Testing of Metal Cask and Concrete Cask

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(CRIEPI)

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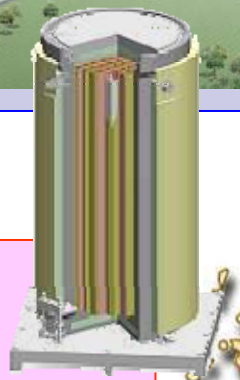
Contents

Spent Fuel Interim Storage in Japan

Location of ISFSI

Mutsu ISFSI (Phase.1)
RFS (2012-)
Max. 3,000 tU



Aomori Prefecture

Hokkaido

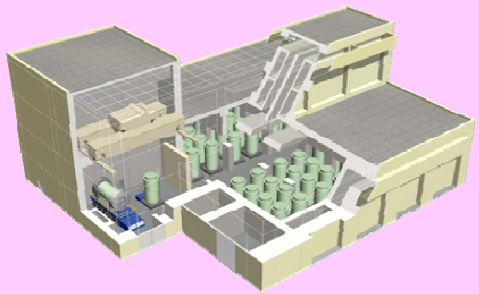
Tokyo

Osaka

Fukushima-Daiichi
TEPCO (1995-)
9 casks (74 tU)
Max. 155 tU

Tokai-Daini
JAPCO (2001-)
15 casks(160 tU)
Max.250 Tu

Hamaoka
CHUBU (2016-)
Max. 700 tUz



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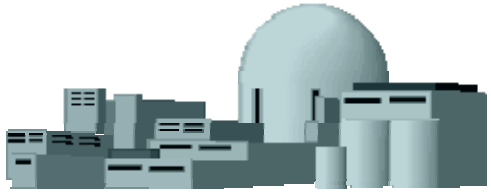
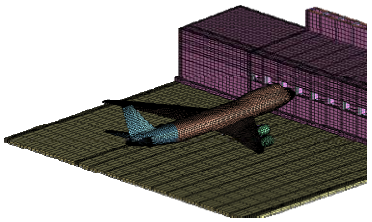
AFR

Safety Evaluation Scenario for Metal Cask



Nuclear Power Station



Transport

Building (Seismic, Thermal, Shielding, Aging)

Aircraft Impact

Normal Condition

Leakage (Aging)

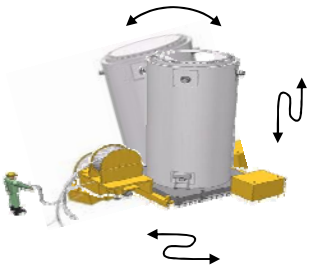
Seismic

Handling accident

Tip-over

Spent Fuel Integrity

Abnormal Condition



Transport after Storage

Reprocessing

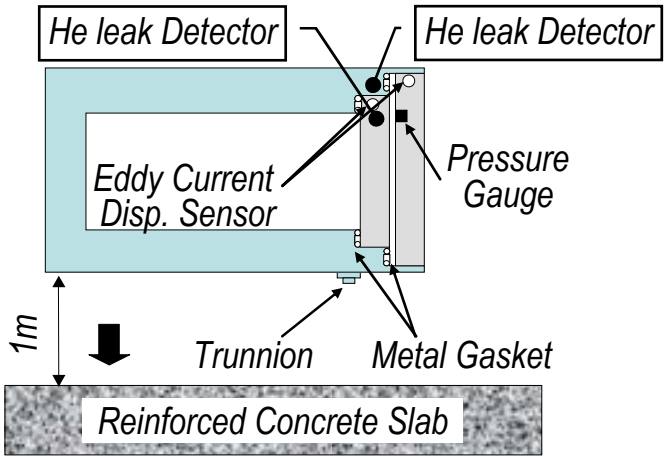
Test Program for Metal Cask Storage

Program Item	1990	----	2004	2005	2006	2007	2008	2009	2010
Containment Performance Test of Metal Cask									
a. Drop Test without Impact Limiter			Full-Scale						
b. Aircraft Crush Test					* Horizontal Test : 2/5Scale * Vertical Test: Full-Scale				
c. Long-term Confinement Test of Lid Structure	Full-Scale (19 years heating)						Open the lids		
Thermal Test of Storage Facility	1/5Scale								

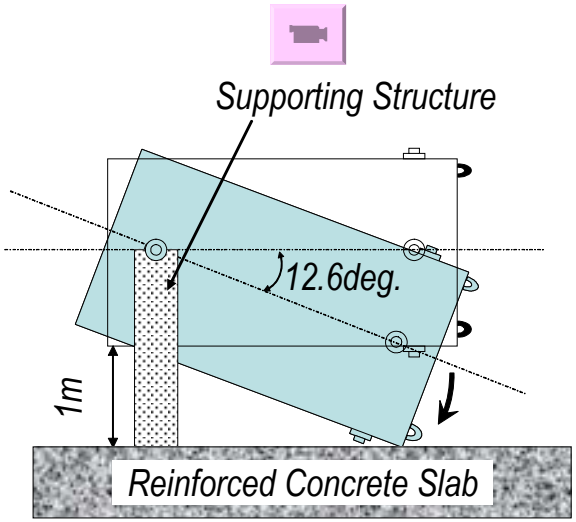
- These demonstrative research works have been carried out under the contract from NISA/METI.

Containment Performance Test of Metal Cask -Short-term integrity of Metal Gasket-

- **Key Issue : Cask Lid Sliding & Opening**
- **Drop test of full-scale metal cask without impact limiter**
  - Measure inventory that may leak at the moment of mechanical impact through lid
  - 2 drop tests with not-degraded gasket
  - Floor Model RC Structure
    4.8m Wide, 10m Long, 1.5m Thick
    fc : 36MPa



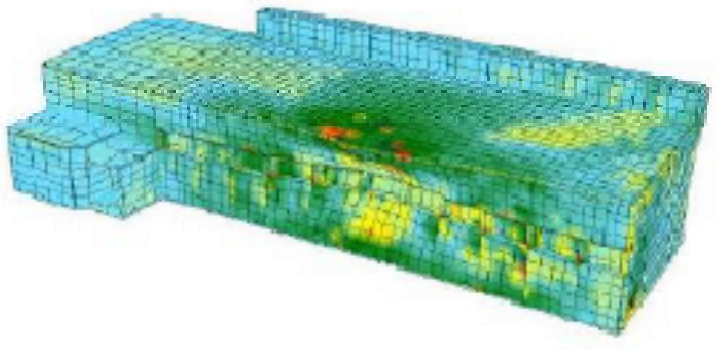
Horizontal drop onto floor



Rotational impact onto floor

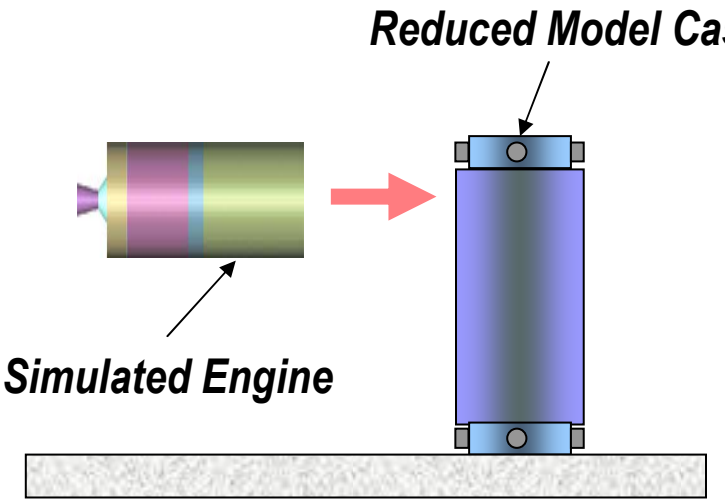
Aircraft Crash Test on Metal Cask Lid Model

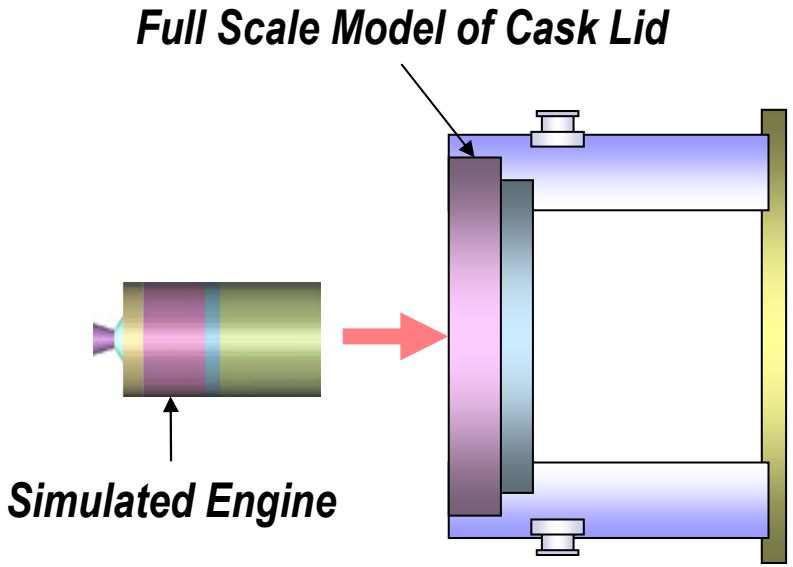
- *Determination of the inherent safety of casks under extreme impact conditions has become increasing interest since the terrorist attacks from 11th Sep. 2001*
  e.g. NEI in US, BAM in Germany
- *Literature gives information about only analytical approaches*



