AGING MECHANISMS INFLUENCE ON TRANSPORT SAFETY OF DUAL PURPOSE CASKS FOR SPENT NUCLEAR FUEL

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An Integrated Approach to the Back End of the Fuel Cycle

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(1) Dry Storage of Spent Fuel in Dual Purpose Casks

(2) Integrated Safety Case Approach for DPC / IAEA TECDOC

(3) DPC related Proposals for Changes of the Transport Regulations

(4) Aging Management Issues of Transport Package Safety

(5) Gap Analysis of the DPC Transport Package Safety Case during long Storage Periods

(6) Inspections before Transport after long Storage of DPC

(7) Conclusions

Dry Storage of SNF&HLW in Dual Purpose Casks

Dry Storage Cask Facility Gorleben; Current Inventory:
- 108 HLW Casks (1 TS 28V, 74 CASTOR HAW 20/28CG, 12 TN 85, 21 CASTOR HAW28M)
- 5 SNF Casks (1 CASTOR Ic, 1 CASTOR IIa, 3 CASTOR V/19)

Foto: GNS (2010)

Differences between DPC Transport Package and DPC Storage Cask

….to be considered in their Safety Cases

DPC Transport Package:

- Impact limiters at bottom and lid side,
  in some designs also circumferentially
- Transport in horizontal position, under canopy
- Acceptance criteria: SSR-6 (e.g. accident test conditions: 9m drop/1m puncture/30 min fire)

DPC Storage Package:

- No impact limiters (on the cask)
- Secondary lid/seal with monitoring
- Protection lid
- Vertical position, inside hall
- Acceptance criteria: national storage req.
  (e.g. on-site transport and handling accidents)

2 Dual Purpose Cask configurations:
Different acceptance criteria lead to different DPC specifications which have ONE „core assembly"
(contents, basket, body, primary lid)

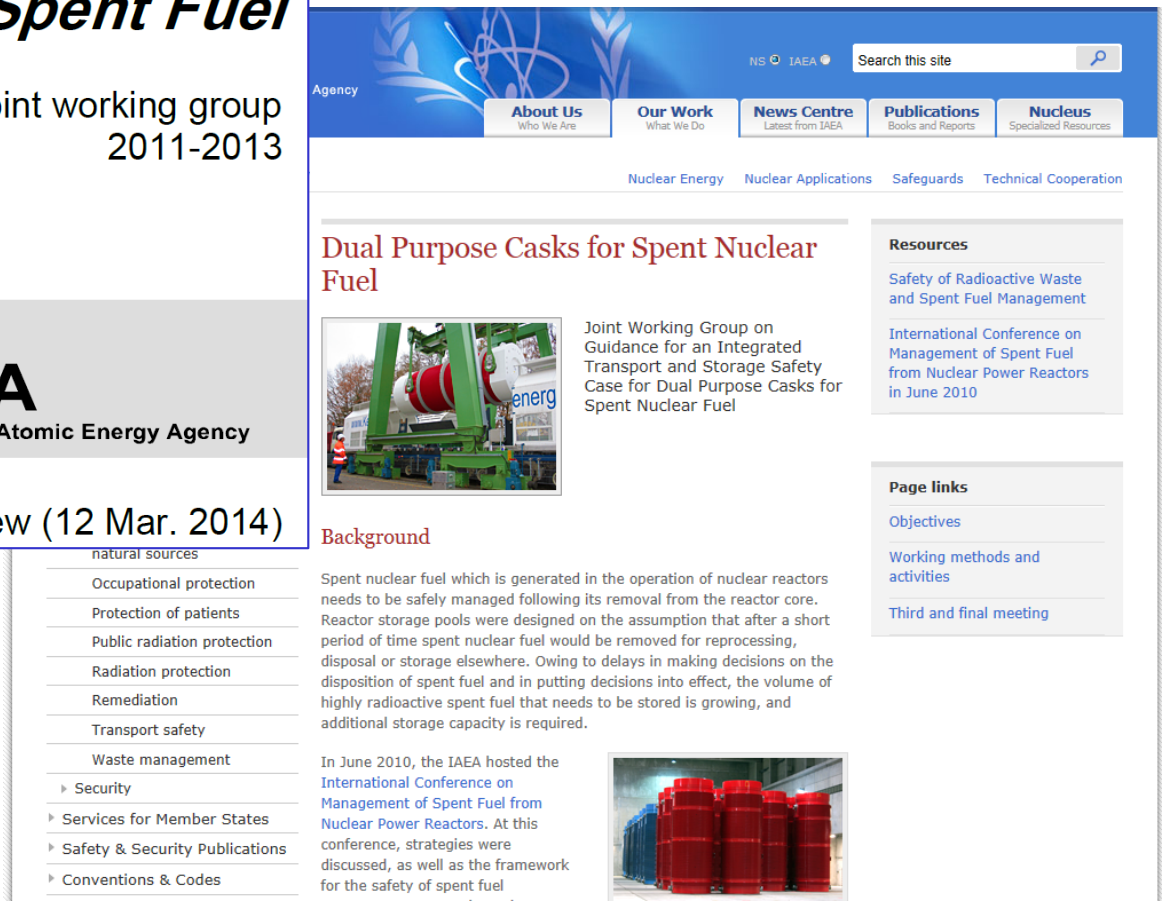
IAEA Approach for an Integrated DPC Safety Case

