Safe solutions for transport and dry storage of defective fuel rods

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Introduction

Defective fuel management is a major challenge for nuclear operators when there is need to find a long-term solution for managing all Used Fuel Assemblies (UFA)

AREVA offers various solutions for meeting operators needs regarding management of defective fuel

Definitions

- Three main categories of defective fuel (regarding containment issue)
  - Leaking fuel: Small holes, hairline cracks
  - Damaged fuel: Bigger holes or cracks, broken rod, missing end plug
  - Fuel debris: Nuclear pellets, fragments of pellets, or fuel powder

- Various types of conditioning of defective fuel
  - **Quiver**: wet storage and/or transport of several defective fuel rods rods together
  - **Bottle**: wet storage and/or transport of one or several defective fuel assembly/ies
  - **Fuel Rod capsule**: wet or dry storage or transport of one defective fuel rod
  - **Capsule canister**: structure for holding fuel rod capsules together with dimensions similar to fuel assembly dimensions for easy handling
Reprocessing of defective fuel: best solution in terms of risk reduction approach

- Reprocessing: most decisive way to get rid of defective UFA

No need to assess behaviour in the long-term of this specific type of UFA

A comprehensive solution that can be implemented for managing all UFA, defective & intact

96% of heavy metal of spent fuel assembly is recyclable

Risk reduction: in the dry storage facility, replacement of DFR* by vitrified residues, designed for long-term dry storage

AREVA operational experience
Defective fuel from all around the world treated at La Hague plant

<table>
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<tr>
<th>Leaking UFA</th>
<th>UFA w leaking rods removed</th>
<th>Capsule canisters</th>
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<tr>
<td>~450</td>
<td>~10</td>
<td>~4</td>
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*Defective Fuel Rods
Transportation of defective fuel
Operational experience

- AREVA proposes a comprehensive range of transport solutions

**Licensed solutions**
- MP197HB cask licensed in the US for transport of defective fuel loaded in dry shielded canisters
- TN®12, TN®13, TN®17/2 & TN®117 casks licensed in various European countries for leaking fuel

**Solution proposed for transportation of damaged fuel and fuel debris**
- Preliminary encapsulation of fuel in screwed fuel rod capsule (more than 10 years experience with this process)
- Existing cask design transport license extension

**Advantage of this type of solution:** Supporting the utility in getting rid of defective fuel once and for all (evacuation from reactor site)

**AREVA operational experience**
Many shipments performed to bring defective fuel rods/assemblies, encapsulated or not, or loaded in quivers from all around the world to La Hague plant in France
Transportation of defective fuel
Safety assessment in Europe

- Confinement
  - In accident conditions, it is assumed that all the fuel cladding is breached, therefore presence of defective fuel as no impact on assessment

- Radiolysis
  - H2 explosion risk safety case is a French safety authority requirement
  - Consequence: transport duration could be reduced to a few months instead of one year and/or number of leaking fuel rods per cask could be limited

- Criticality
  - In case of severe accident, it is assumed that the whole content (basket and fuel elements) is ruined & mixed in center of the cask, therefore presence of defective fuel has no impact on assessment

- Shielding
  - Defective fuel elements placed in usual UFA compartment or in capsule or can => same or additional shielding => same or less dose rate generated by the cask
Interim dry storage in the US

Solution licenced by US NRC considering following requirements

- **Leaking fuel assemblies**
  Stored in usual spent fuel assembly compartment with additional end caps that have multiple holes → unrestricted flooding and draining

- **Damaged fuel assemblies and fuel debris**
  Stored in failed fuel can that is placed in compartment which is slightly larger than fuel assembly compartment

Example of dry shielded canister for interim dry storage of spent fuel:

AREVA 37PTH canister which can be loaded with 4 leaking fuel assemblies along with intact fuel assemblies

Advantage of this type of solution:
Short-term cost-effectiveness
Safety Assessment

- **Confinement**
  - Ensured by top & bottom end caps (leaking fuel), by failed fuel can (damaged fuel and fuel debris)

- **Radiolysis**
  - No specific draining, drying & leaktight tests procedure for defective fuel

- **Criticality**
  - In case of severe accident, rod breakage may occur in rods with known pre-existing gross cladding failure => limitation in the cask on the number of rods with known gross cladding damaged

- **Shielding**
  - Specific loading plan with defective fuel in dedicated basket compartment

Operational experience

- AREVA has been implementing interim dry storage of defective fuel assemblies in the US for many years

- AREVA licensed Dry Shielded Canisters
  - For leaking fuel: 32PTH, 37PTH, 24PT4, 61BT/BTH, 69BTH
  - For damaged fuel & fuel debris: 24PTHF

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Long-Term storage of defective fuel rods

Welded fuel rod capsule

Development based on existing screwed fuel rod capsule

Operations performed in the reactor pool for minimal dose rate, can be implemented in hot cell for specific customers needs

Specific drying operation for each DFR* loaded in fuel rod capsule

Patented drying process allows physical and reliable demonstration of residual amount of water within DFR*

* Defective Fuel Rod
Long-Term storage of defective fuel rods

Operations

Step 1: Preparation* of the Defective Fuel Rod and transfer* into the Fuel Rod Capsule

Step 2: Transfer of the loaded Fuel Rod Capsule to the encapsulation facility

Step 3: Single drying of the Def. Fuel Rod, welding of the Fuel Rod Capsule and NDT** of the welds

Step 4: Transfer* of the finalized Fuel Rod Capsule into the Capsule Canister

Step 5: Transfer of the loaded Capsule Canister into the Transport / Storage Cask

Step 6: Transfer to the storage facility

* Operational experience available
** Non Destructive Testing

Dimension of a Capsule Canister is similar to a Fuel Assembly

Cask can be loaded with mixed content of capsule canisters and intact fuel assemblies

* Operational experience available
** Non Destructive Testing
Welded capsule / Capsule Canister (CC) in AREVA transport and storage cask: Safety assessment in Europe

- **Confinement**
  - For intact fuel, fuel cladding = 1st barrier; for defective fuel, capsule = 1st barrier

- **Radiolysis**
  - No specific draining, drying & leaktight tests procedure for CC (loaded with capsules which are loaded with DFR*)
  - Very low amount of residual water, physically demonstrated by drying process, ensures there is no impact on safety evaluation

- **Criticality**
  - In case of severe accident, it is assumed that the whole content (basket and fuel elements) is ruined & mixed in center of the cask, therefore presence of defective fuel has no impact on assessment

- **Shielding**
  - Less dose rate generated by the cask as number of encapsulated rods in CC is less than number of rods in FA**

The technology developed by AREVA is the most efficient in terms of residual water in the defective fuel rod and allows to obtain a robust safety demonstration for the transport license and the storage license in the long term dry storage facility of the AREVA transport and storage cask

"AREVA technology = the best available technology"
Conclusion

Nuclear utilities & used fuel management organizations have to assess the final management of all their used fuel assemblies, defective included.

AREVA has developed and is developing technologies that meet the customers needs and the utmost safety requirements:

- Robust and experienced transport solutions for defective fuel assemblies
- US NRC approved, short-term cost-effective solution for interim dry storage of defective fuel assemblies
- The best available technology for long-term dry storage of defective fuel rods, compatible with both geological disposal & reprocessing: the welded encapsulation with associated transport & storage casks
- Reprocessing remaining most decisive way to get rid of defective fuel in a risk reduction approach (defective fuel replaced in the dry storage / geological disposal by final residues package, designed for long-term storage/disposal)
Thank you for your attention!

Questions?

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