- *In Japan, Aircraft impact onto Nuclear Power Station*
  - *If probabilities of aircraft impact exceeds 10^{-7} time/NPP*Year, external impacts caused by aircraft crashes have to be considered*
  - *Protection measures might be necessary to reduce the effect of damage.*

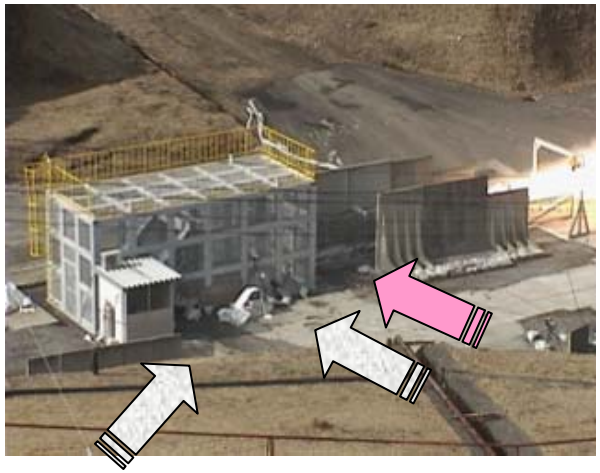
Airplane Crash Tests

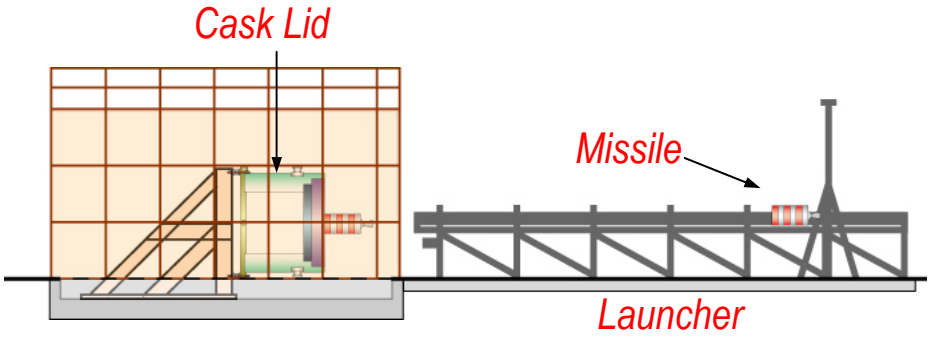




Horizontal crash test of 2/5 reduced cask model crashed by a simulated engine (Jan. 2008)

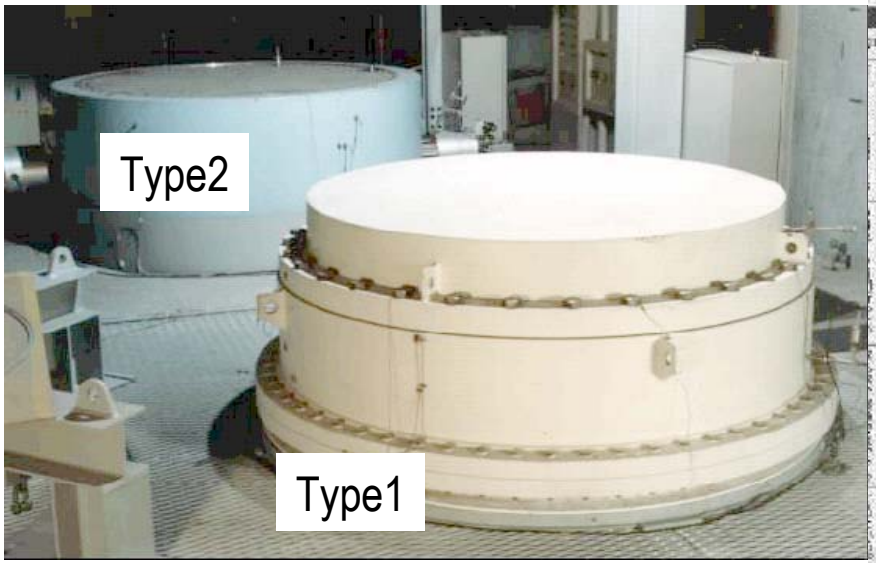
Vertical crash test of full scale model cask lid crashed by a simulated engine (Nov. 2008)





Long-term Confinement Test (1)

- To confirm long-term confinement of metal gaskets under normal storage condition
  - 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
    (Actual condition : Gasket temp. decrease)



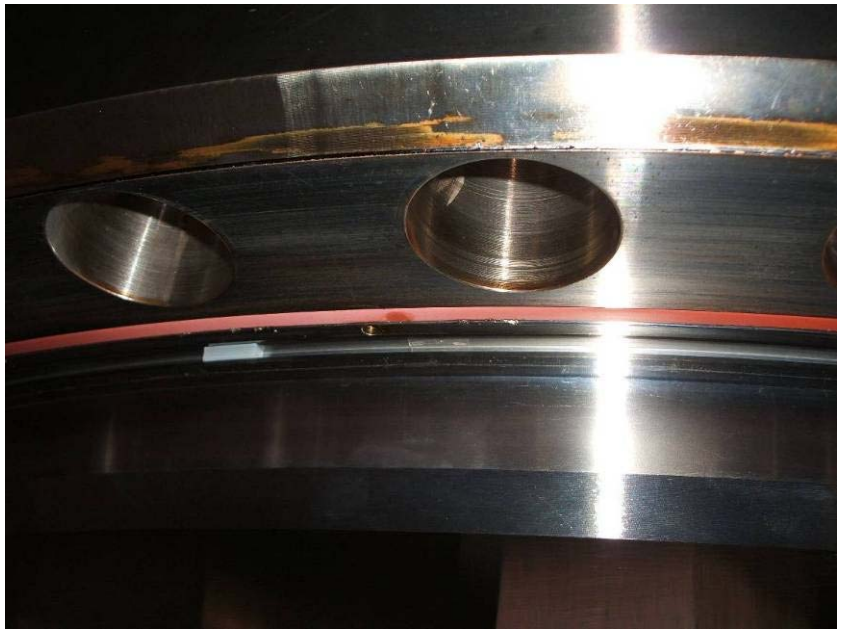

電氣
ENERGY
電中研
金属キャスク長期密封性能
100年間の健全性確認

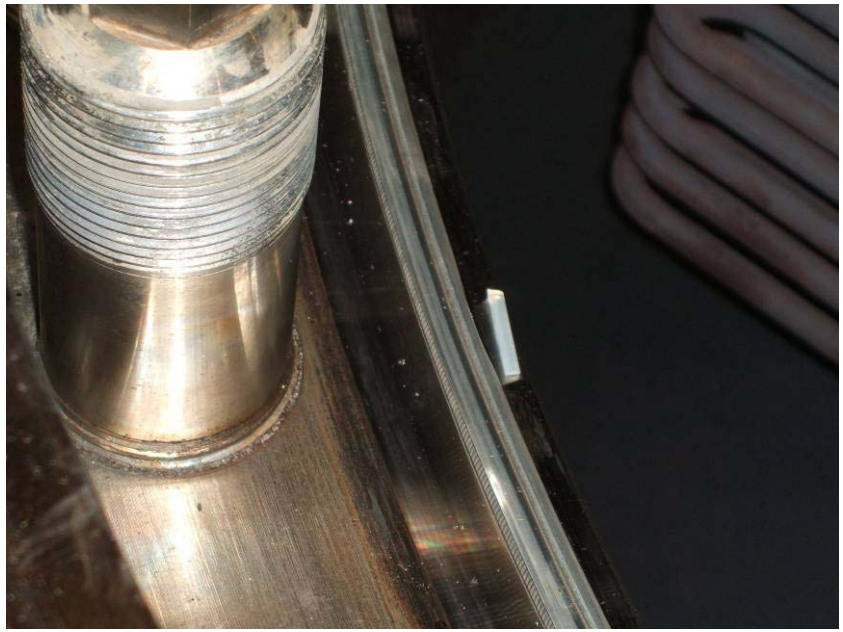
Long-term Confinement Test (2)

- To confirm the characteristics of metal gaskets after thermal aging
  - Open the lids
  - Verification of components

    Elastomer Gasket, Silver Gasket, Aluminum Gasket

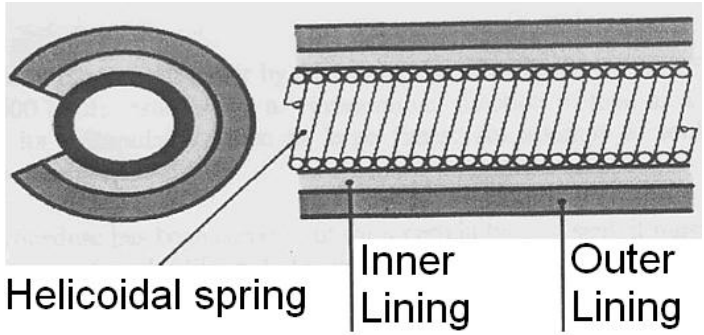
    Tightening bolt, Pressure gauge, Surface condition of the flange and so on.





