Siempelkamp

Nukleartechnik

Content

- Seismic Event
- Corrosion Resistance
- Seal Ageing
- Stress corrosion cracking

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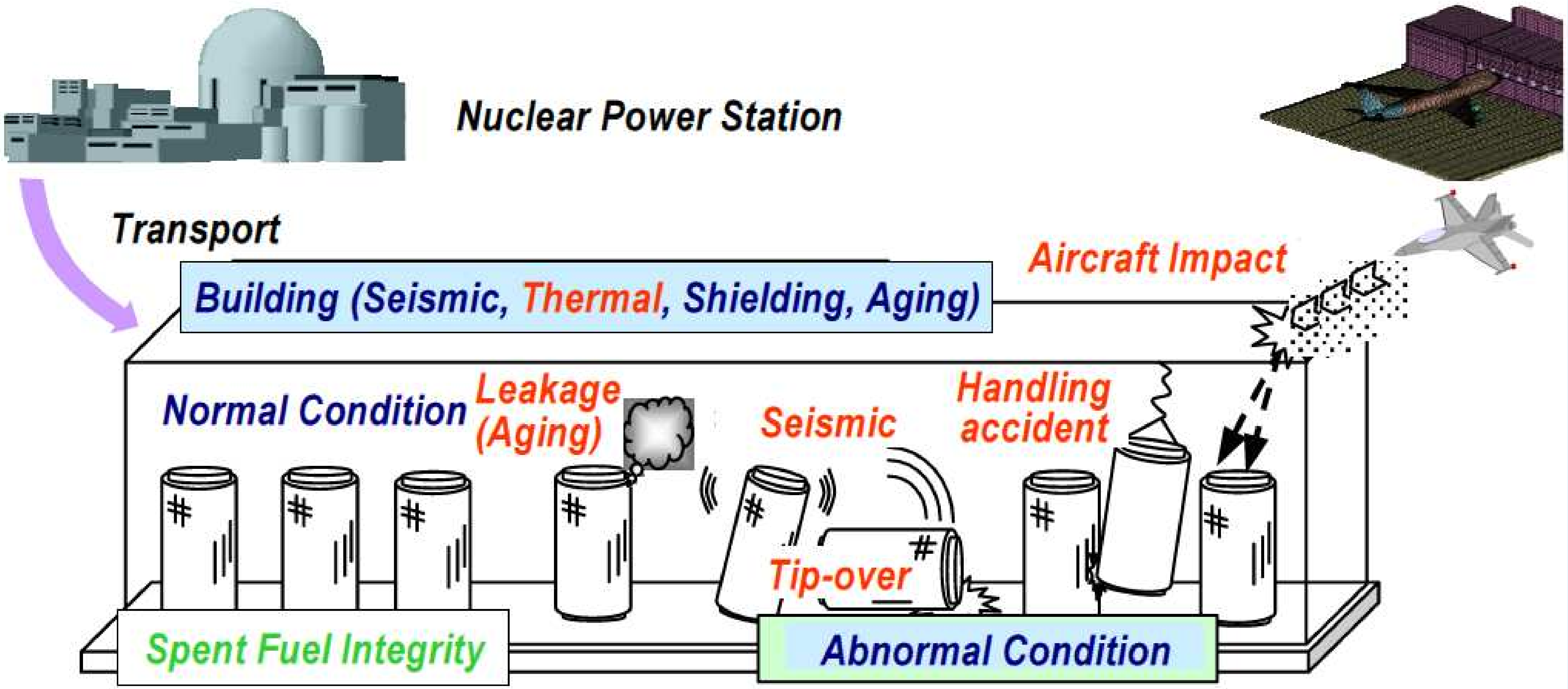
Seismic Event

Safety Evaluation Scenario for Metal Cask



Source: IAEA-CN-178/KN24 2010

Interim storages

Surry/USA

Philippsburg/Germany

The DCI cask can be stored in a horizontal as well as in a vertical position.

For seismic events the DCI casks can be fixed at the surface using a trunnion fixation.
The DCI cask has four trunnions at the bottom side where the cask can be fixed.

Even when there is no fixation on the surface and a cask tipps over during a severe earthquake, the damage to the DCI cask is negligible.

