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Session on Storage and Transport of High Burnup Fuel

REGULATORY PERSPECTIVE ON HIGH BURNUP FUEL STORAGE AND TRANSPORTATION ISSUES IN SPAIN

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01 | Fuel Cycle

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01 | ISFSI

Design	Storage Design Model	For use at ISFSI	Transport Design Model
ENSA	DPT	Trillo	DPT
Holtec	HI-STORM 100(Z)	Jose Cabrera	HI-STAR 100
Holtec	HI-STORM 100	Ascó	HI-STAR 100

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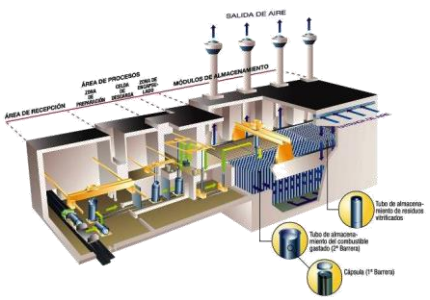
01 | Centralized Storage Facility



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01 | Regulatory Requirements

- Subcriticality
- Shielding
- Confinement
- Retrievability
- Heat removal

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02 | Subcriticality

- Use of burnup credit (BUC) methodologies for Criticality Safety Analysis:
  - Licensed since 1990 for pool storage
  - Full BUC (all isotopes) for PWR spent fuel pools
  - Credit to burnable poison (Gd) for BWR
  - Currently licensed for dry casks
  - Only actinides and a few selected fission products are included
- Expected evolution for dry casks:
  - Use of additional fission products

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02 | Subcriticality issues for HB fuel

- Validation of the burnup calculation:
  - Need for additional experimental assay data for high enrichment and high burnup fuel
  - Measurement campaigns performed by Spanish organizations (CSN, Enresa, ENUSA) with participation of ORNL
- Axial burnup distribution impact on reactivity ("end-effect"):
  - The effect on reactivity increases with burnup
  - Not bounding end-effect estimation methods have been submitted

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02 | Subcriticality issues for HB fuel

- Misloading events:
  - The effect of the event on reactivity increases with burnup
  - Current guidance requires an analysis if a measurement of the fuel burnup is not performed
  - The analysis of the misloading event has always been required in Spain so far

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03 | Classifying SNF

- Fuel undamaged based on function:
  - SNF storage and subsequent transportation
  - SNF condition at the time of loading
  - Impact of alteration (degradation) mechanisms
- Issues:
  - Effect of Hydrogen and hydrides on the cladding mechanical properties
  - Behavior of highly corroded cladding
  - Oxide spallation
  - SCC of the top nozzle joint to the skeleton

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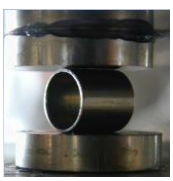
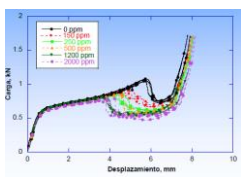
03 | Effect of hydrides

- Hydride formation promotes cladding embrittlement:
  - Hydrogen concentration
  - Non-uniform hydride distribution: hydride rim





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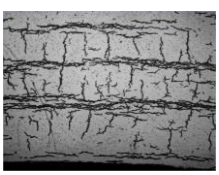
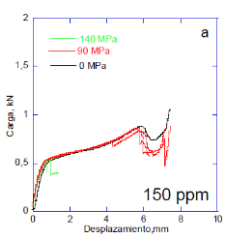
03 | Effect of hydrides

- Orientation of hydrides: radial hydrides





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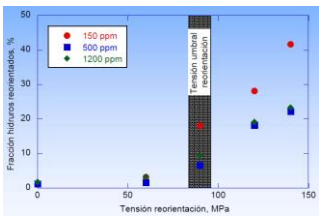
03 | Effect of hydrides

- Hydride re-orientation conditions: dependence on the temperature history and hoop stress on the cladding



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03 | Excessive corrosion

- Population of fuel assemblies showing highly corroded cladding
- Cladding wall thinning due to the thickness of the oxide and of the hydride rim:
  - Decreased resistance
  - Mechanical properties affected by the high Hydrogen contents
  - Higher hoop stresses on the cladding
  - The material should be more prone to hydride re-orientation

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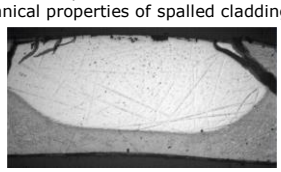
03 | Oxide Spallation

- Population of Zry-4 fuel assemblies showing oxide spallation
- Behavior of spalled cladding under bending or impact loads:
  - Formation of hydride lenses
  - Mechanical properties of spalled cladding



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04 | Summary

- Relevant high burnup fuel storage and transportation compliance issues have been described
- Methodology issues and code validation needs for BUC application still remain
- The understanding of the effect of cladding corrosion and hydriding should be improved in order to predict cladding failure
- R&D activities are ongoing to address these issues, in collaboration with other Spanish organizations