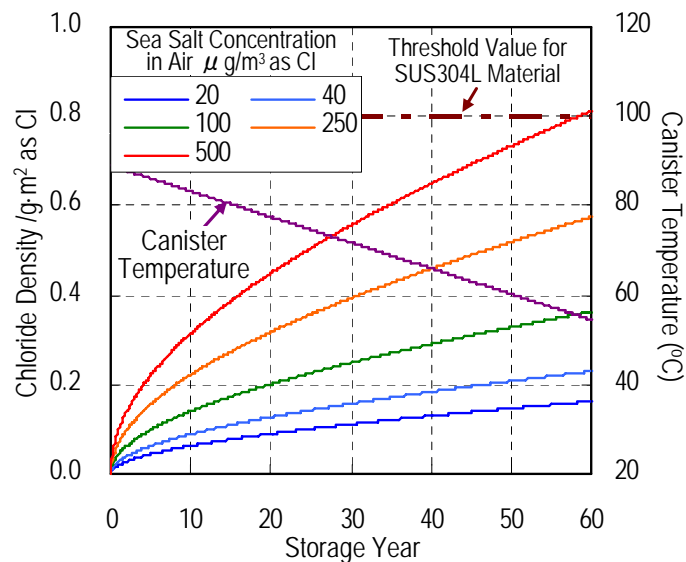


(Specimen B for 5000hr, Hardness 247Hv)