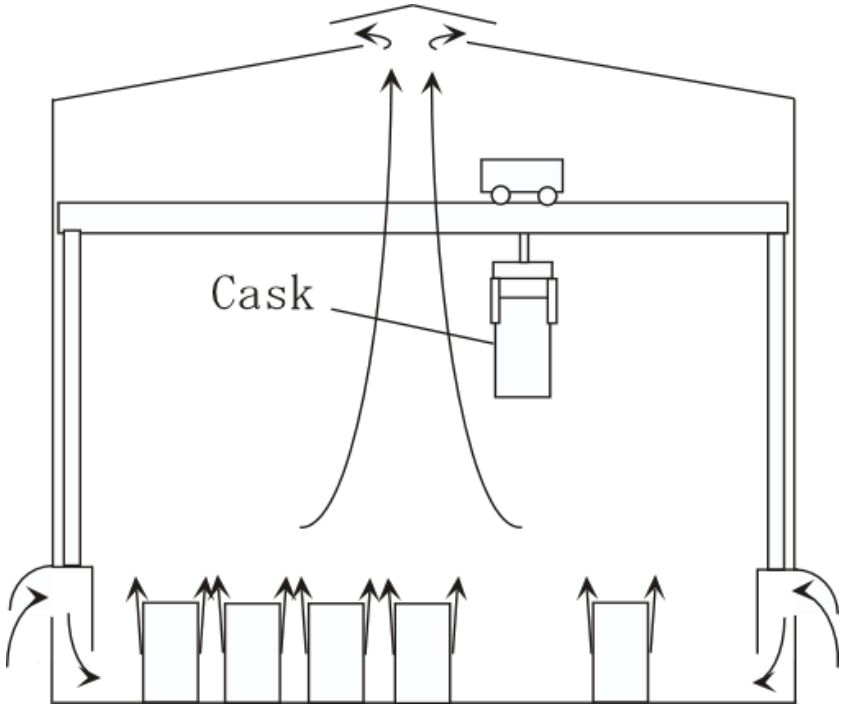
International Cooperation relating to ageing of sealing performances

- ***To study the evolution with time and temperature of the sealing performances of Helicoflex metal gaskets applied to storage casks.***
  - ***Participants CEA (France), GNS (Germany), CRIEPI (Japan)***
  - ***Duration: October, 1st, 2009 to March 31 th, 2013.***
  - ***Objective Modelling of the behaviour and the precision of the lifetime prediction***

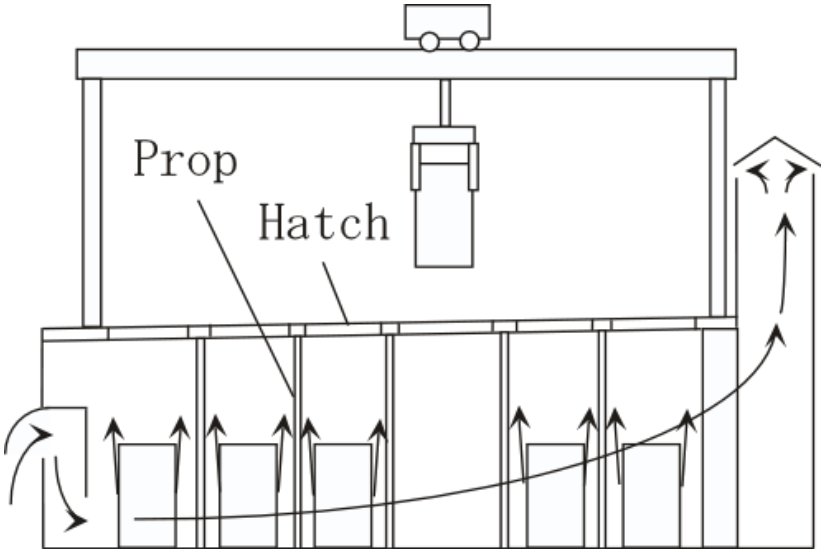


Cask storage facilities

Conventional facility

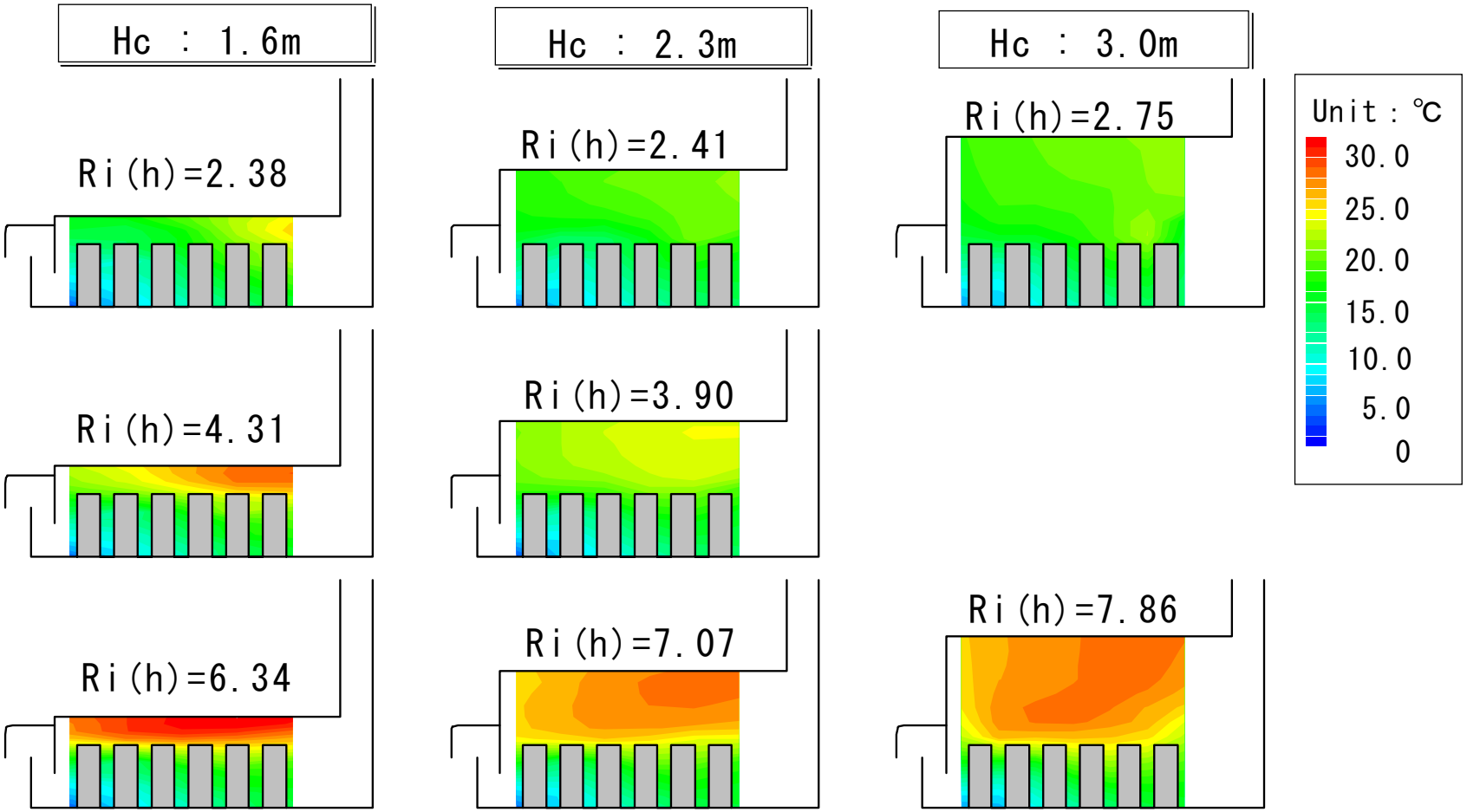


New-type facility



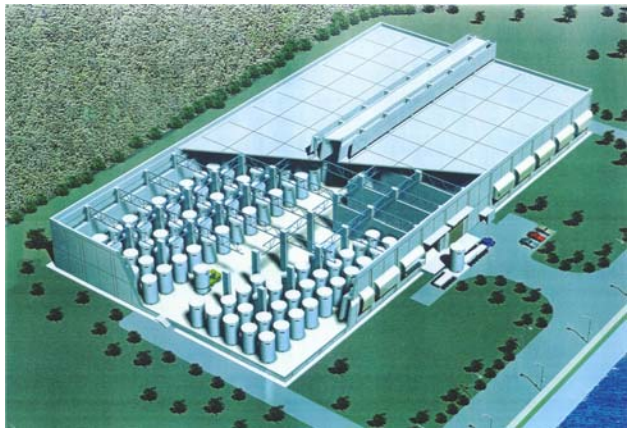
Propose fundamental length (the ceiling height and the stack height) of the cask storage facility from the viewpoint of thermal-hydraulics.

