ENSA (Grupo SEPI)

Operational Experience of Transportation of Spent Nuclear Fuel in Spain
&
ENSA's licensing approach for High-burnup Spent Nuclear Fuel

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Design & Licensing Spent Fuel Cask

IAEA Technical Meeting:

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

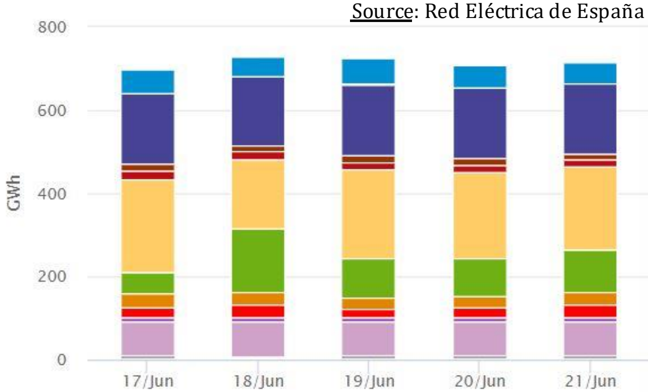
Vienna, 24^{th}-26^{th} September, 2019

Outline

1. Introduction: Spent Nuclear Fuel (SNF) Scenario
2. Operational Experience of Transportation of SNF
3. SNF Management Strategy
4. SNF Transport Regulatory Requirements
5. SNF Transport Packages Approved
6. ENSA's Licensing Approach for High-burnup (HBU) SNF
7. Conclusions

1. Introduction: SNF Scenario

Source: Red Eléctrica de España



- > 20% electricity generated from nuclear
- 10 reactors at 7 NPPs:
  - ✓**7 operating;**
  - 1 permanently shutdown:
  - 2 under dismantling & decommissioning