Seismic Events

JSC Engineering Center for Nuclear Containers

APPROVE

Deputy Director General –
Chief Designer
A.A.Zubkov
«12» 02 2014 г.

TRANSPORT PACKAGING SET
TUK-153

Seismic Analysis
02-142.01PP7

Deputy Chief Designer — A.V. Rodin
Principal Engineer — V.V. Mukhin
Principal Design Engineer — V.I. Vasilyev

Saint Petersburg
2014

First Application | Ref. No | Signature and Date | Copy Inv. No | Repl. Inv. No | Signature and Date 30.04.2013 | Original Inv.No 5029

Example in Russia:
According to Russian regulatory document "НП-031-01" the DCI cask is classified as category I in terms of its importance to safety in the event of an earthquake.
The document "НП-031-01" was based on IAEA SAFETY SERIES No. 50-SG-D15 (Seismic Design and Qualification for Nuclear Power Plants)

According to IAEA the cask is also classified as category I.

Result: The seismic calculations demonstrate that in case of a seismic emergency the DCI cask strength is ensured and its integrity and functionality is maintained!

Corrosion resistance

Corrosion Resistance

Cask Storage History

Open air storage by INEEL of CASTOR® V/21

First stored casks:

- **CASTOR® Ic-Diorit (ZWILAG, CH) since 1983**
- **CASTOR® V/21 (Surry, USA) since 1985**
- **CASTOR® THTR/AVR (Ahaus, D) since 1992**
- **CASTOR® THTR/AVR (Jülich, D) since 1993**
- **CASTOR® V/19, CASTOR® IIc,
CASTOR® HAW 20/28CG (Gorleben, D) since 1997**

Cask storage over 30 years periods

Corrosion Resistance

CASTOR® V/21

- **NUREG-Report CR-6745**

  "There is no evidence of degradation of the CASTOR® V/21 cask systems important to safety from the time of initial loading of the cask in 1985 up to the time of testing in 1999"

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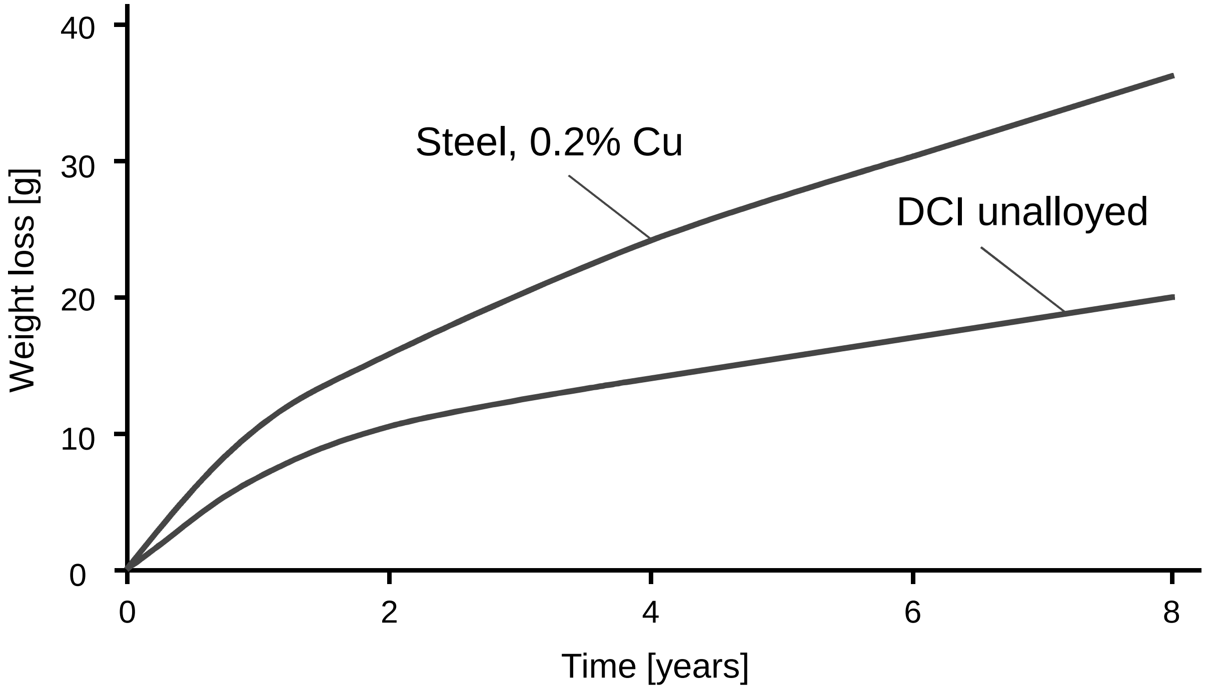
GNS

