Cooperation BAM/ITU on hot cell testing of SNF rod segments

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Outline

- **Spent fuel issues for transport**
  - Fuel rod behavior and assumptions in
    - Criticality safety analysis
    - Containment assessment
  - High burn-up fuel
  - Experimental testing

- **R & D**
  - Cooperation with Institute for Transuranium (ITU), Karlsruhe, Germany

- **Conclusions**

Spent fuel issues for transport licensing

Regulatory transport conditions (IAEA test scenarios)

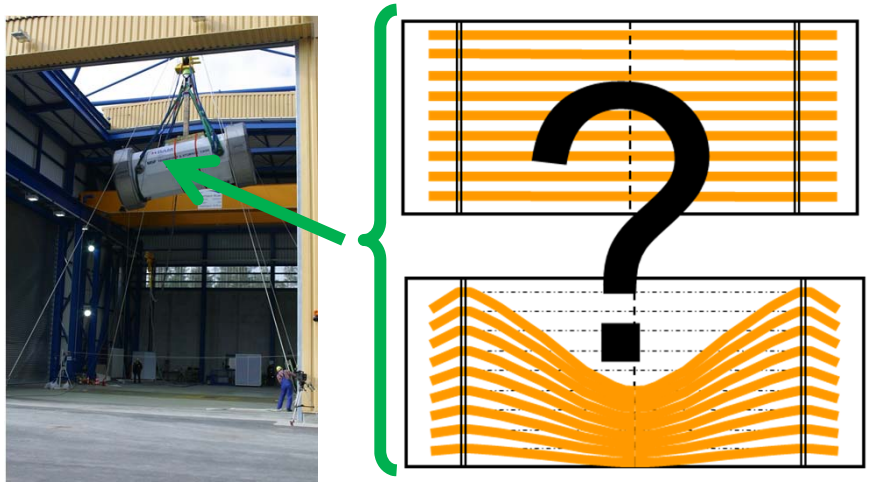
- **Routine** conditions of transport
  - Regular transport
  - No incidents

- **Normal** and **accident** conditions of transport
  - Impact loads of drop tests
  - Thermal load of fire test
  - Examples:
    - 0.3 m drop onto unyielding target
    - 9 m free drop onto unyielding target
      + 1 m puncture drop
      + 30 minutes fire at 800 °C

- BAM as competent authority for the mechanical / thermal design assessment for approved transport packages

Spent fuel issues for transport licensing

Interface for criticality safety analysis



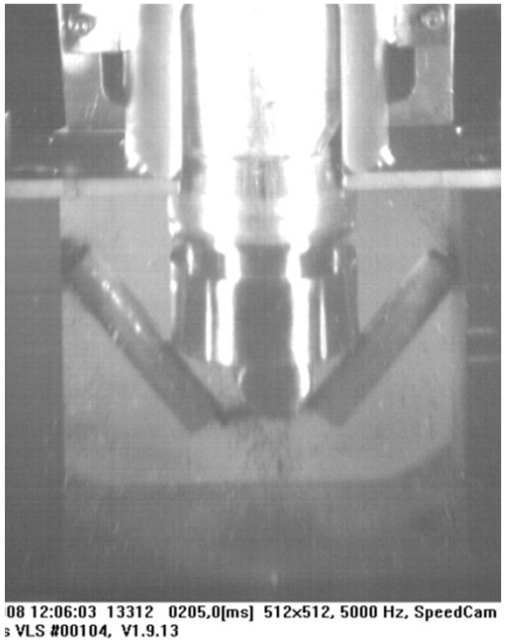
- Influence on criticality safety
  (accident conditions of transport)
  - Deformation of fuel assembly
    (distances between fuel rods)
  - Fuel rod breakage
    → evaluation of mass of fissile material in cavity

- Limited data
  → **simplified enveloping approach necessary**

Spent fuel issues for transport licensing

Interface for criticality safety analysis (cont'd)

- Assessment by BAM based on:
  - Deformation state → fracture points of fuel assembly (mechanical approximation with beam theory)
  - Amount of released fissile material per fuel assembly (based on experiments)
  - → Total amount of released fuel in cavity