Hydro
Nuclear
Coal
Gas
Wind

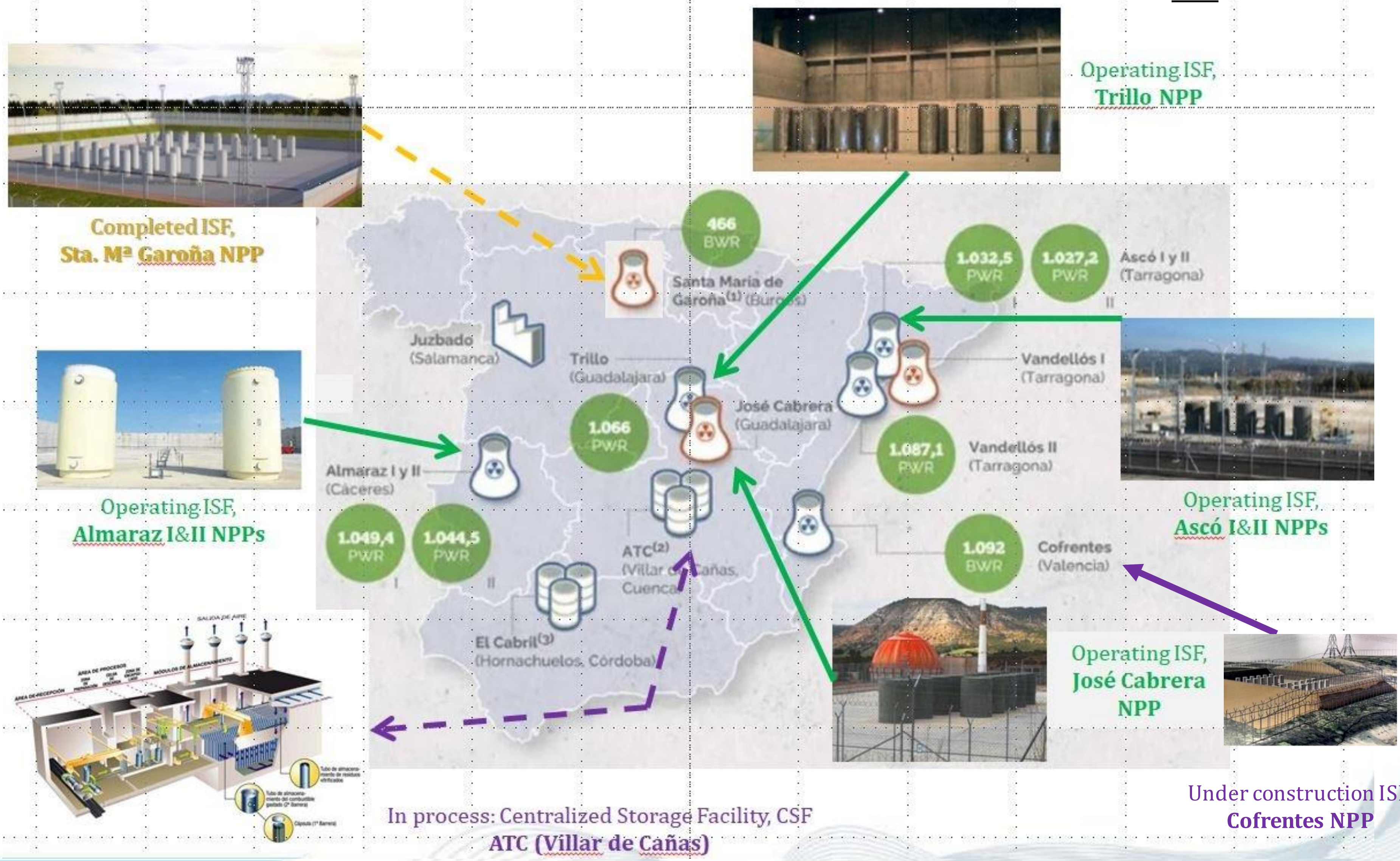
52%

- Open cycle strategy for the back-end:
  - **a) Interim dry storage in ISF at nuclear sites;**

    2 technologies: **bare fuel casks** & **canister systems**
  - b) Interim dry storage in a Centralized Storage Facility
  - c) Deep Geological Repository
- > 6.700 MtU (20.000 FA), after 40 years of NPPs operation