Temperature distribution (1/5 scale model)



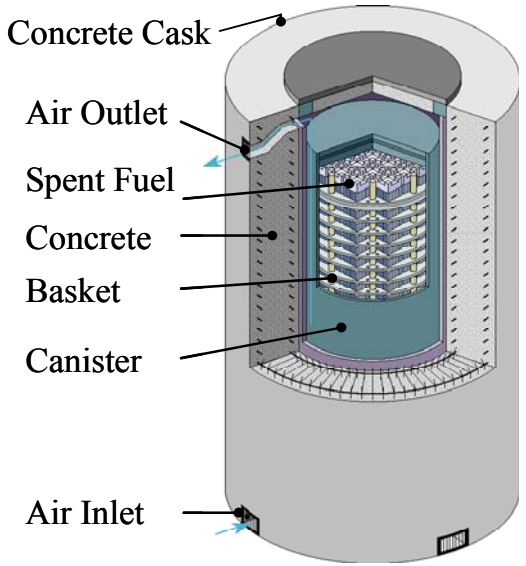
The ceiling height and stack height directly influences the heat removal characteristic of the facility.

Study of Canister Based Concrete Cask Storage Technology



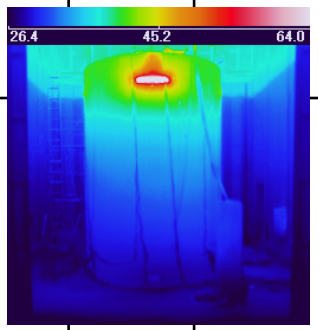
- *Why concrete cask storage is studied?*
  - *Diversification of SF storage technology*
  - *Economic reason*

- *Technical and Safety Issues on a Concrete Cask Storage*
  - *Stress strain cracking (SCC)*
  - *Leakage monitoring during storage period*
  - *NDE on lid closure weld*
  - *Periodic self-inspection requirement*
  - *SF transportation after the storage period (50y)*

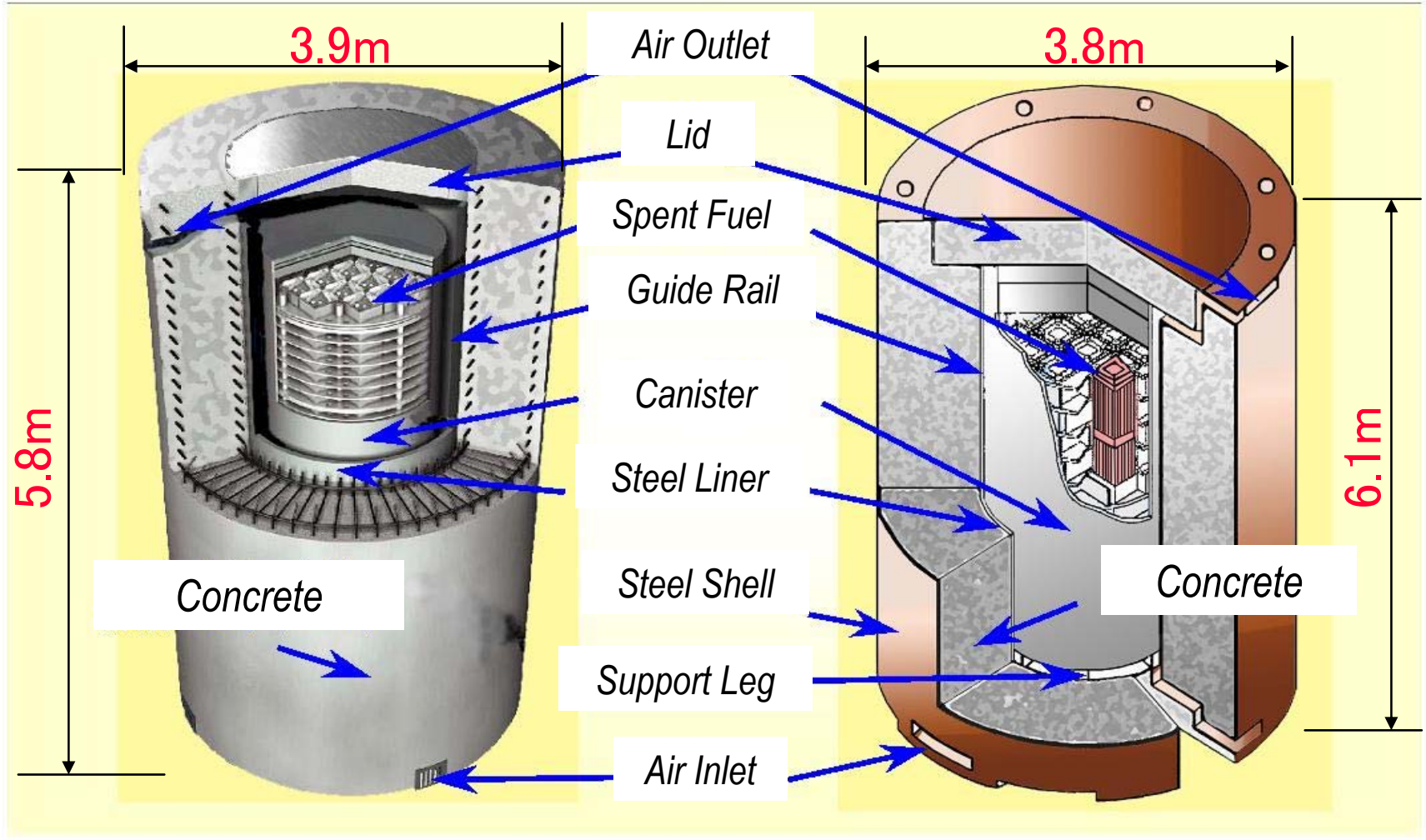


Qualification Test of Concrete Cask Performance

Program Item	2000	2001	2002	2003	2004	2005	2006	2007	2008
	Phase 1				Phase 2				
a. Basic Design									
b. Fabrication of Full-scale Concrete Casks									
c. Demonstration Tests Heat Removal				Full scale					
MPC Drop				Full scale					
Seismic		1/3 scale			Full scale				
d. SCC Evaluation Tests					Laboratory and Field Tests				