Preparation of a Safety Case for a Dual Purpose Cask for Storage and Transport of Spent Fuel

Draft report of WASSC/TRANSSC joint working group
2011-2013

IAEA
International Atomic Energy Agency

Draft for IAEA internal review (12 Mar. 2014)



[WG webpage](http://www-ns.iaea.org/tech-areas/waste-safety/spent-fuel-casks-wg.asp?s=3)
http://www-ns.iaea.org/tech-areas/waste-safety/spent-fuel-casks-wg.asp?s=3

Proposals for changes of SSR-6, derived from IAEA meetings, and proposed by Japan in the SSR-6 revision cycle

§106 : addition of **„shipment after storage“** to the **scope of the regulations**

§ 503: Before each *shipment* of any *package*, …..
(e) For *packages* intended to be used for *shipment* after storage, it shall be ensured that all *packaging* components and *radioactive contents* have been maintained during storage in a manner such that all the requirements specified in the relevant provisions of these Regulations and in the applicable certificates of *approval* have been fulfilled.

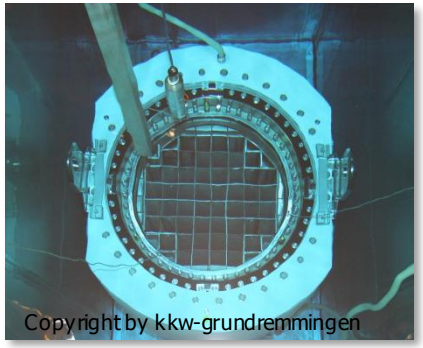
§ 614bis: The *design* of *packages* intended to be used for *shipment* after storage shall take into account ageing mechanisms. (Explanation of Ageing Management Program, which should be included in the Management System, is provided in SSG-26 paras 306.4 and 306.4bis.)

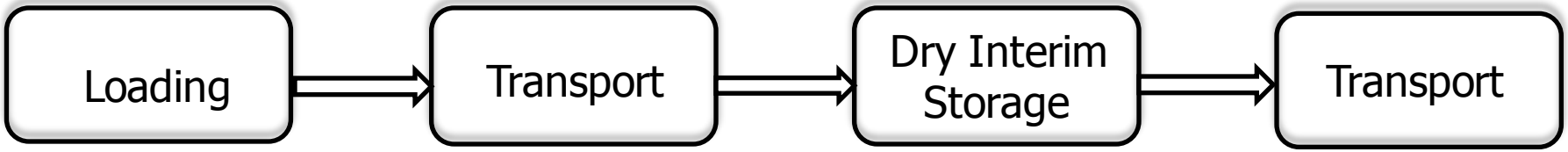
§ 809. An application for *approval* shall include:

(f)bis If the *package* is to be used for *shipment* after storage, the applicant shall state and justify the consideration of ageing mechanisms on the safety analysis and within the proposed operating and maintenance instructions.

(j)For *packages* which are used for *shipment* after storage, a gap analysis program shall be provided. The gap analysis program shall describe a systematic procedure to consider changes of regulations, changes in technical knowledge and changes of the state of the *package design* during storage. (Explanation on Gap Analysis Program is provided in SSG-26 para. 809.3.)