1. Introduction: SNF Scenario

Source: Foro Nuclear



1. Introduction: SNF Scenario

Source: Foro Nuclear

Ensa technology

Bare fuel type casks

Completed ISF, **Sta. Mª Garoña NPP**

Ensa technology

Bare fuel type casks

Operating ISF, **Trillo NPP**

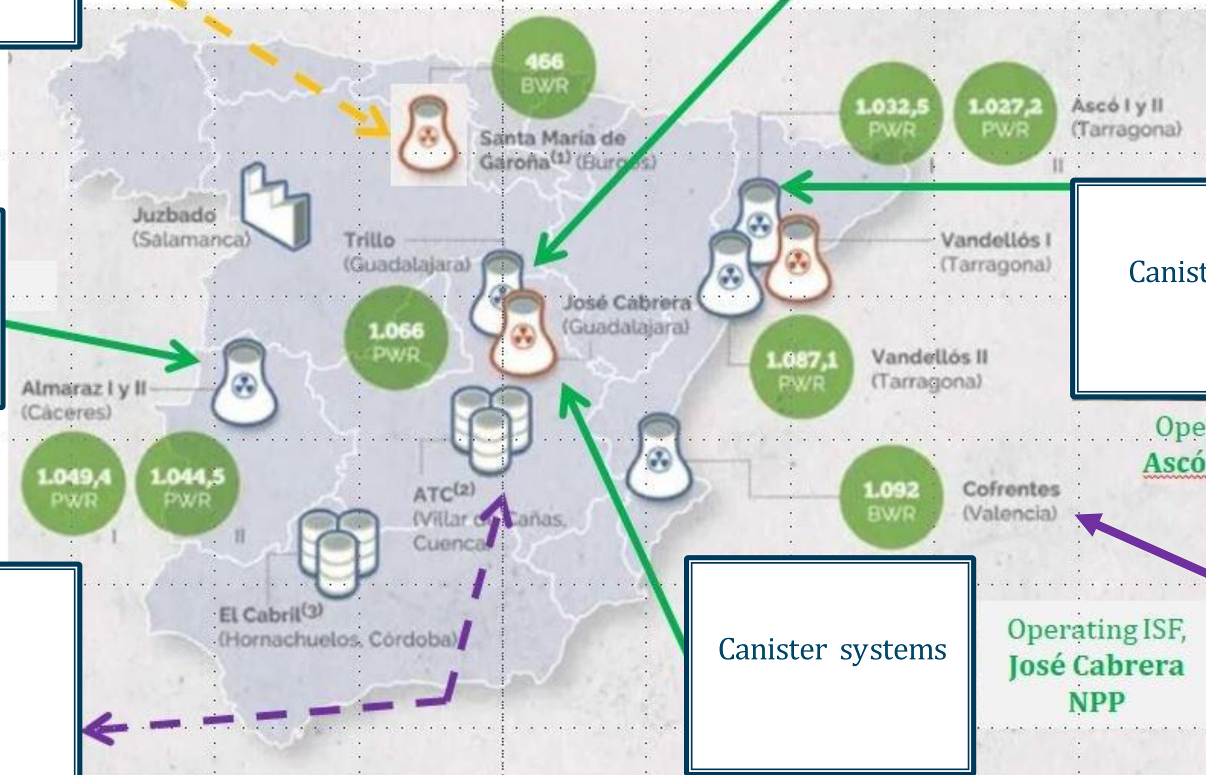
Ensa technology

Bare fuel type casks

Operating ISF, **Almaraz I&II NPPs**

Canister systems

Operating ISF, **Ascó I&II NPPs**



Vault systems

Canister systems

Operating ISF, **José Cabrera NPP**

Bare fuel type casks

Under construction ISF, **Cofrentes NPP**

In process: Centralized Storage Facility, CSF **ATC (Villar de Cañas)**

2. Operational Experience of Transportation of SNF

➢ **70's to mid 80's**:

The majority of the SNF produced by the first generation of Spanish NPPs was **transported abroad**:

- *Sta. María de Garoña (BWR)*
- *José Cabrera (PWR)*
- *Vandellós I (GCR)*

✓ Transported to U.K. and France, for **reprocessing**

✓ Advantageous **economical agreements**, and severe control of nuclear materials

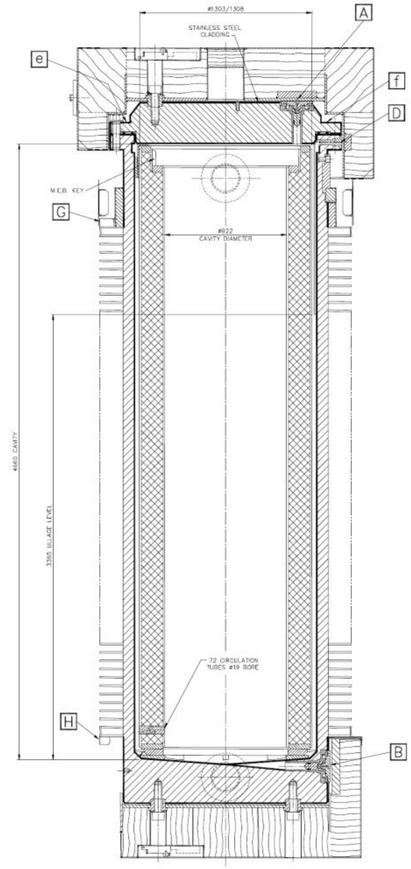
2. Operational Experience of Transportation of SNF

➢ **70's to mid 80's**:

SNF from *Sta. María de Garoña* NPP was transported to **Windscale/Sellafield (UK)**

<u>Fuel parameters (SNF):</u>

- Design: **GE-7 (BWR)**
- Burnup: **8.6 - 22.7 GWd/MTU**
- U-235 enrichment: **2.1% - 2.5%**
- Cooling time: **< 5 years**