Basic Design : Concrete Cask



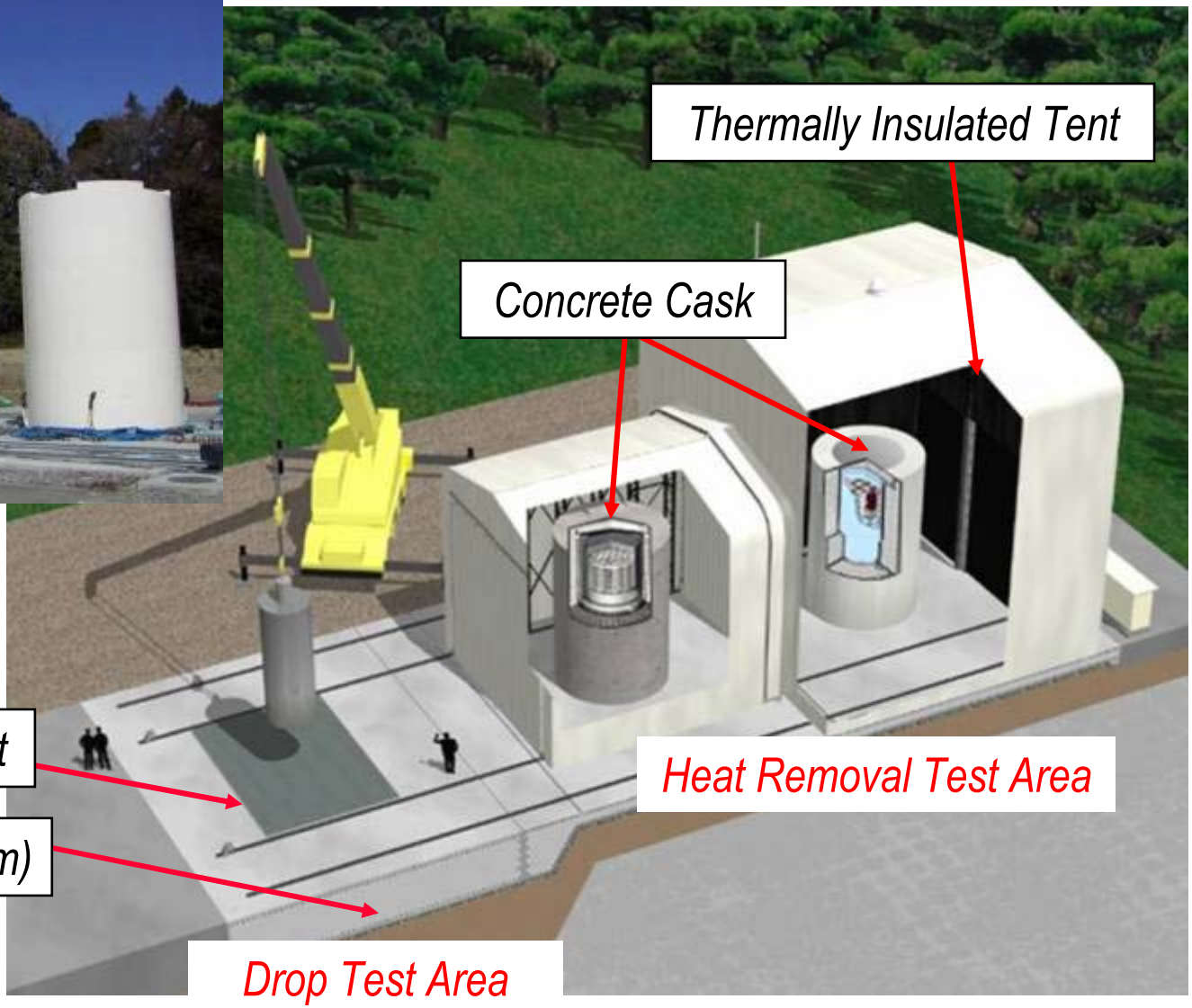
Max. Weight : 185t

Reinforced Concrete Cask:RC

Max. Weight : 184t

Concrete Filled Steel Cask:CFS

Test Facility in CRIEPI Akagi Test Center

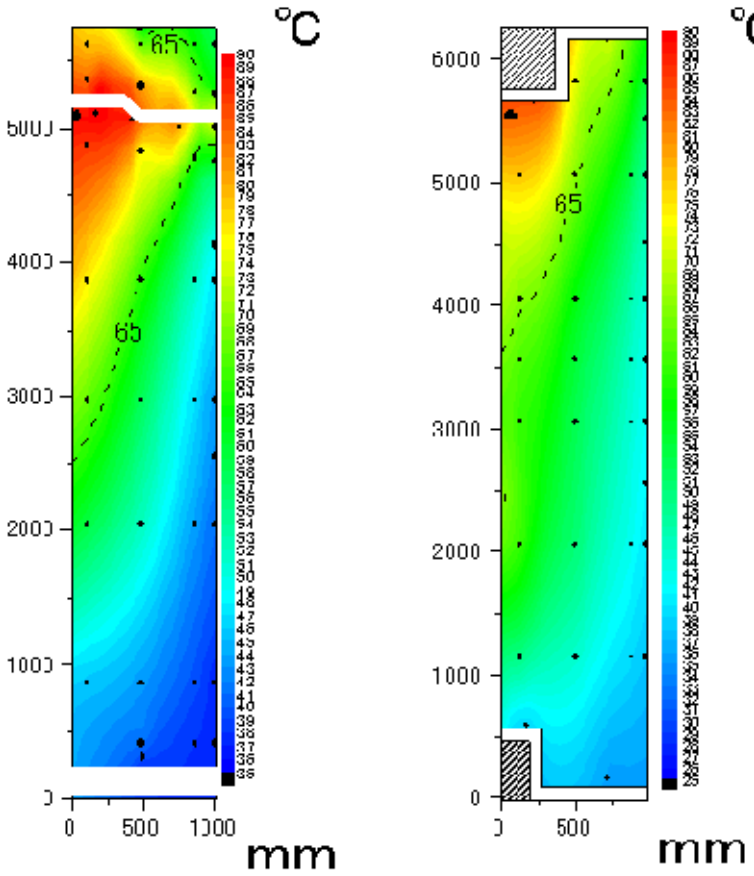


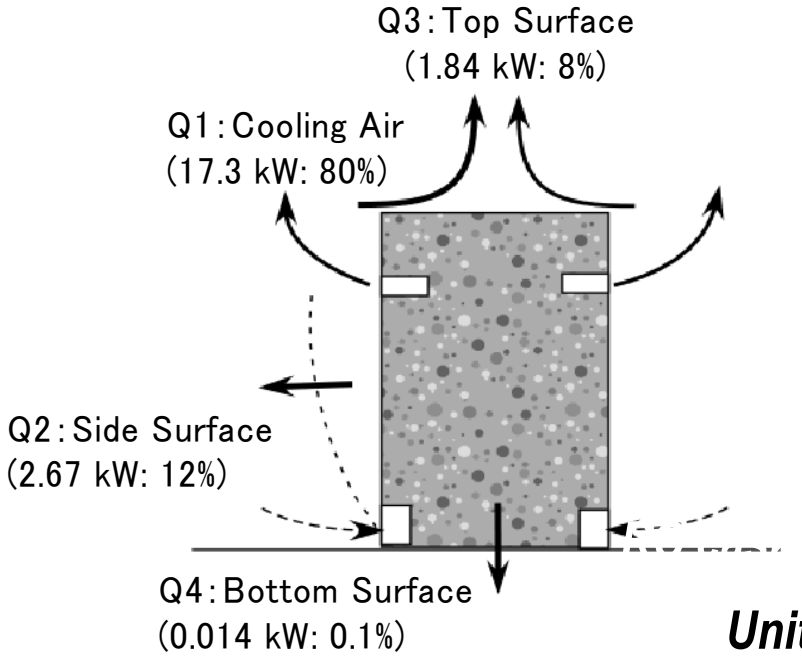
Heat Removal Test of Concrete Cask

- Normal Condition -

Q=22.6kW

RC cask **CFS cask**



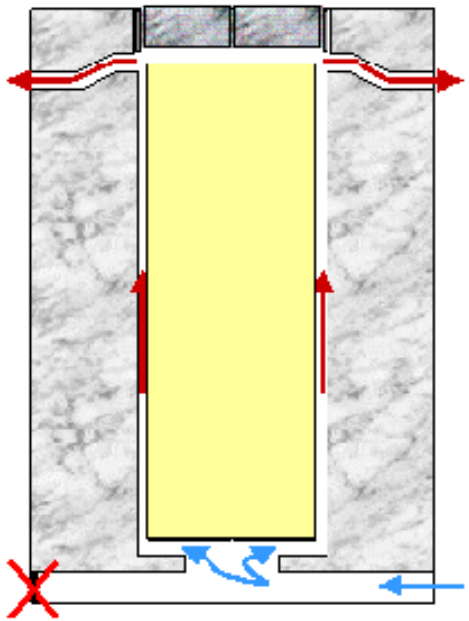


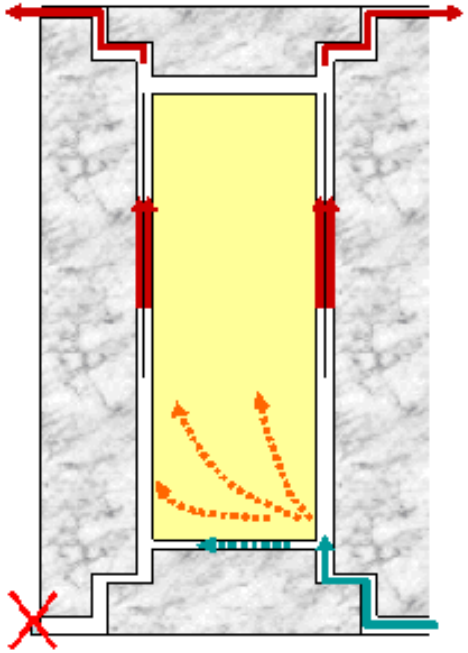
Unit : (°C)

Cask Type	RC	CFS
Inlet Air	33	33
Canister Surface	209	192
Guide Tube	301	228
Temp. Increase of Cooling Air	65	52
Storage Container	91	83
Temp. Limit for Concrete	< 90	< 90

Heat Removal Test of Concrete Cask (50% Blockage)