Corrosion Resistance

Corrosion

Ductile Cast Iron in comparison with Steel



- **Nodular graphite makes the difference**
- **Corrosion resistance highly advantageous for final storage**

- **DCI provides favourable characteristics for long-term integrity against corrosion due to the structural material (graphite pearlite) and the increasing passivation layer**
- **Hence, the relevant safety requirements can be assured even under long-term aspects**

Source: S. Hasse, Duktiles Gusseisen, Schiele & Schön, 1996

Corrosion Resistance

Corrosion Studies on the Material Combination Used for the POLLUX Cask for Direct Disposal of Spent Fuel Elements in Rock Salt Formations; E. Smailos "Korrosionsuntersuchungen an der Werkstoffkombination des POLLUX-Behälters zur Direkten Endlagerung abgebrannter Brennelemente in Steinsalzformationenen" KfK 4552 (KfK: research centre Karlsruhe):

Summary of the results
The corrosion behavior of nodular cast iron was not significantly influenced by the simultaneous corrosion of all the other POLLUX materials.
The corrosion attack was non-uniform and the corrosion rates are about 65 µm/a in the NaCl-rich brine and for 200-210 µm/a in the $MgCl_2$-rich brines.

Storage time: 100 a
Multiplied by the corrosion rate: 100 a * 210 µm/a = 21 mm in 100 a
Wall thickness: 400 mm

→ **corrosion can be neglected**

Seal ageing

Test Program for Metal Cask Storage (BAM)

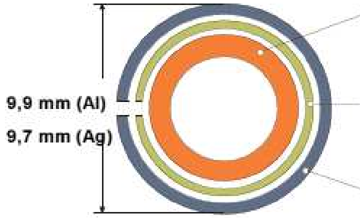
PATRAM 2010 *London, UK*

BAM: German authority

Investigation of Metal Seal Resistance

Typical cask seal of the Helicoflex® type →

Required standard helium leakage rate
$Q_{He} < 10^{-8}$ Pa·m³/s



Helical spring
(stainless steel 2.4969)
Inner jacket
(stainless steel 1.4307)
Outer jacket
(Al 3.0255 or Ag 99.99)

Test series to demonstrate long-term resistance

(1) CEA Atomic Energy Commision (France):

- 1973 – 1984 six test seals (1,9 m and 3.6 m outer Ø) with > 650 thermal cycles between ambient temperature (+20°C) and +130/150°C to increase ageing mechanisms
- since 1984 (25 years) continuation of test series at ambient temperature (+20°C) with helium leakage rate measurements twice a year

(2) CRIEPI Central Research Institute of Electric Power Industry (Japan):

- since 1990 two full-scale test seals (outer jacket of Al and Ag) at 160°C

→ Results so far: no significant changes in leakage rates

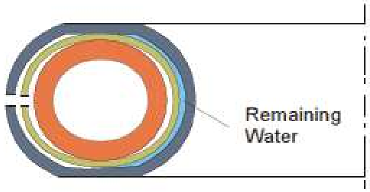
Source: BAM; Patram 2010

Test Program for Metal Cask Storage (BAM)

PATRAM 2010 London, UK

BAM corrosion tests with water in the gap between inner and outer seal jacket since 2001

→ boronated pool water (2400 ppm)
→ 10^{-3} mol sodium chloride dissolution



Result: no leakage rate increase so far!

Leakage rate measurements with seals prepared with defects in the outer jacket

Result: no leakage rate increase!