<u>Transportation packages:</u>

- Design: **NTL9** and **NTL11 flask, Type B(M)F**
- Validated by Spanish Ministry of Industry in **1980**
- Capacity: **7** and **17 FA**
- Maximum allowed burnup: **36.5** and **38.5 GWd/MTU**
- Maximum allowed thermal power: **24.5** and **35 GWd/MTU**

<u>Transportation data:</u>

- 52 transportations performed (36 with NTL9 package and 16 with NTL11 package)
- **500 FA** were transported, by **road** and **maritime** routes

2. Operational Experience of Transportation of SNF

- **From mid 80's onwards**:

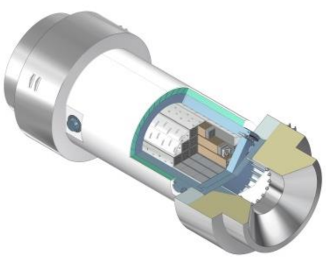
- Agreement conditions changed: <u>Spain shall became responsible of all the radioactive waste</u>, after reprocessing
- SNF transports from *Sta. María de Garoña* and *José Cabrera NPPs* **ceased**
- Only the remaining spent fuel from Vandellós I was transported in late 80's, because early shutdown of the NPP:
  - Transported by road to **Marcoule** (France), for reprocessing
  - Spain pays a daily fee to France for storing the vitrified HLW
  - 4 units of TN-81 casks have already been fabricated to return to Spain the vitrified HLW (*date not already decided*)

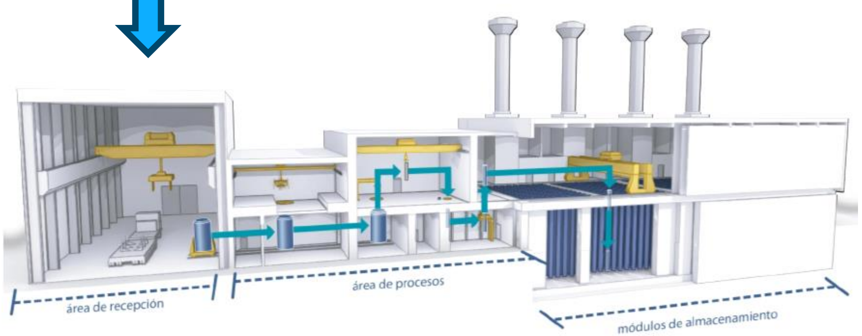
- **1984**:

- A public company, **ENRESA**, was created to manage all radioactive waste produced in Spain, including SNF from power reactors
- Spain established an **open cycle** strategy for the management of the SNF
- All remaining SNF is **wet** and **dry stored** at 7 different NPP sites

