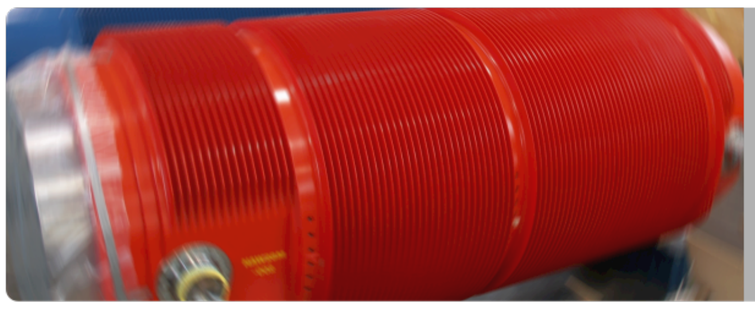
Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

TECHNISCHE UNIVERSITÄT DRESDEN

Institute of Process Technology, Process Automation and Measuring Technology

IPM HOCHSCHULE ZITTAU/GÖRLITZ



Development and testing of methods for the non-invasive analysis of the inventory status for transport and storage containers during extended interim storage - DCS-Monitor II

Project duration: 01.04.2020 – 31.03.2023
Project leader: Prof. Dr.-Ing. U. Hampel (TUD), Prof. Dr.-Ing. A. Kratzsch (HSZG)
Project employees: M. Wagner, S. Kobelt (TUD); S. Reinicke (HSZG)

Situation in Germany

- No availability of a long-term storage facility for heat generating high-level radioactive waste
- Since 01.07.2005 storage discharged spent fuel elements on-site of nuclear power plants presented by the German Atomic Energy Act
- Aim: availability of long-term storage in 2050 storage
- Approval of interim storages and TSC for 40 years
- Conflicting objectives:
  - Maximum safety and the broadest possible public participation
  - Short duration of the process (planning, approve and building)

  → Very unlikely opening of a long-term storages for heat generating high-level radioactive waste in 2050 /1/

  → Expected commissioning and start of storage according to the long-term storages commission only in the 21st century /1/

CASTOR® in the interim storage (nuclear power plant Neckar-westheim) Source: EnBW Energie Baden-Württemberg AG

Cooperative project

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF
IPM HOCHSCHULE ZITTAU/GÖRLITZ

Partners:

- HZDR / Dresden Technical University (TUD)
- IPM / University of Applied Sciences Zittau/Görlitz (HSZG)
- Supported by Federal Ministry for Economic Affairs and Energy

Motivation:

- Gaining information through "Look inside"
- Proving the safety of storing
- Providing support of the elongation of approval
- Increasing the thematical accaptance of general public

Tasks:

- Deep experimental and simulativ analysis radiographical diagnostics
- Development of measurment systems for gamma rays, neutrons and myons
- Qualification of diagnostics for a monitoring concept especially for csk typ CASTOR®
- Field studys on real casks in interim storages

>>> What has to be done when the approval of the intermediate storage and the CASTOR® expires? <<<

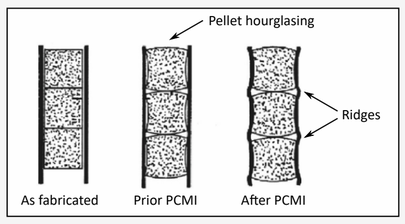
Possible damages of storage cask inventory

fuel assembly lifetime: reactor operation → dry interim storage

pellet-cladding interaction (PCI) during first operating times of fuel rods /2,3/

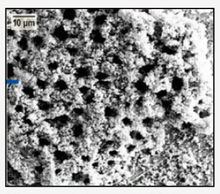
change of the outer fuel pellet matrix by formation of porous boundary areas /4/

change of the complete fuel pellet matrix by formation of fragments /2,4/



Schematic representation of the processes Oxide layers (white) on fuel rods /10/ leading to a pellet-cladding interaction /11/

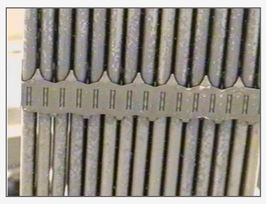
deposition of corrosion products (CRUD) on fuel rods and assemblies /7/



Microscopic image of CRUD particles deposited on fuel rods /7/

wall weakening of the fuel rod cladding tubes by mechanical abrasion (fretting) and corrosion /4,8/

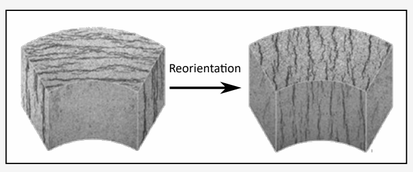
change of the material structure of fuel rod cladding tubes by hydride intercalation /5,6/



Oxide layers (white) on fuel rods /10/

deformation of fuel assemblies by flow forces /9/

Re-orientation of hydrids (formation of radial hydrids) /4,5,6/



Orientation of hydrides in cladding tubes during hydration (pic. (a); especially during reactor operation) and after re-orientation (pic. (b); especially during intermediate storage period) /5/

Temperature-dependent wall expansion of the fuel rod cladding tubes (creep) /4,5,6/