Holger Völzke
BAM III.4

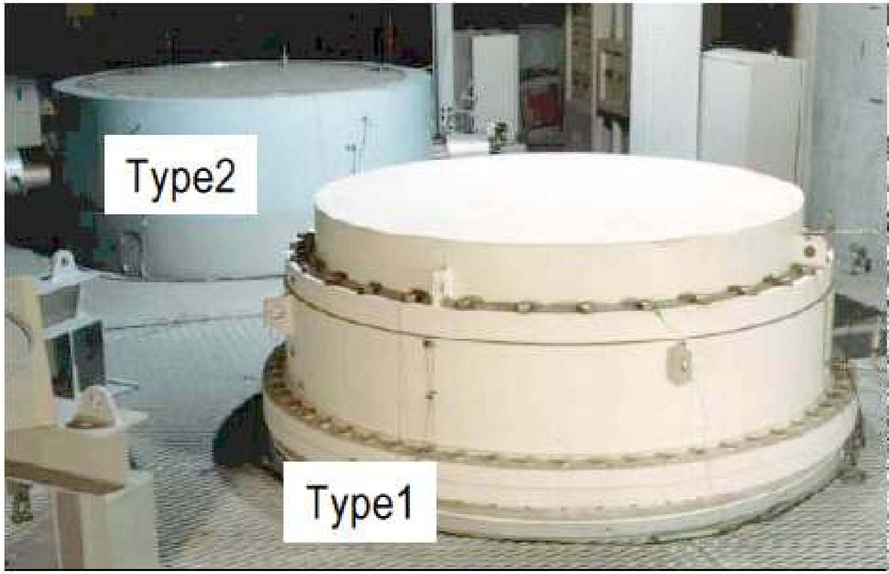
Oct. 07, 2010

9

Source: BAM; Patram 2010

Long-term Confinement Test (1) (Japan)

- *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
電中研
金属キャスク長期密封性能
100年間の健全性確認

Source; IAEA-CN-178/KN24 2010

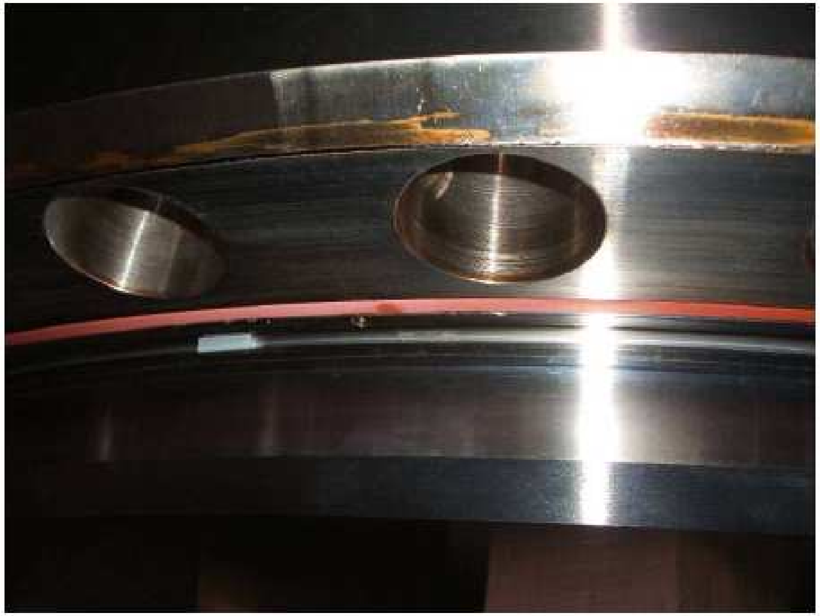
Long-term Confinement Test (2) (Japan)

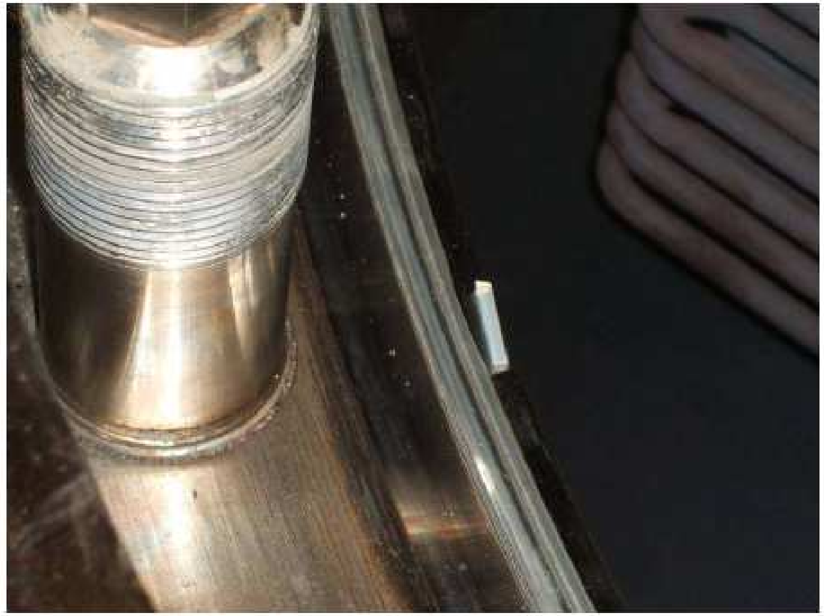
To confirm the characteristics of metal gaskets after thermal aging