3. SNF Management Strategy

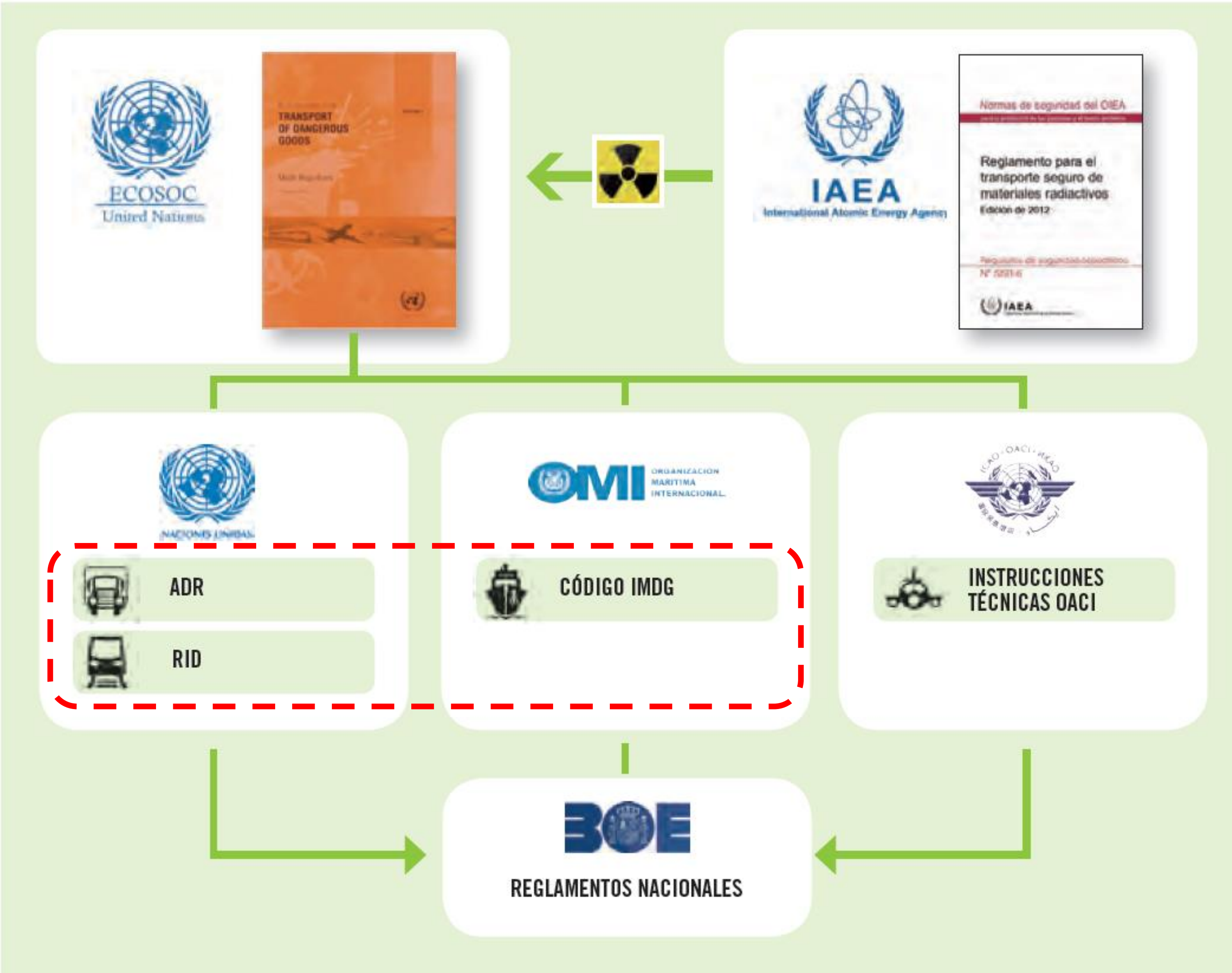
- ✓ SNF remains temporary wet and dry stored at the NPPs (**spent fuel pools** and **ISFs**)
- ✓ Later on, all casks will be transported to the **ATC (Centralized ISF)**. Once in the **ATC**:
  1) Temporary storage of transport casks at the ATC cask storage building
  2) Transfer of SNF and HLW from transport cask to welded canisters, in a 'hot cell'
  3) Interim dry storage in welded canisters (100 years design life)
- ✓ After, all SNF and HLW will be transported to a future **Deep Geological Repository (DGR)**, for final disposal





ATC Technology: Vault system for SNF and HLW (Vitrified)

4. SNF Transport Regulatory Requirements



CSN
CONSEJO DE SEGURIDAD NUCLEAR

Is the nuclear competent authority.