Operational phases to be considered for the assessment of material compatibility and variation of component properties due to aging effects

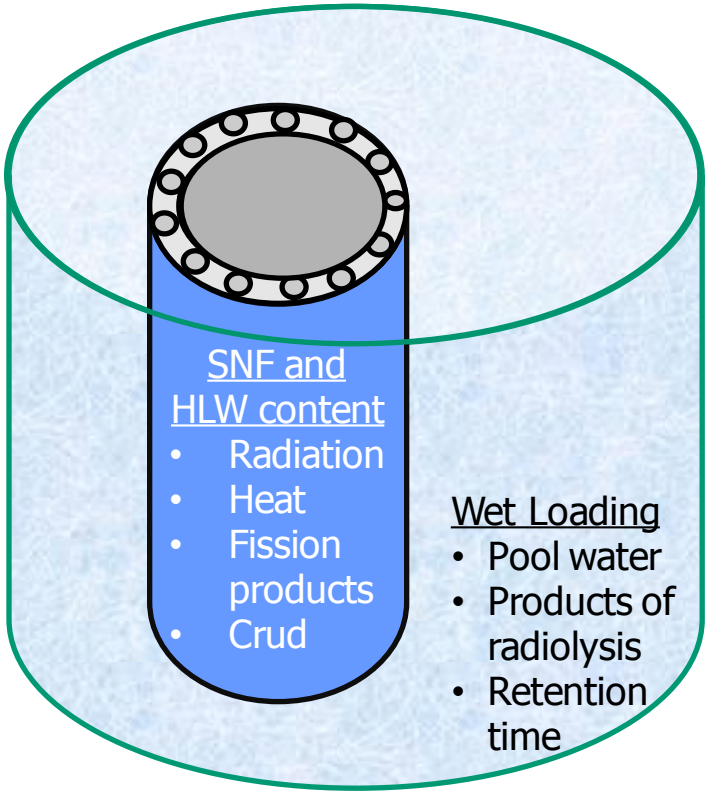




- From these operational phases one can derive boundary conditions for the analysis of aging effects and chemical and physical compatibility of a single material and of materials/components among each other
- Probable forms of metal corrosion as well as degradation phenomena of packaging materials, components and radioactive content induced due to radiation and/or heat have to be assessed for cask design approval.

[S. Schubert et al., PATRAM 2013]

Cask Loading



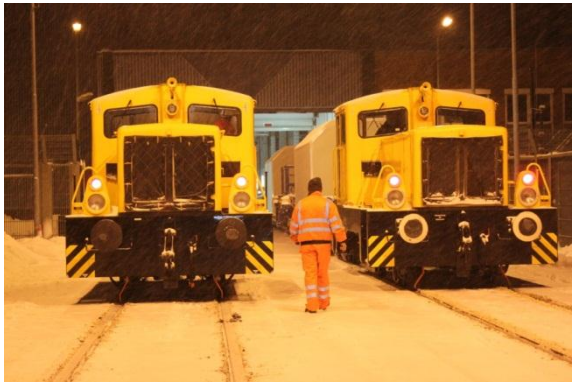
Cask Storage

All effects under long term considerations

Cask Transport

Environment

- Water
- Humidity
- UV-Radiation
- Temperature
- Atmospheric pollution



Changes of a material/component can be generated, e.g. by

- Corrosion, creep, fatigue of metals
- Enclosure of hydrogen, hydrogen embrittlement
- Changes in the lattice structure of metals
- Cross-linking and degradation of polymers
- Aging of surface protection, shock absorbing materials etc.

Design considerations to limit **aging effects** (e.g. proper material/component selection) and **operational conditions** to limit access of damaging agents (e.g. drying/evacuation, humidity control) are important issues of safety assessment, package design and management system approval.

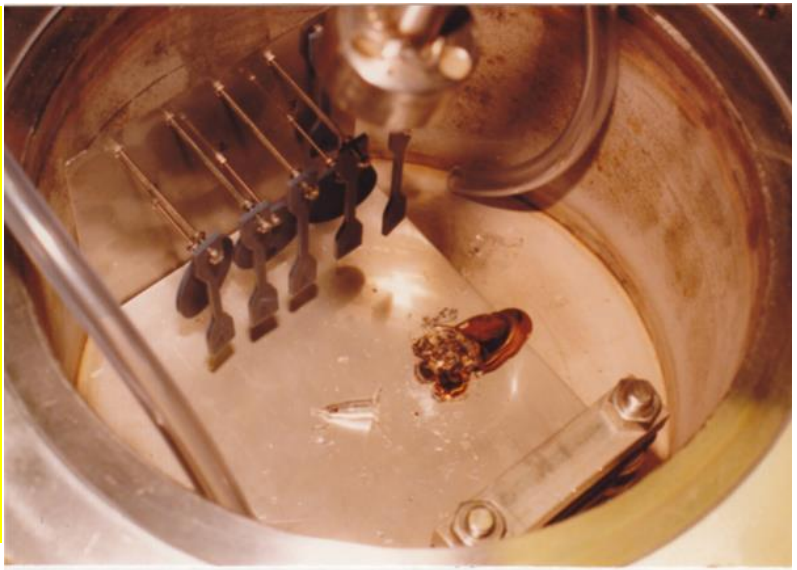
Component Material	Material	Degradation factors	Design consideration
Neutron shielding	Resin, polyethylene	Thermal, radiation	Establishment of weight loss rate of neutron shield material in shielding analysis.
Basket	Aluminum alloy, boron-aluminum alloy; neutron absorbers	Thermal, radiation	Establishment of allowable stress, considering ageing deterioration in structural and compositional analysis for criticality control.
Metal gasket	Aluminum, silver	Chemical, thermal	Moisture control and establishment of temperature limit of the metal gasket.
Elastomeric O-ring	EPDM, FKM	Chemical, radiation, thermal	Material selection
Cask body	Coating	Chemical	Inspection and necessary maintenance
Trunnions	Polymer sealants	Chemical	Inspection and necessary maintenance