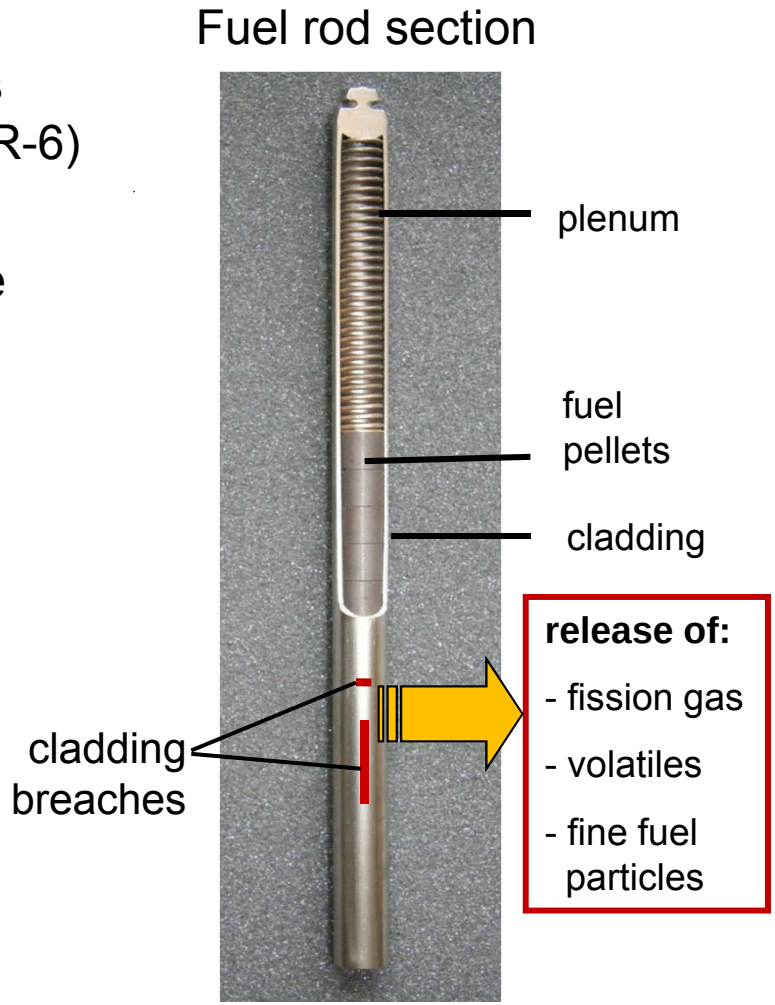


Source: *Papaioannou et al: Jahrestagung Kerntechnik, 12-14 Mai (2009)*

→ **Input for criticality safety analysis (BfS, Federal Office for Radiation Protection)**

Activity release calculation

- Maximum loss of radioactive contents specified in transport regulations (SSR-6)
- **Fuel rod failure and activity release**
  (normal and accident conditions of transport)
- Cladding breaches lead to:
  - Activity release into cask cavity
    (gas, volatiles, fine fuel particles)
  - Increase of cask internal pressure
  - → **Assumption of Failure rates**



Spent fuel issues for transport licensing

Activity release calculation (cont'd)

- **Failure rates** of fuel rods
  - Normal conditions of transport (e.g. 0.3 m drop)
    - 3 % for burn-up ≤ 55 GWd/t_U (based on NUREG/CR-6487 report)
    - 100 % for burn-up ≤ 65 GWd/t_U
  - Accident conditions of transport (e.g. 9 m drop)
    - 100 % for all burn-up (based on NUREG/CR-6487 report)

→ Amount of released fissile products in cavity

→ Containment analysis based on **standard leakage rate**

R & D - Motivation

Institute for Transuranium Elements (ITU), Karlsruhe, Germany

- **BAM**
  - Missing data about high burn-up fuel under RCT, NCT
    - Material behavior, failure rates

- **ITU**
  - Hot cell facilities
  - Stock of high burn-up fuel rods available for testing
  - High interest on experimental testing