- *Open the lids*
- *Verification of components*

  Elastomer Gasket, Silver Gasket, Aluminum Gasket

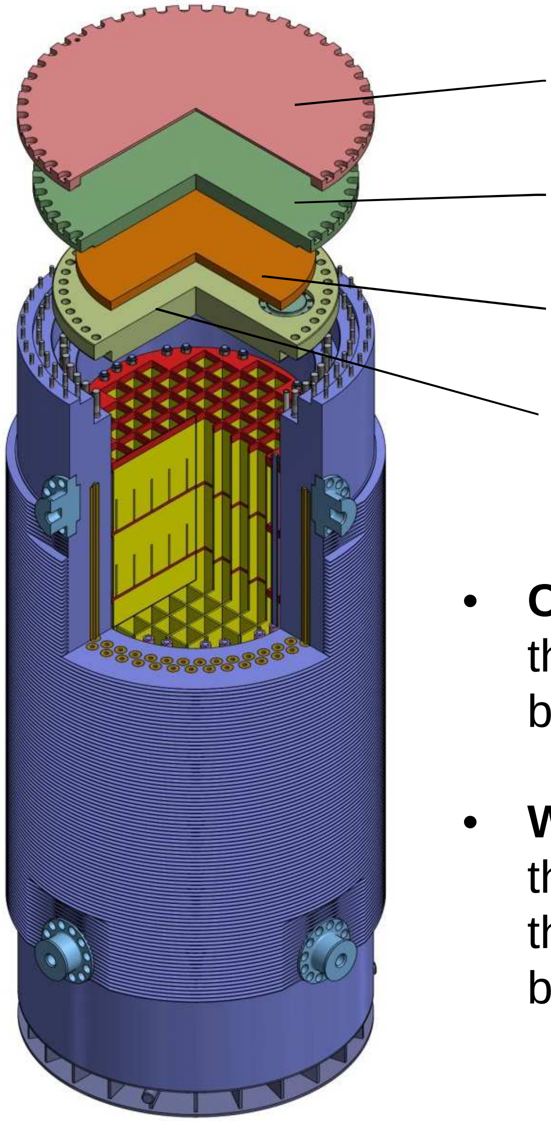
  Tightening bolt, Pressure gauge, Surface condition of the flange and so on.





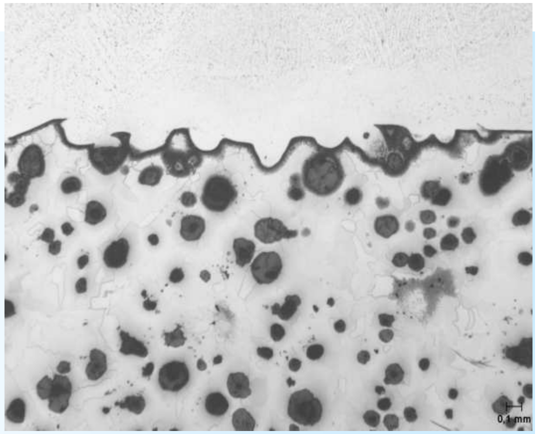
Source: IAEA-CN-178/KN24 2010

Options for a seal leak



NiFe-
weld
material

Base
material
EN-GJS-400



Microstructure of welded zone (etched)

- **Change the seals of the secondary lid**
  the shielding protection during this procedure is still given
  by the primary lid and the moderator plate