For those components inside the cask and inside the lid closure system, which cannot be changed during the use, it is essential to capture all potential degradation influences at the initial assessment!

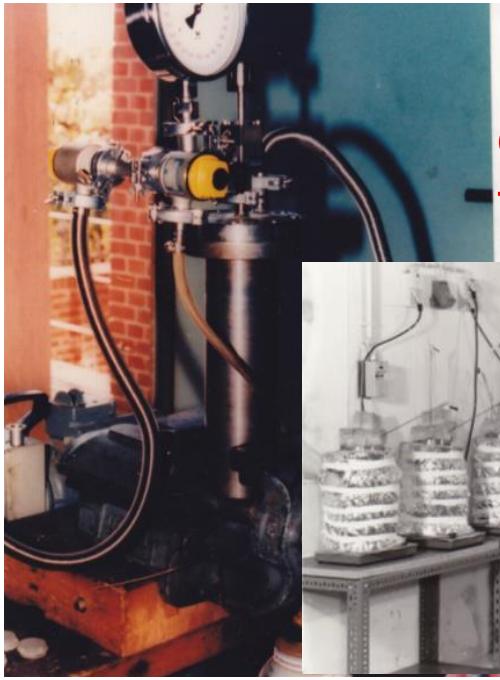
From IAEA-TECDOC-DRAFT "Preparation of a safety case for a dual purpose cask containing spent fuel"

Cs corrosion tests of the lid closures of 9 small heated containers (BAM,1992)

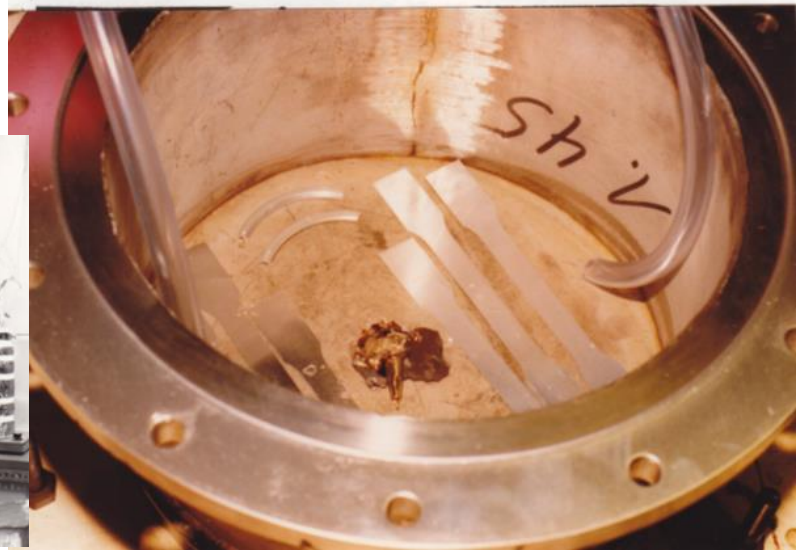
Can Cesium, released from defective fuel rods, cause corrosion of metal seals?



Cs corrosion test of Aluminum and Silicon specimen



BAM investigations could demonstrate that this is not the case!