RC Cask



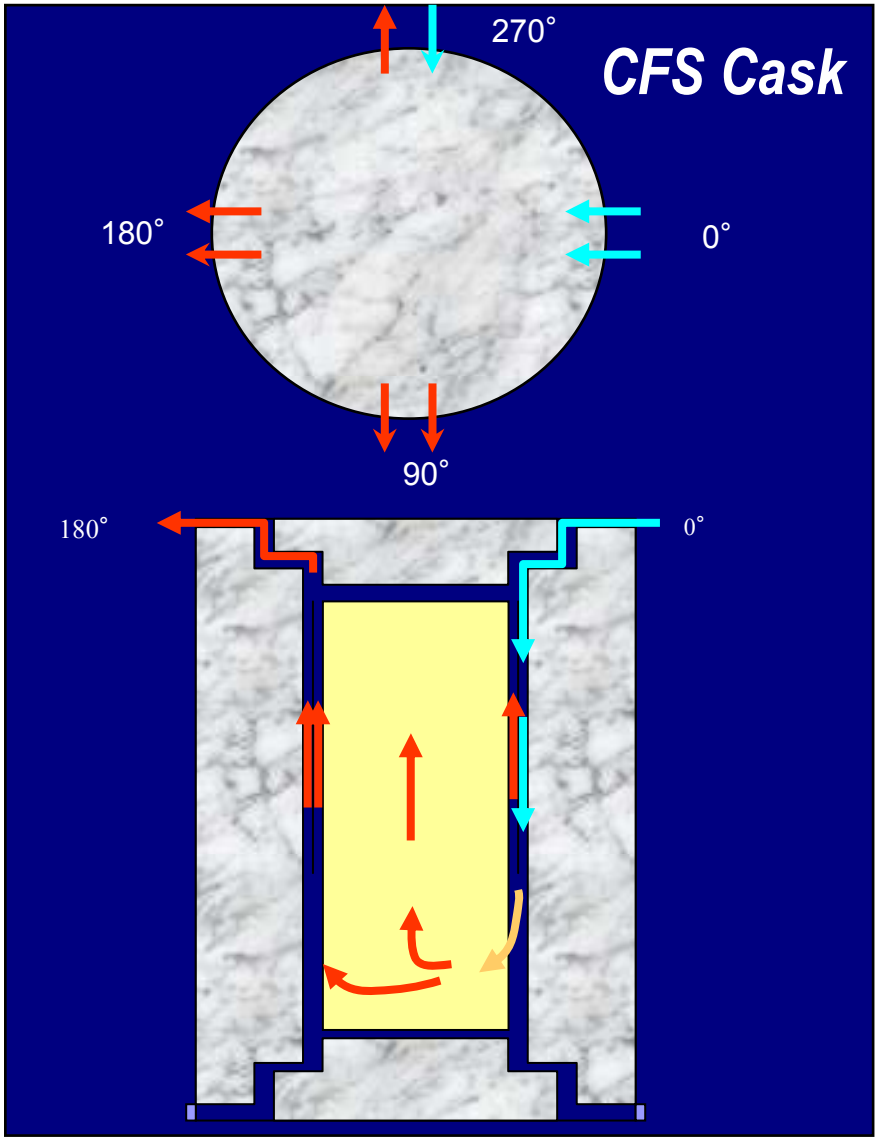


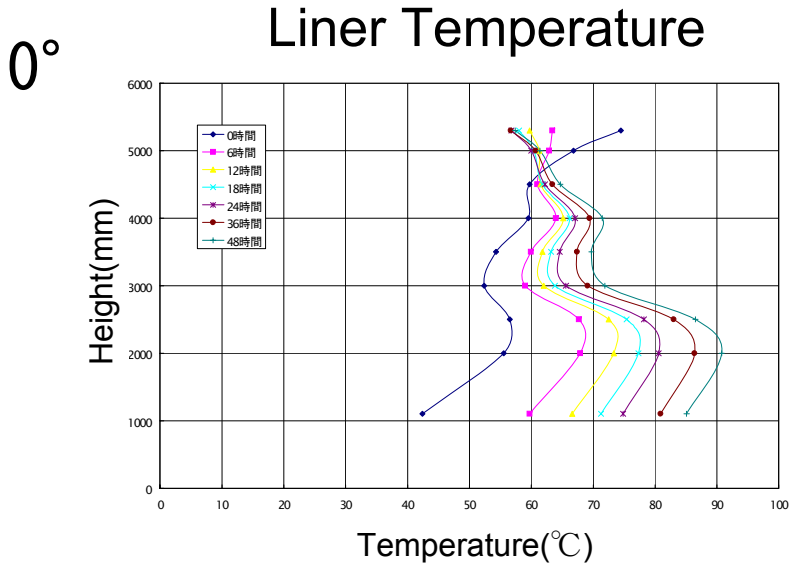
CFS Cask

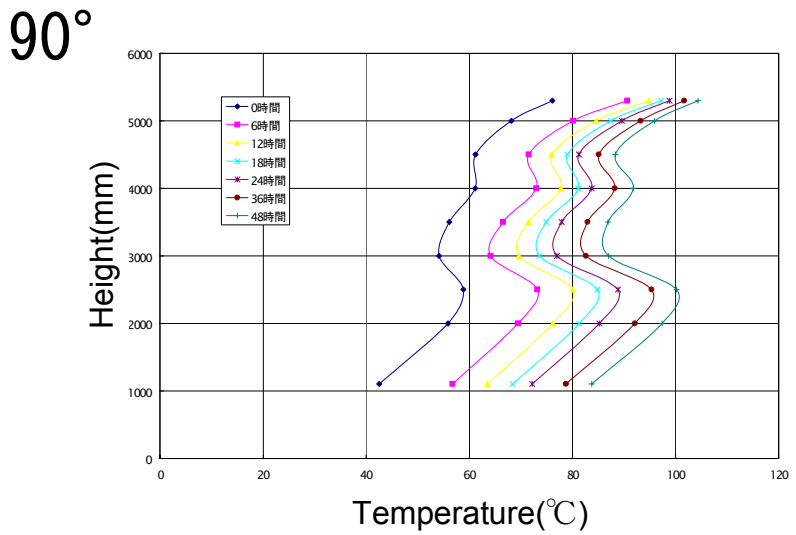
Unit : (°C)

Cask Type	RC		CFS	
Cooling Condition	Normal	50% blockage	Normal	50% blockage
Inlet Air	33			
Canister Surface	209	214	192	200
Guide Tube	301	306	228	235
Temp. Increase of Cooling Air	65	70	52	66
Storage Container	91	96	83	93

Heat Removal Test of Concrete Cask (100% Blockage)



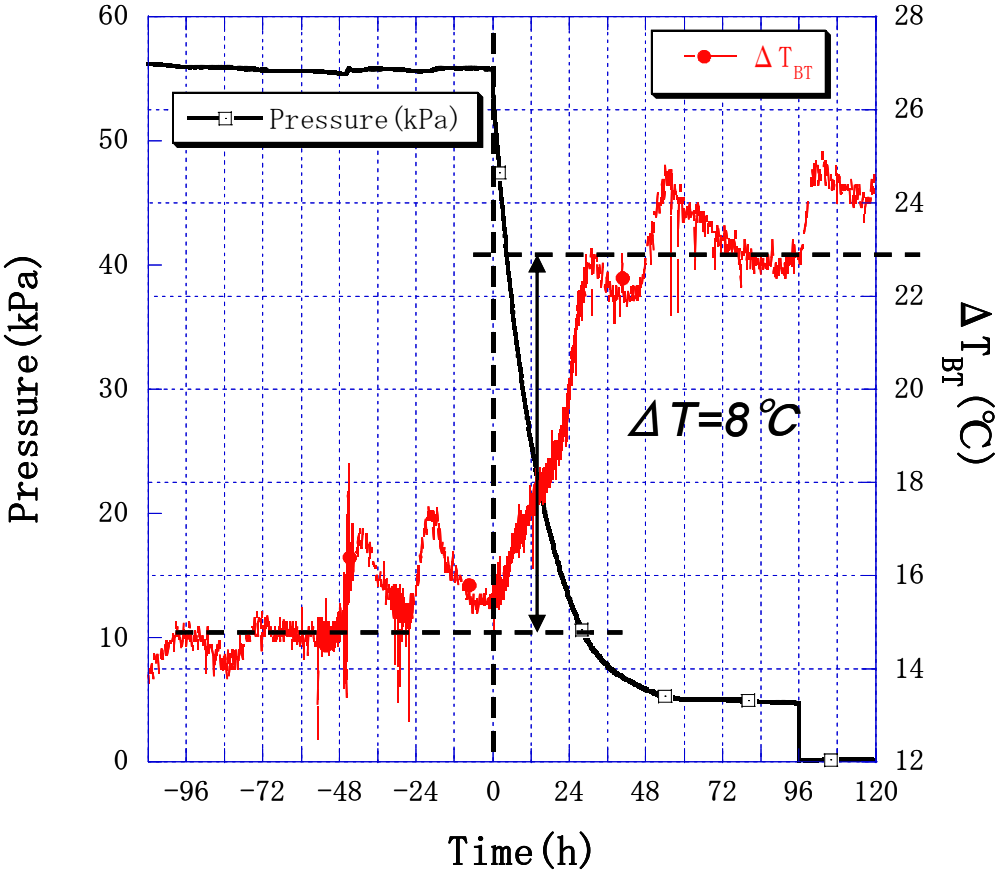




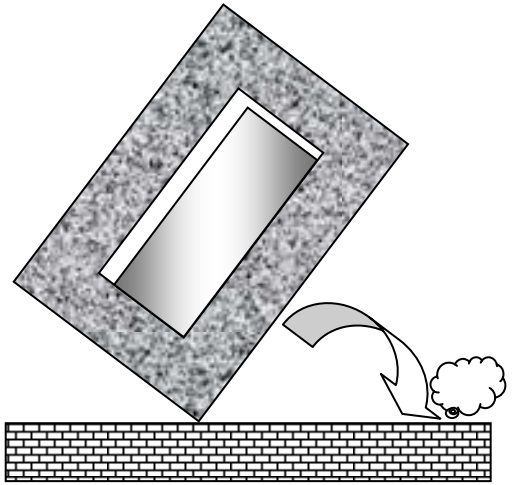
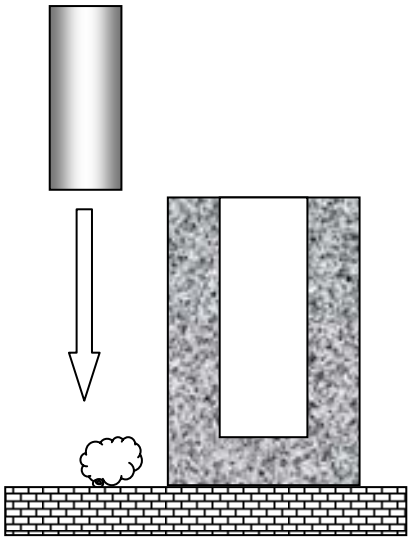
He leak detecting method using by ΔT_{BT}

$$\Delta T_{BT} = (T_{center\ of\ Bottom} - T_{center\ of\ Top})$$

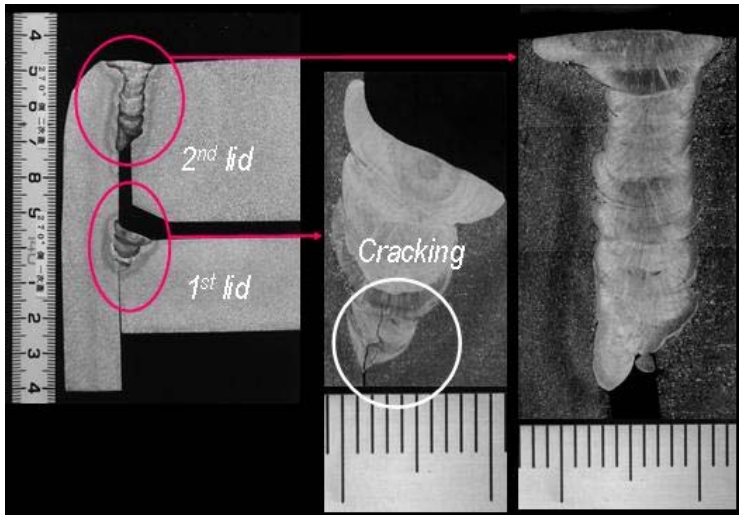
ΔT_{BT} and Pressure



Drop Test Scenario of Canister in Concrete Cask

Canister	CS + SUS Basket	Al Alloy Basket
Accident	Tip-over during handling	Drop during handling
Orientation	Horizontal	Vertical
Height	1m	6m
Condition	Tipping-over from height of GC 	Drop height from Cask Height 