- **Welding of the secondary lid to the cask**
  this procedure is qualified and licenced by the BAM (German authority);
  the shielding protection during this procedure is still given
  by the primary lid and the moderator plate

Stress corrosion cracking

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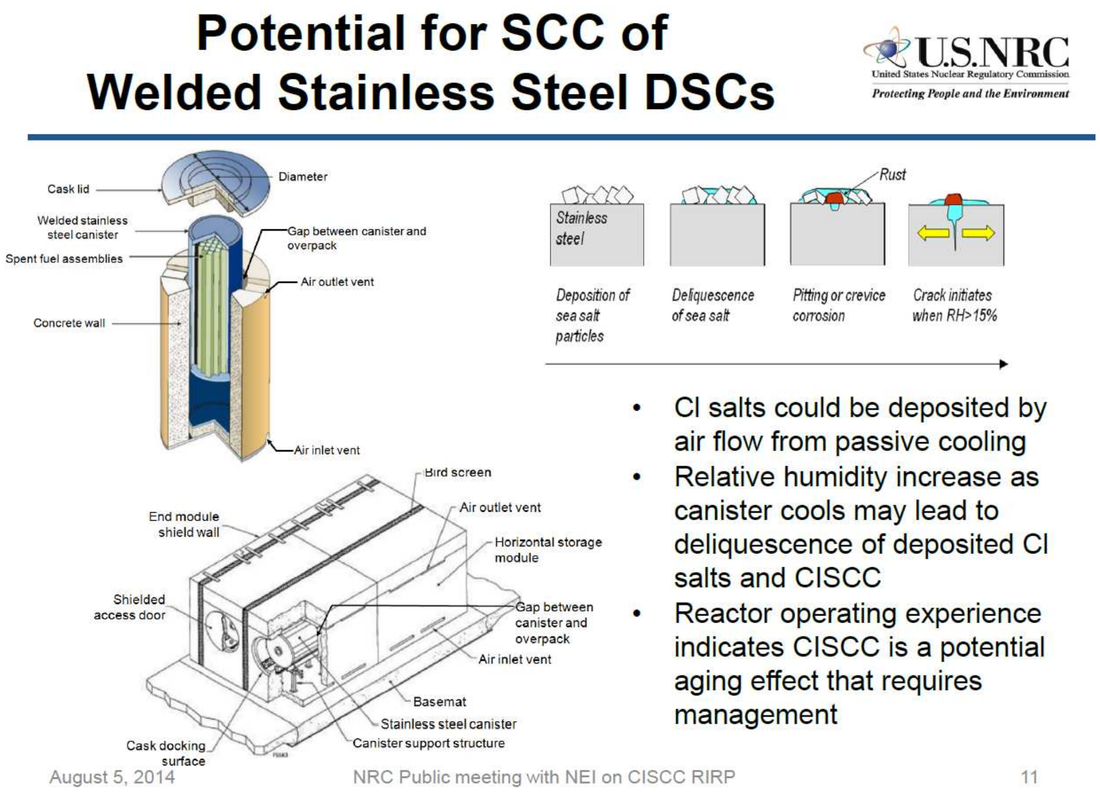
Potential for Stress Corrosion Cracking (SCC) for DCI (1)



Source: D.S. Dunn, NRC Public Meeting, August 2014

- **DCI with chloride-containing solutions is no critical corrosion system for SCC; DCI has a good corrosion resistance against salts and solution of salts**

  ⇨ less actions for aging management

- **Impurities and stresses from welds increase the susceptibility for SCC**

  ⇨ CASTOR® and TUK cask bodies have no welds

- **Experience from NRC:**

  “Based on the 1999 examination and testing results, there was no evidence of cask, shielding, or fuel rod degradation during long-term (14 years) storage that would affect cask performance or fuel integrity. There was no evidence of exterior or interior cask deterioration during storage period, nor were there any signs of seal or shielding failure.” (from NUREG/CR-6745)

Potential for Stress Corrosion Cracking (SCC) for DCI (2)

For stress corrosion cracking three facts has to be exist:

- The material has to be sensitive to stress corrosion cracking
- Tensile stresses
- A specific corrosion aggressive medium

In ductile cast irons the inner stress is compression (given by the physics of the DCI).

As one of the three necessary requirements does not exists, stress corrosion cracking is no object for DCI