Cracked Zircaloy fuel rod cladding tube Source: Fabiola Testergebnisse

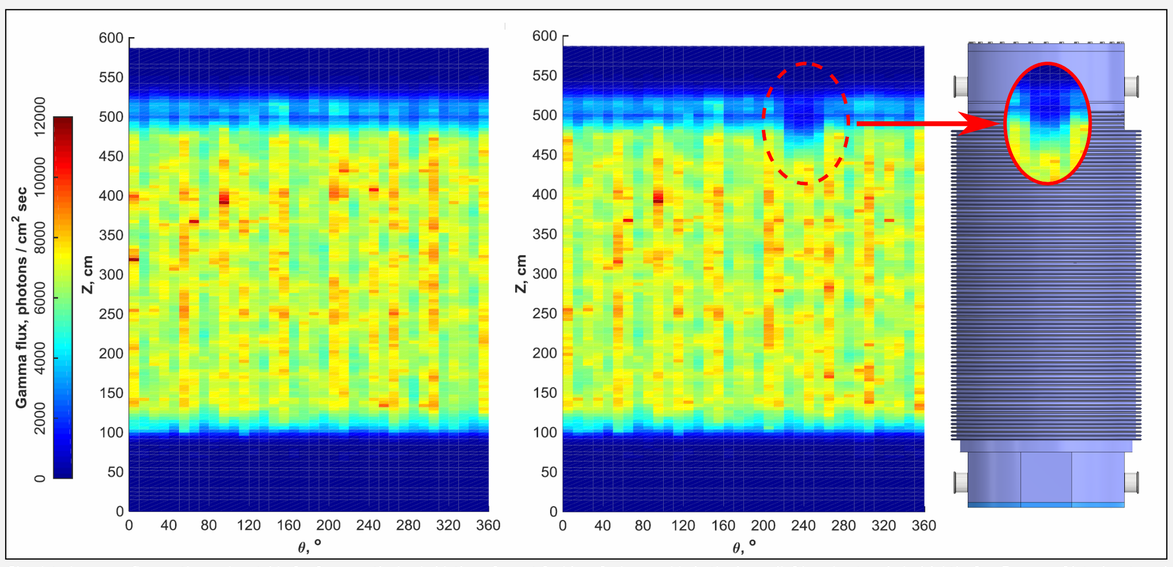
Possible loss of integrity of the fuel rod cladding tubes /4,5,6/

Possible release of fission products inside the CASTOR® /4,5,6/

Gamma- und neutron field

Simulation: Monte-Carlo (MCNP)

- Around the cask (CASTOR V/19®) with highly detailed cask and spent fuel models
- Supposed damage scenario:
  "Vertical subsidation of spent fuel um 9 cm for several fuel assembly positions"



Simulated gamma flux on the cask outside for 9 cm vertical subsidation of spent fuel in a fuel assembly in the inner (left) and outer circle (right) after 5 years of interim storaging

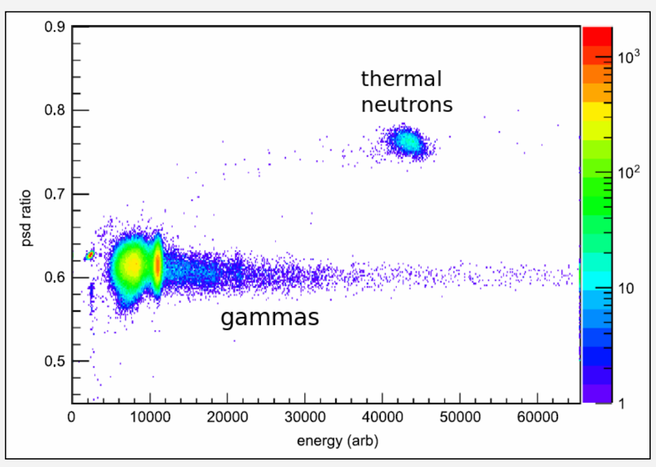
→ Vertical subsidation only for outer fuel assemblies detectable
→ Inner ones are shielded by outer ones and not analyzable
→ Radiation flux above the cask about magnitude orders smaller
→ Measurements in the lid area are not constructive

Measurements in real term conditions

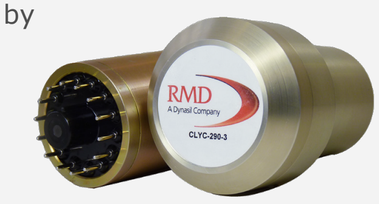
- With which side effects has to be dealed in the interim storage (e.g. neighbor casks)?
- How long are the measurement durations?
- How well can be differed between gamma rays and neutron occasions?

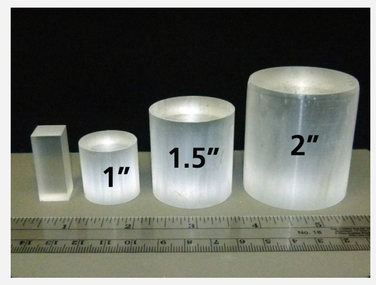
Dual detector - CLYC scintillator

- Material: Cs2LiYCl6:Ce Scintillation crystal
- Li-6 enrichment: ≥ 95 % → max. thermal neutron sensitivity
- Wavelength of emission: 275 - 450 nm
- Scintillation light yield:20.000 photons/MeV (gamma rays)
- GEE for thermal neutrons: 3.2 MeV
- Shielded and permanently mounted to a photomultiplier tube
- Discrimination between neutrons from gamma rays by Pulse shape discrimination (PSD)



Pulse-shape discrimination for CLYC, exhibiting distinct regions for gamma and thermal neutron events Source: www.arxiv-vanity.com/papers





CLYC detector and crystal sizes Source: www.rmdinc.com

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