- Minimum amounts of salt for SCC initiation should be set to **0.8g/m² as Cl**

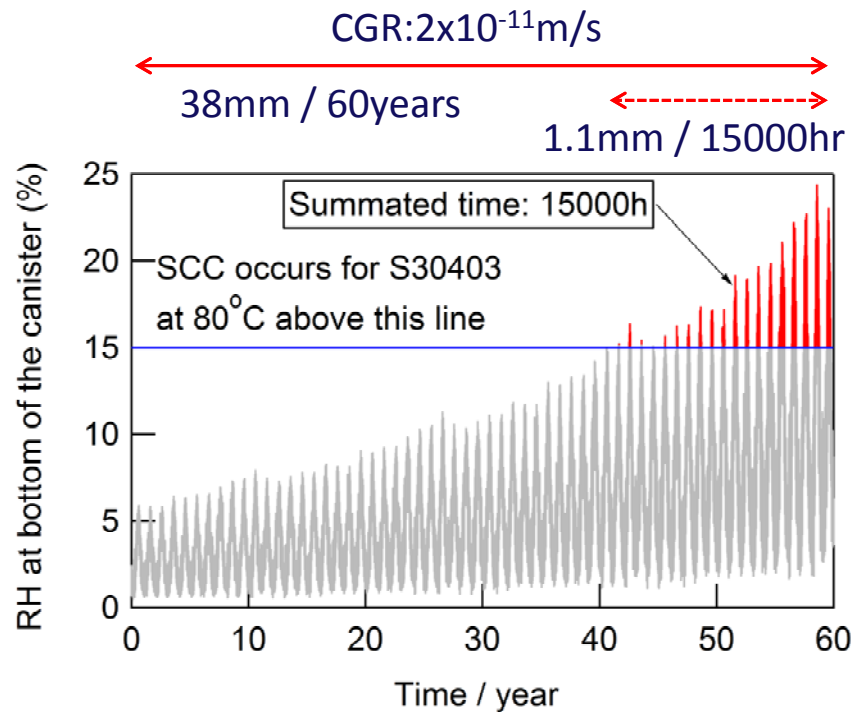
Prevention of the Initiation of SCC

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

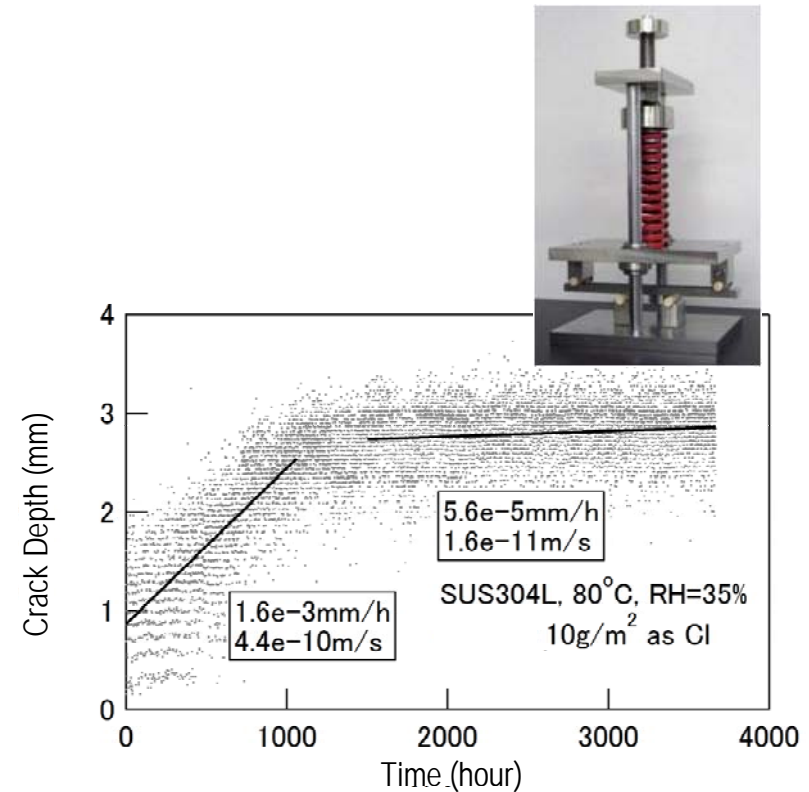


Crack Growth Depth (CGD) Control

- 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]



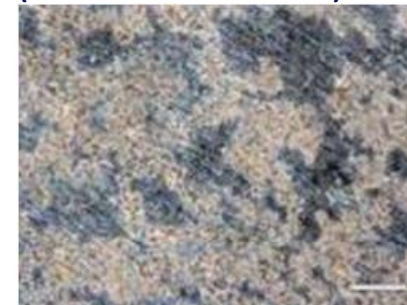
[CGR Tests by bending tests]

SCC Test using Small Scale Test Model with Surface Treatment

- Salt Concentration on the surface
 - 10g/m² 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**



Non-Treated surface
(SCC occurrence)

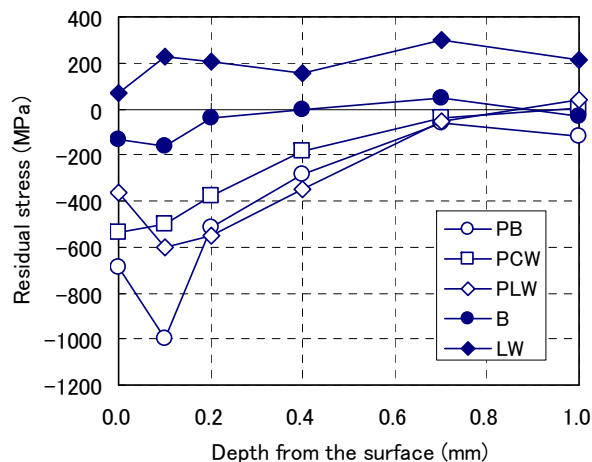


Treated surface by LPB
(only corrosion)

[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/m² 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]

Summary

- Concern of losing containment requirement in Long-term Storage and countermeasures were addressed
 - Metal Cask Storage (**Metal Gasket**)
 - High resistance of lid structure (water exclusion etc.) for severe mechanical loads were demonstrated by full-scale experiments.
 - Confinement performance of metal gaskets for long-term use may be checked numerically.
 - Concrete Cask Storage (**Stainless Steel Canister**)
 - SCC of normal stainless steel would be effectively prevented by removal of residual stress from weld and low chloride concentration in the air.
 - Spent Fuel Performance
 - Various Activities (Monitoring data and Destructive tests) should be continued to accumulate the technical information for long-term integrity of nuclear spent fuel.