Drop Test of Canister in Concrete Cask

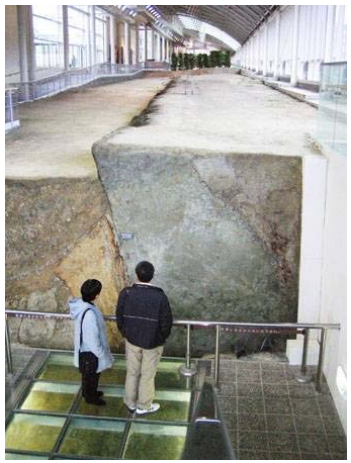


- *Leak-tightness is kept before and after drop tests*

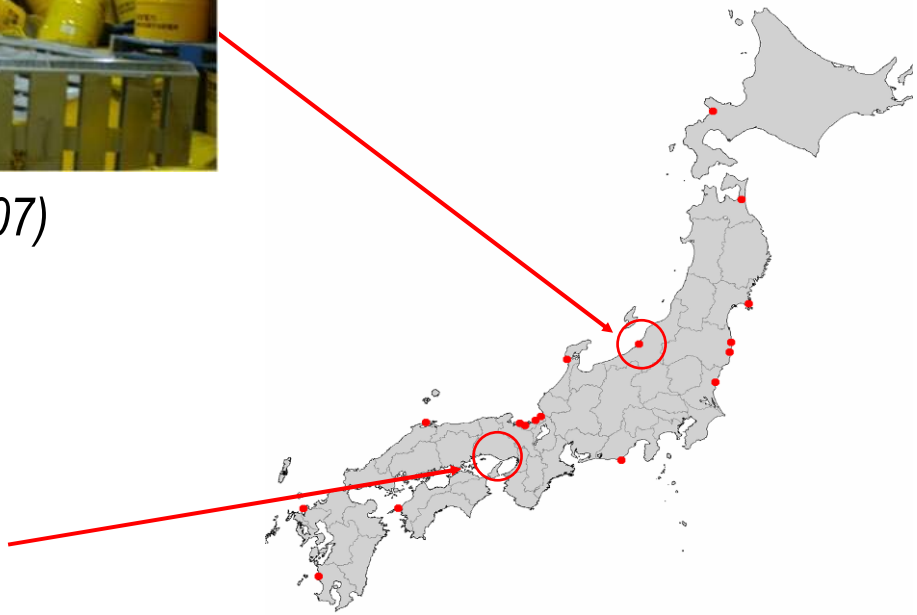
Test of Free-Standing Concrete Cask under Strong Earthquake

PATRAM 2007: K. Shirai et al. by CRIEPI

Niigata Chuetsu-Oki Earthquake(2007)



Great Hanshin-Awaji Earthquake(1995)



Location of nuclear power plants in Japan

Technical requirements for Seismic Evaluation

- **NISA/METI on April 2006**

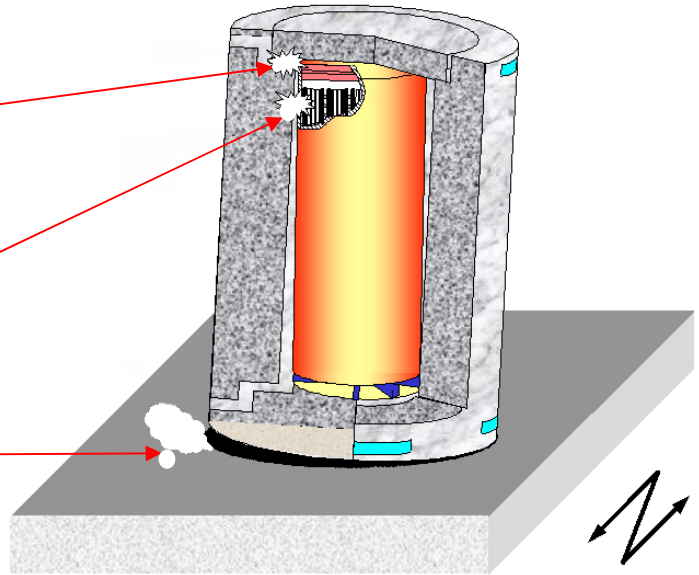
  Concrete cask should be protected from Tipping-over or Interfering neighbor casks, and the Integrity of the nuclear spent fuel also be intact during the strong earthquake motions

- **Seismic Response of Non-Fixed Storage Cask**
  - **Concrete Cask has Multiple Gap Structures**

Annulus space for cooling air between Canister and Container

Gap between NSF and Basket

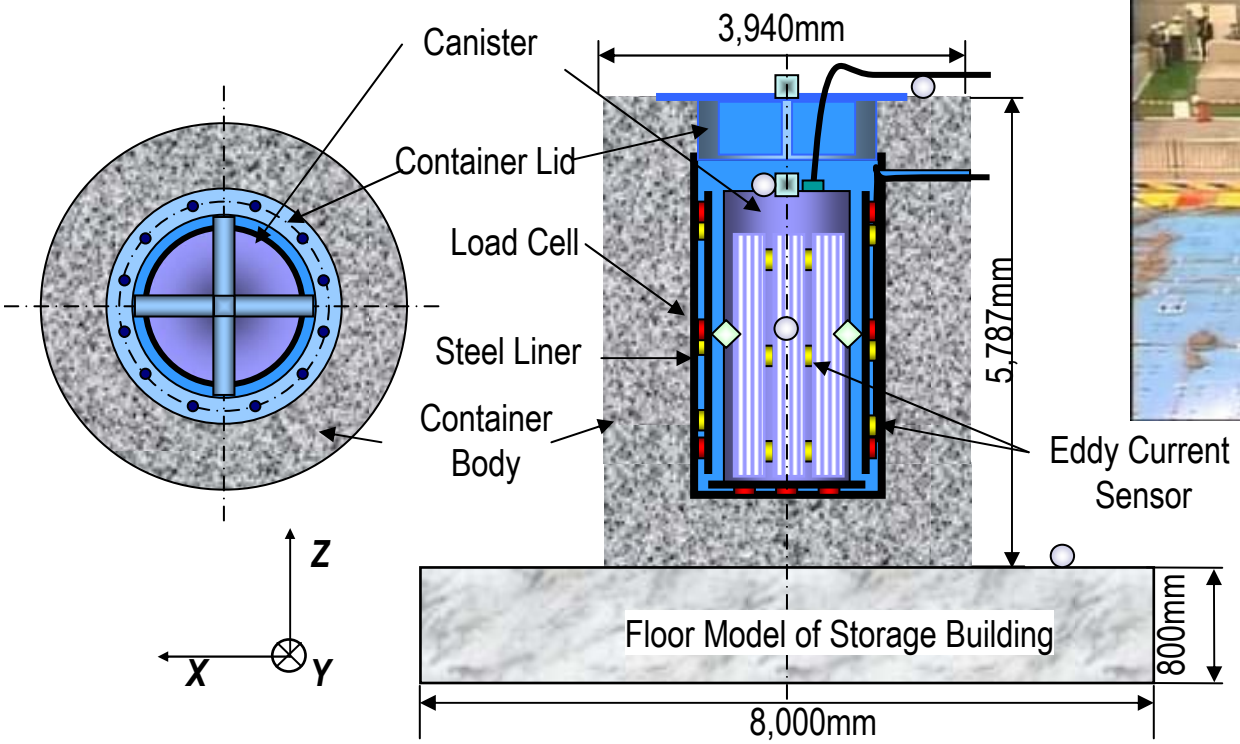
Rocking, Sliding and Jumping behavior



- **Complicated seismic response of NSF with interactive reaction force**

Seismic Tests of Concrete Cask

- National Research Institute for Earth science and Disaster prevention (NIED)
- 3-D Full-Scale Earthquake Testing Facility “E-Defense “
- Full-Scale Concrete Cask : Outer Diameter 4m, Height 6m, Weight 190ton
- Full-Scale MPC with 1 17X17PWR and 20 Dummy PWR Fuel
- Floor Model : Width 8m, Height 0.8m, Weight 125ton