- **Collaboration Agreement since 09/2014**

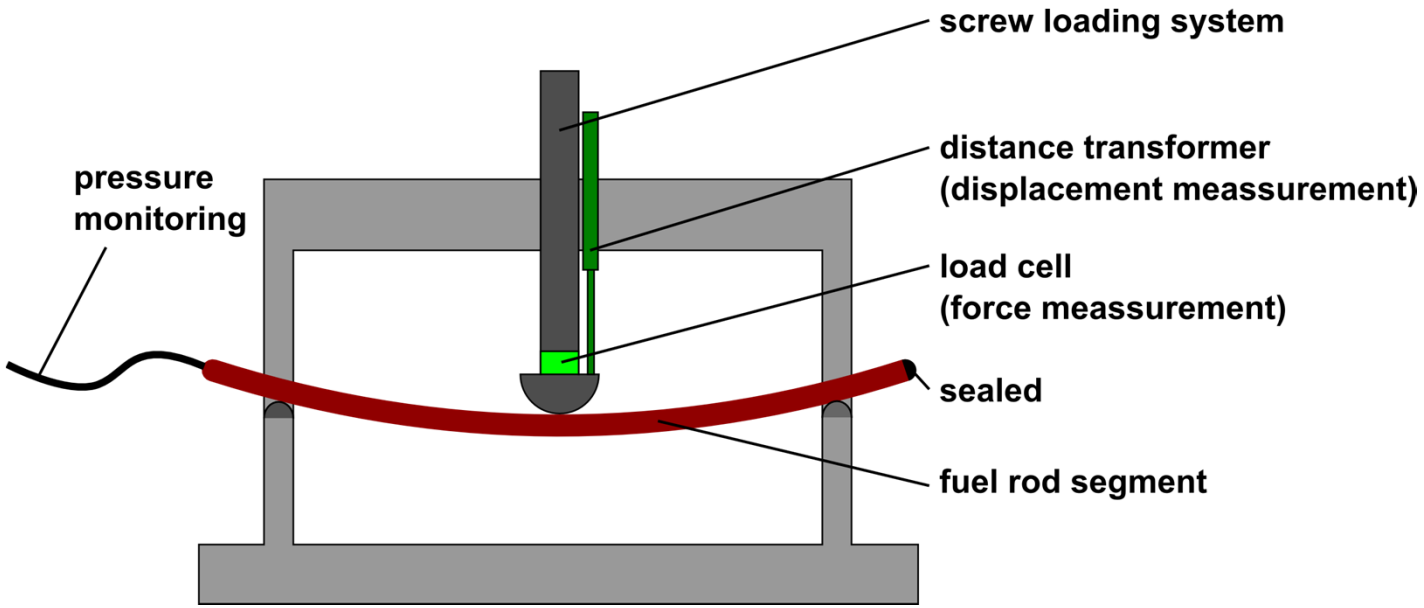
R & D - Concept

- **Joint proposal**
  - Simple set-up to start soon
  - Quasi-static 3-point-bending test of fuel rod segments
  - Pressure monitoring (leakage detection)
  - Loads up to pressure fall
  - Comparison with NCT free drop loads
    (e.g. equivalence of bending moments)

- **Goal**
  - Better understanding of fuel rod failure initiation

R & D - Experimental set-up (ITU)

- Testing of fuel rod segments in hot cell
- Internal pressure applied
- Load cell for force monitoring
- Distance transformer for displacement measurement
- Live monitoring of pressure in fuel-rod-segment



R & D - Update

- Cooperation agreement signed
- Horizontal set up
- Set up allows variable length of fuel rods segments
- Hand driven screw load system
- Screw caps with elastomeric gaskets for sealing of fuel rod
- Selection fuel rod segment with respect to
  - Burn-up unevenly distributed over the fuel rod length
  - Inhomogeneities in fuel rods (e.g. by spacers)

- **Device is currently under construction**

R & D – Way forward

ITU

- Coordination of experimental set-up
- **Manufacturing of testing device**
- Cold-testing
- Testing of screw caps concerning its sealing function
- Selecting material to be tested
- Insert of device into hot-cell
- Begin of testing

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BAM

- *Numerical analysis of test set-up to identify governing mechanical parameters*
- *Comparison of test set-up/results with regulatory conditions*

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Conclusions

- Spent fuel issues for transport
  - Criticality safety analysis
  - Containment assessment
  - Limited data of fuel behavior

- R&D
  - 3-point bending test of spent fuel rods in cooperation with ITU