CSN follows <u>guidance</u> and <u>safety recommnedations</u> from the **U.S. Nuclear Regulatory Commission**

5. SNF Transport Packages Approved

Package Name	Package type	Licensee	Designer	Approved content	Transport restrictions
R72	B(M)F	TRANSNUBEL	ROBATEL Industries	Irradiated fuel rods NFH	170 – 310 W/m -
ENSA-DPT	B(U)F	ENRESA	ENSA	KWU 16X16	≤ 49 GWd/MTU
HI-STAR 100	B(U)F	ENRESA	HOLTEC International	W 17X17 NFH	< 45 GWd/MTU -
ENUN 52B	B(U)F	ENSA	ENSA	GE-6 GE-7	≤ 32.5 GWd/MTU ≤ 37.5 GWd/MTU
ENUN 32P	B(M)F	ENSA	ENSA	KWU 16X16 W 17X17 NFH	≤ 58 GWd/MTU < 45 GWd/MTU -
ENUN 24P	B(U)F	ENSA	ENSA	AFA 2G AFA 3G/3GAA	≤ 57 GWd/MTU ≤ 47 GWd/MTU

- All packages are designed to transport PWR or BWR SNF;
- **No MOX fuel is loaded at any Spanish NPP;**

6. ENSA's Licensing Approach for HBU SNF

Technology: **Bare fuel type casks**, Dual-Purpose

ENSA - DPT
Trillo NPP
KWU 16x16 PWR

Max. BU: 49 GWd/MTU

ENUN 32P
Trillo NPP, Almaraz NPP
KWU 16x16 PWR
W17x17 PWR

Max. BU (KWU): 58 GWd/MTU
Max. BU (W): 45 GWd/MTU

ENUN 52B
Sta. María de Garoña NPP
GE-6/7 BWR

Max. BU: 37.5 GWd/MTU

↓

ENUN 32P

Max. BU (KWU): 65 GWd/MTU
Max. BU (W): 60 GWd/MTU

↓

ENUN 52B

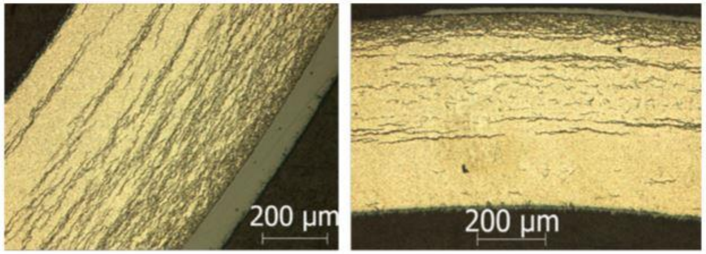
Max. BU: 52 GWd/MTU

2021 licensing necesities, from operating NPPs and decomissioning actors

6. ENSA's Licensing Approach for HBU SNF

Source: NUREG-2224 (Draft)

- Issues impairing HBU cladding structural performance:
  - ✓ Corrosion thickness
  - ✓ Hydrogen absorbed content
  - ✓ Inner pressure in fuel rod
  - ✓ Fuel rod temperature drops



Zircaloy-4
67 GWd/MTU

ZIRLO™
68 GWd/MTU

- Spanish regulatory position: follow U.S. NRC standard: "Interim Staff Guidance 11", Rev. 3 (2003):
  - ❖ Establishes threshold for HBU: average burnup > **45 GWd/MTU**
  - ❖ Approval of transport casks for HBU handled on a case-by-case basis, until specific NRC guidance is developed

- Consequences for spent fuel casks in Spain:
  - ➢ All transport CoCs limited to a maximum burnup of 45 GWd/MTU;
  - ➢ All spent fuel loaded in a cask shall have an approved transportation CoC;

No authorization for removing HBU from spent fuel pools

6. ENSA's Licensing Approach for HBU SNF

Progressive approach for removing 45 GWd/MTU limitation from transport CoCs

1) 2016: Development of proprietary analysis methodology:

- Scope: analyze and justify spent fuel rod cladding structural performance, under all postulated **transport** scenarios for Type B casks
- Applied for W17x17: Zircaloy-4 & Zirlo cladding materials
- Established:
  - ✓ Assumptions on cladding conditions
  - ✓ Cladding bibliography source data for mechanical properties
  - ✓ Specific and conservative acceptance criteria for cask safety analysis

Not approved by regulator:

- Lack of specific fuel data from applicable bibliography or experiments
- Recommendations to perform additional conservative safety evaluations assuming failure of HBU rods (i.e. fuel reconfiguration)

6. ENSA's Licensing Approach for HBU SNF

Progressive approach for removing 45 GWd/MTU limitation from transport CoCs

2) 2017/2018: Analysis and licensing of specific cases

ENUN 24P
Specific cask to transport PWR 17x17 HBU across P.R. of China
From pool to pool. No interim dry storage
Demonstration that minimum fuel rod temperature always above **DBTT** + Defense in depth safety analysis
✓ Max. BU (Zr-4): **47 GWd/MTU** ✓ Max. BU (M5): **57 GWd/MTU**
Limitation: demonstrate maximum thickness of cladding oxide layer, through measuring campaigns

- Approved by Spanish regulator (2017);
- Approved by Chinese regulator (2018);

Transport of HBU from Daya Bay and Ling Ao NPPs to Lanzhou wet storage facility

6. ENSA's Licensing Approach for HBU SNF

Progressive approach for removing 45 GWd/MTU limitation from transport CoCs

2) 2017/2018: Analysis and licensing of specific cases

ENUN 32P
Dual-Purpose cask, Storage and Transportation of HBU in Spain PWR 16x16 and 17x17
Interim dry storage + transportation
Corrossion thickness layer measuring campaigns + Conservative estimation of maximum hydrogen content absorbed by fuel rods lower than **limiting threshold**
✓ Max. BU (16x16 – DX-Els08.b): **52 GWd/MTU** ✓ Max. BU (16x16 – DX-D4): **58 GWd/MTU**
Limitation: estimate hydrogen absorbed content. *Limited to a population of 128 FA aprox.*

- Approved by Spanish regulator (2018);

Dry Storage of HBU in the ISF located at Trillo NPP

6. ENSA's Licensing Approach for HBU SNF

Progressive approach for removing 45 GWd/MTU limitation from transport CoCs

3) 2018/2019: Development of proprietary analysis methodology:

- Scope: analyze and justify compliance of regulatory acceptance criteria of all safety functions for **storage** & **transport**
- Applied for W17x17, KWU 16x16 (PWR) and GE-11 (BWR) SNF: Zircaloy-4, Zirlo, Duplex and Zircaloy-2 cladding materials;
- Established:
  - ✓ Lessons learned and experienced acquired in previous licensing processes
  - ✓ Following draft NUREG-2224 licensing approaches;
  - ✓ Cladding bibliography source data for mechanical properties;
  - ✓ Better understanding of cladding performance after ENSA's participation in international SNF research projects

6. ENSA's Licensing Approach for HBU SNF

Progressive approach for removing 45 GWd/MTU limitation from transport CoCs

3) 2018/2019: Development of proprietary analysis methodology:

International Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test project in 2017, with ENUN 32P cask

30 cm Horizontal Drop Test in 2018, with 1/3 scale mock up of ENUN 32P cask

- ✓ Better understanding of cladding performance after ENSA's participation in international SNF research projects

Methodology under review by Spanish regulator

7. Conclusions

- During the 70's and until mid 80's, part of the SNF generated in Spanish NPPs was **transported** to U.K. and France for **reprocessing**
- The situation changed in 1984: Spain shall became responsible for all its radioactive waste. ENRESA was founded and an **open cycle strategy was adopted**, with interim dry storage in ISFs at NPPs and at a Centralized ISF. Later on, all SNF will be finally disposed in a DGR
- Several **packages are approved** for transportation of SNF (PWR and BWR). Some of them, also for **HBU** with specific restrictions
- **Storage and Transport of HBU is an issue**, that currently limits the removal of SNF from NPPs spent fuel pools. There is NOT MOX fuel in the spent fuel pools
- ENSA is currently applying an on-going progressive licensing approach, to modify the CoC of its dual-purpose proprietary package designs, to **increase the inventory of HBU SNF authorized to be stored and transported**

Thanks very much!

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