The Problem of Aging Management (of the Cask, its Content, the Safety Case, the Design Approval Certificates, the Storage License etc.) and Transportation after some Decades of Storage

- Design assessment and approval of transport package design and safety evaluation in storage licensing should be linked effectively, ideally in an integrated, holistic approach, considering aging influences
- Permanent validity of transport package design approval certificate is the best measure for industry and authorities of constraint towards stable control and the safety case`s state-of-the-art improvement; in case of technical or regulatory changes a gap analysis to update the safety case has to be performed, or corrective actions before transport have to be planned and justified
- International cooperation, experience exchange and joint research is established, e.g. at IAEA, Joint TRANSSC/WASSC Working Group, Coordinated Reserch Project on extended SNF storage, USA/International, BAM/CRIEPI Colaboration etc.

IAEA-TECDOC
"Preparation of a safety case for a dual purpose cask containing spent fuel"

„Gap Analysis“:
Evaluation of the effects of changes of regulations, standards, scientific and technical knowledge on the safety case

Judgement if safety is sufficiently met, or development of compensating measures to justify the appropriate level of safety

Prerequisite for transport package design approval certificate renewal

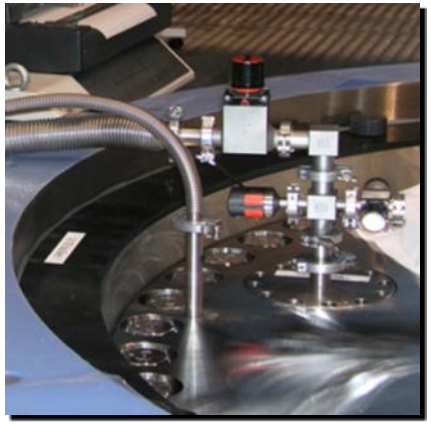
'Pure' Transport Packaging: after unloading, all sections accessible

➡ **system of periodic inspections**

Transport after Storage: **system of specific tests and inspections**

➡ accessible package sections

- visual inspections,
- load testing,
- replacement of components



➡ check of the containment system

- check of the pressure monitoring system,
- lid screws (tightening torque),
- leak-tightness

➡ measurements

- verification of shielding effectiveness

CASTOR© THTR/AVR

Interim Storage of SNF of decommissioned gas cooled high temperature research reactor in Jülich, Germany

- ✓ 152 casks loaded between 1993 - 2009
- ✓ Monolithic ductile cast iron cask body
- ✓ Double lid closure system (permanent pressure monitoring)
- ✓ Metallic seals
- ✓ Upper & lower pair of trunnions
- ✓ Bottom & top impact limiters (steel sheeted, wood filled)
- ✓ Up to 22 years in storage

© FZJ

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Transport preparation of

152 casks is ongoing

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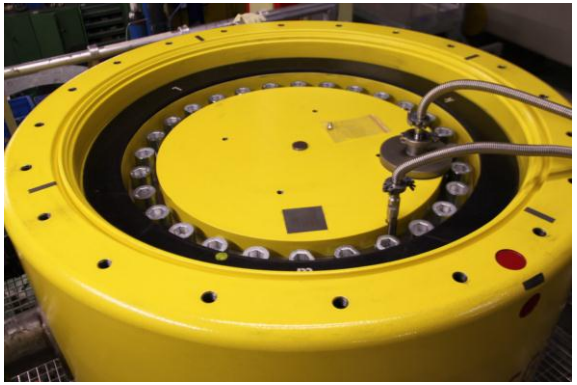
Preparation for shipment to another destination

Example:
Leak-Tightness Test



Example:
Repair & Testing
of Trunnions

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(1) Check of documentation of pressure monitoring system ✓

(2) Visual check of surfaces ✓

(3) Block-Position measurement of all lids ✓

(4) Examination of bolting torque of primary lid bolts ✓

(5) Leak-tightness tests of lid systems (33 primary lids) ✓

(6) All seals of 55 reassembled secondary lids renewed and leak-tight tested ✓

(7) Inspections of bolts and threaded holes (one hole repaired) ✓

(8) Check of trunnions, refurbished and replaced, 55 casks load tested ✓

CASTOR© THTR/AVR casks **fulfill** current regulatory requirements,
55 packages were inspected and tested (2014)

Transport ability was retained after more than 20 years of storage !

Essentials for aging management of dual purpose transport packages:

1. **Design that considers ageing resistance of components and materials**
   (materials aging assessment, corrosion resistant inner and outer surfaces/coatings, medium penetration barriers, quality in manufacturing/documentation etc.)

2. **Operational conditions that prevent degradation propagation and ingress of corrosive agents as much as possible**
   (drying, evacuation, inert gas atmosphere etc.)

3. **Periodic package design approval certificate renewal**
   (gap analysis of the safety case, management system adaption etc.)

4. **Inspection program for tests before transport**
   (appropriate selection of measures considering storage experiences etc.)