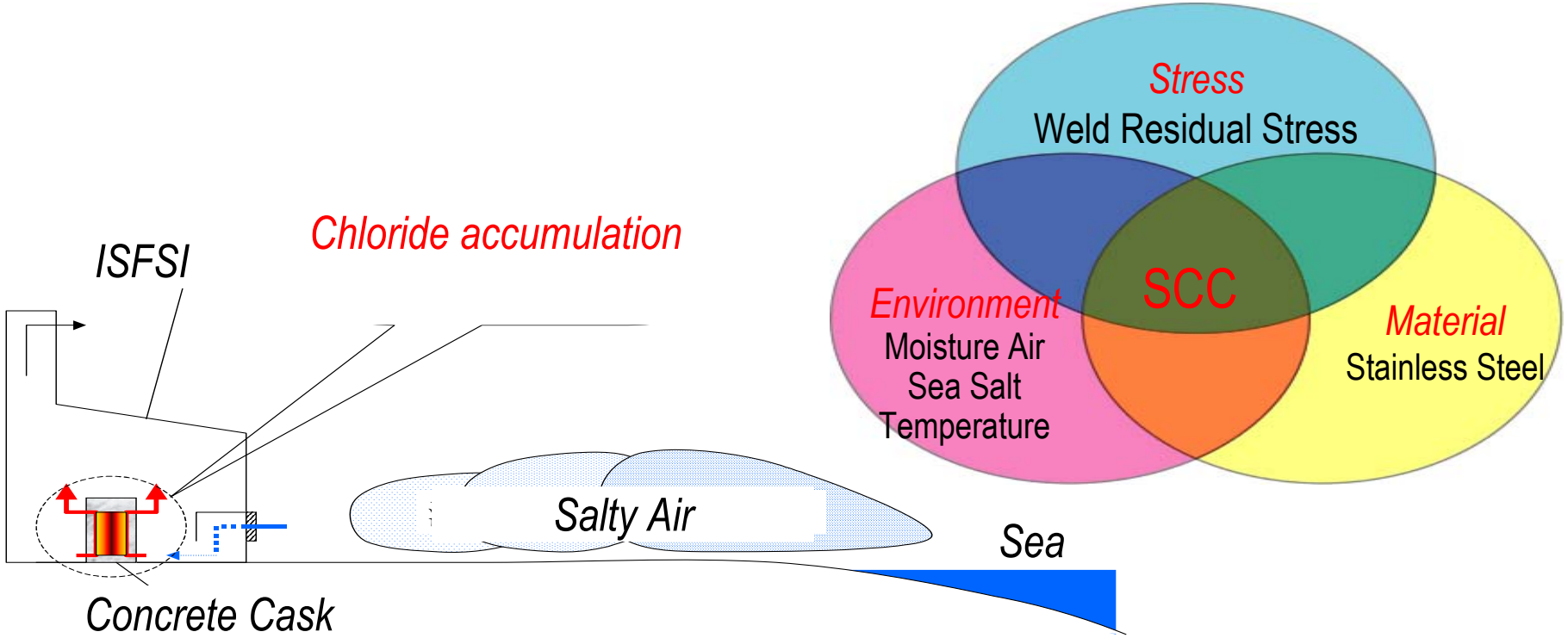


Measuring Items

- *Acc. A(x,y,z)*
- *Disp. D(x,y)*
- *Angle, Angular Vel. ω, θ (x,y)*
- *Strain $\varepsilon(\theta,z)$*
- *Impact Load I.L.. (x,y,z)*

Deterioration of Metal Canister in Salty Air Environment

- *ISFSI in Japan is likely installed at coastal sites*
- *Temperature decreases during storage period and salt condensation increases on canister*
- *Austenitic stainless steel : Vulnerable for SCC under a certain unique set of circumstances*
- *Cause a loss of containment ?*

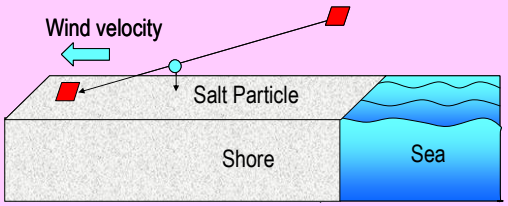


Key research items for SCC in CRIEPI

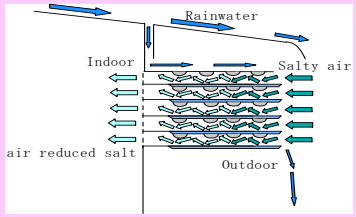
Evaluation of salt amount on the heated canister surface

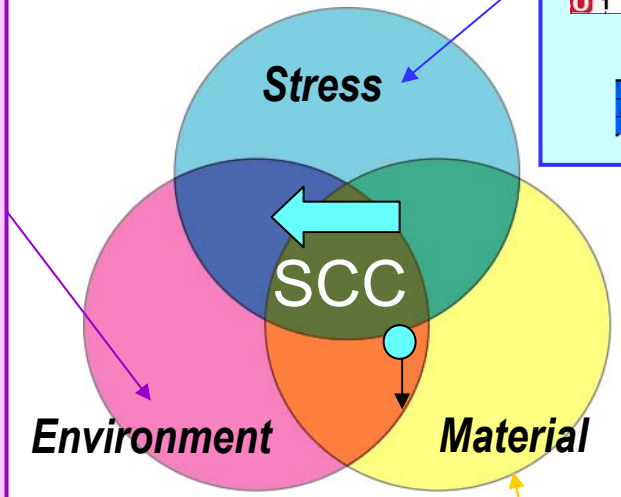
Measurement of salt concentration in the air

Diffusion analysis for the wind-driven sea salt particle

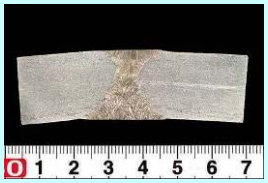


Development of salt particle collection device

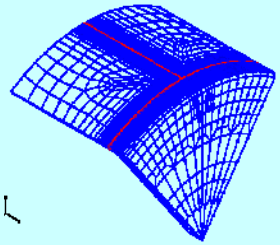


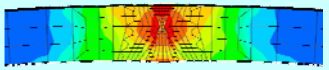


Weld residual stress test



Weld residual stress analysis



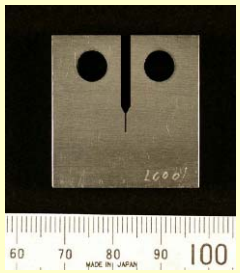


Canister Surface Inspection Test at INL

Corrosion test

Crack initiation test

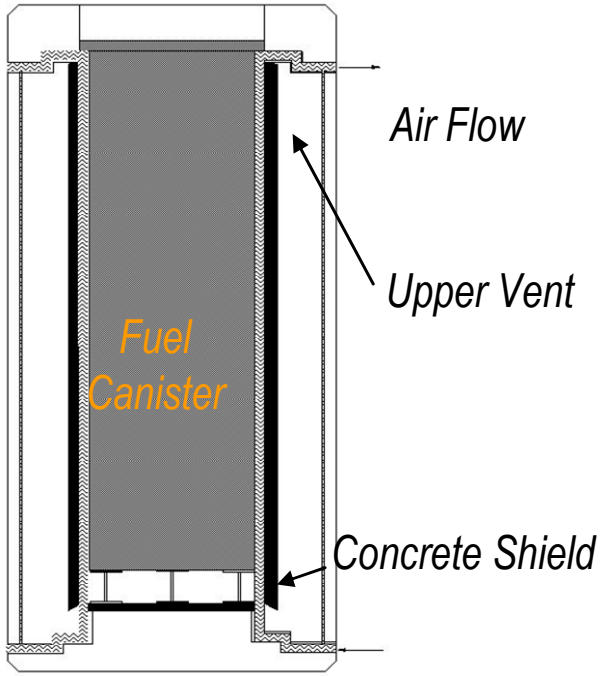
Crack growth test



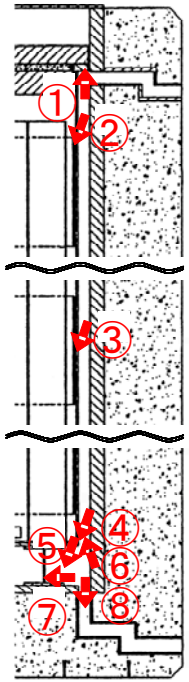
Long-term Performance of Canister in Concrete Cask at INL

- *INL Dry Cask Storage Experiences*
  - *Part of a demonstration program from DOE*
  - *6 casks (MC-10, 125B2, CastorV-21, REA2023, TN24P, VSC-17)*
  - *Stored from 1991.January (over 15 years storage)*
  - *Casks are monitored for temperature, fission product release to the fill gas, and external radiation levels*

(at INL, 2004.Dec.)



Canister Surface in Concrete Cask Storing SF for 15 yrs at INL



① Annulus top

②MPC top

③MPC middle

④MPC bottom

⑥Support structure plate

⑦Support structure side

⑧ Annulus air inlet

Visual inspections revealed some surface rust present but no large scale flaking. No gross corrosion, pitting, or general attack, and all coatings appear to be intact.

Summary

- *In Japan, utilities are planning to commence the operation of the first ISF in 2012. Regulatory authority correspondingly modified the reactor regulation law and has been settling the relevant safety rules to operate the interim storage facility. To prepare the safety requirements and promote the rational reviewing procedure for the application of ISF establishment license, CRIEPI is steadily performing the key research studies, which includes degradation of cask component materials, leakage from the lid at accidents during the subsequent transportation after storage.*