German Storage Concept for Spent Fuel and High Level Waste

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Technical and Operational Issues Related to the Transportation of High-burnup and Irradiated Mixed Oxide Fuels and the Transportability of Long-Term Stored Spent Fuel

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German Nuclear Power Plants in Operation by 2019

- Fukushima today
- Philippsburg 2 (1402 MW)
- Gundremmingen B (1284 MW)
- Grafenheinfeld (1345 MW)
- Isar 2 (1410 MW), Emsland (1329 MW), Neckarwestheim II (1365 MW)

Timeline:
- Nov. 2003
- May 2005
- Aug. 2011
- Jun. 2015
- 2020
- 2022

Fukushima:
- 12/2019

Today:
- 12/2014
- Grohnde (1360 MW), Brokdorf (1410 MW)
- Philippsburg 2 (1402 MW)
- Gundremmingen B (1284 MW)
- Grafenheinfeld (1345 MW)
- Isar 2 (1410 MW), Emsland (1329 MW), Neckarwestheim II (1365 MW)
The German situation – SNF lifecycle since 2005

- Reactor operation
- Wet storage
- Cask loading
- Dry storage at on-site facility
- Final repository
Reorganizing responsibility and costs

Under the new regulations since summer 2017:

• Dismantling, decommissioning, conditioning and packaging remains with the operators of NPPs

• Responsibility for interim storage and final disposal lies with the government

• Storage costs covered by a public fund under public law. The NPP operators provided the liquidity by paying 24 billion Euro into this fund.

• **Operational as well as financial responsibility for interim and final storage are combined in the hands of the government**
Waste streams strategies

Defueling

Fuel assemblies and waste from reprocessing (HLW waste)

Repository site to be found and build

BGZ

Dismantling and decommissioning

Waste from operation and decommissioning (LLW and ILW)

NPP

BGE

Repository Konrad

BGZ operated storage facilities for SNF in Germany

- 2 central storage facilities *
- 11 on-site storage facilities
- 3 building designs
Building concepts to be considered

Tunnel design

Steag design

WTI design
Milestones to autarchy

1. until December 31, 2018

2. since January 01, 2019

3. while dismantling NPP

4. after dismantling NPP

5. final repository
Reference concept of an autarkic „on-site“ storage facility
Principles of Dry Interim Storage in Germany

- Current storage period limited to 40 a
- Use of dual purpose casks (DPC) with the option of transportation during the storage period at any time
- Monolithic thick walled metal cask body
- Inert conditions by vacuum-drying and helium filling
- Permanently monitored sealing system of the two lids
- Repair concept in case of failure of a metal seal

CASTOR® V/19  CASTOR® V/52  CASTOR® HAW28M
Fulfilment of the four protection goals by the system cask/storage
Amounts of SNF and HLW in Germany as of Dec. 2017

- Reprocessed SNF/Vitrified HLW: 6673 M\(_{\text{HM}}\)
- SNF in dry-storage at central storage facilities: 4995 Mg
- SNF in dry-storage at on-site storage facilities: 674 Mg
- SNF in wet-storage: 3030 Mg
- Fuel loaded into reactors: 1443 Mg
- SNF in dry-storage at on-site storage facilities: 16.817 M\(_{\text{HM}}\)
Inventories in Germany

- 1139 casks in stock (by dec. 2017)
- Approx. 1900 casks expected by defueling last NPP, (~2029)
- 14 different cask types
  Mainly CASTOR® and TN™ casks
- Spent fuel, vitrified waste, failed and special fuels originating from PWR, BWR, VVER, AVR/THTR
- MOX up to 65 GWh/Mg avg.
- HBU up to 65 GWh/Mg avg.
- „LBU“ moratorium-fuels
- HEU from research reactors
- Zry-2/4, Zirlo, M5, E110 cladding
Situation of interim storages in Germany

- Limitation of storage licenses for dry SF storage facilities to a storage period of 40 a starting from the first emplacement of a DPC
- Storage licenses expire between 2034 and 2047

Starting in 2017 amending the Repository Site Selection Act from 2013

- Proofs of safety have to be provided for a storage period > 40 a
- Extended storage beyond the 40-year storage period is prepared
Major issues in Germany

- MOX and high burn-up EU, ERU
- Several cladding materials → integrity of spent fuel

- Inventories inaccessible
- 14 different cask types → individual casks models and inventories need to be considered

- Extended storage unavoidable
- Expiration of storage licenses
- Autarchy of facility after NPP dismantling → Renewal of storage license
Strategies

Fuel

• Evaluation and assessment of integrity parameters for every type of fuel element
  • Fuel data (EOL)
  • Fuel data (in storage)
  • Temperature modelling
  • Cladding behaviour
  • Fuel assembly and rod design data

➢ Gap-Analysis specific to German needs
➢ Literature surveys
➢ Initiation and participation in nationally coordinated research programs
Strategies

Casks

- Integral Aging-Management Program
- Cask-specific periodic safety inspections
- Continuously-improving inspection procedures implementing newly-found aging relevant degradation mechanism

➤ Gap-Analysis by cask manufacturers specific to German needs
➤ Long-term availability of spare parts
➤ On-site repair concepts
➤ Proof-of-concept of non-invasive inspection methods
Strategies

- Integral Aging-Management Program
- Building-specific periodic safety inspections
- Continuously-improving inspection procedures implementing newly-found aging relevant degradation mechanism

➢ Renewal of storage licenses
➢ Refurbishments to keep storages at state-of-the-art
➢ Increasing safety measures
➢ Autarkic operation of storage facilities until final repository is operational
Conclusion

• Integral Aging-management has to be improved continuously
• Gap-analysis specific to German situation
• Research programs needed

➢ Fuel-rod and cask-integrity is crucial for renewal of storage licenses

➢ Same applies to the transport of SNF from interim storage to the future final repository site
Thank you for your attention!

Join us at the Workshop “Zwischenlagerung” October 22th and 23th 2019 in Berlin

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