Safe solutions for transport and dry storage of defective fuel rods

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Outline

1. **Introduction & Definitions**
2. **Reprocessing** of defective fuel assemblies
3. **Transportation** of defective fuel assemblies
4. **Safe interim dry storage** of defective fuel assemblies
5. **Safe long-term dry storage** of defective fuel assemblies and rods
6. **Conclusion**

Introduction

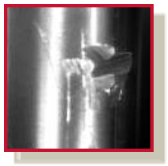
Shutdown reactor: cost optimization

Reactor pool management optimization

- **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**

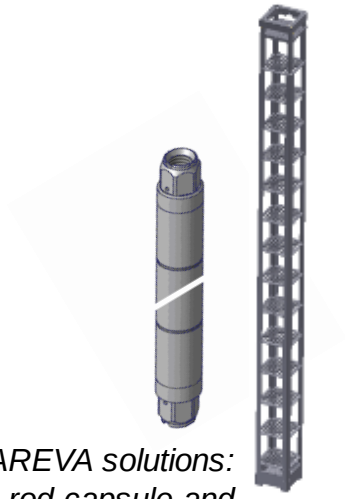
- **Definitions**
  - **Three main categories of defective fuel (regarding containment issue)**



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



AREVA solutions: fuel rod capsule and capsule canister

  - **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

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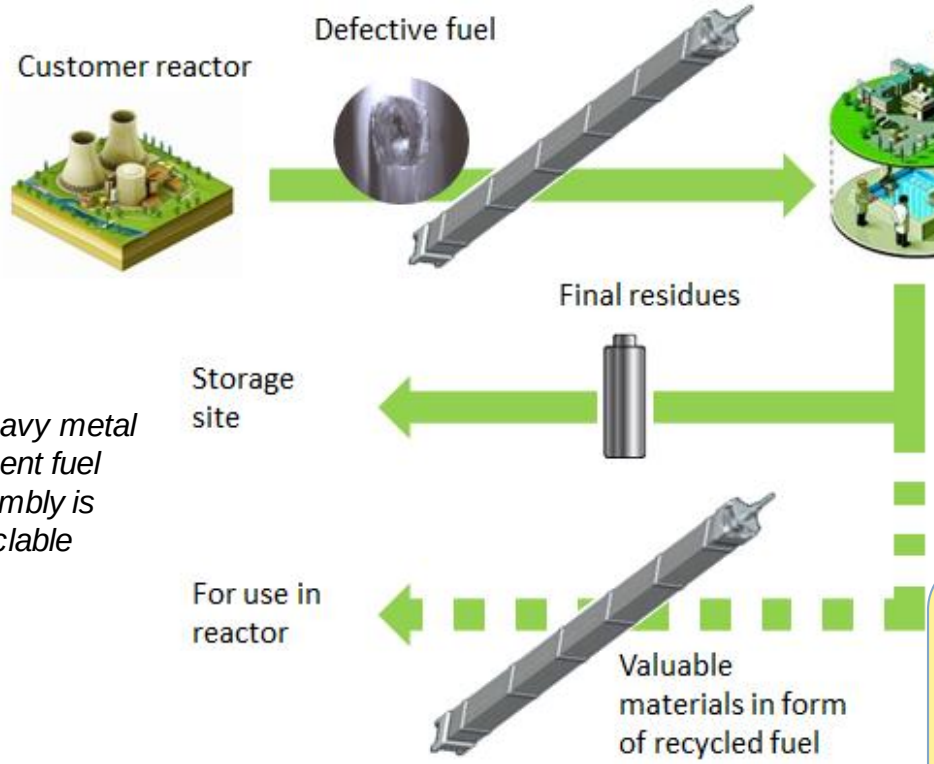
Reprocessing of defective fuel: best solution in terms of risk reduction approach

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



96% *of heavy metal of spent fuel assembly is recyclable*

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

AREVA operational experience

Defective fuel from **all around the world** treated at La Hague plant

Leaking UFA	UFA w leaking rods removed	Capsule canisters
~450	~10	~4

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

**Defective Fuel Rods*

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Transportation of defective fuel Operational experience

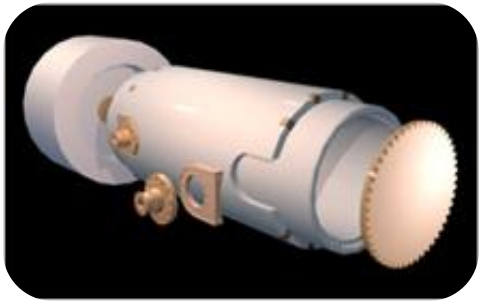
- **AREVA proposes a comprehensive range of transport solutions**

  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**



MP197HB spent fuel transport cask

AREVA screwed fuel rod capsule: particle-tight or both particle-tight & gas-tight

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**

TN®17/2 used fuel transport cask

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

TN®12 used fuel transport cask licensed in France for transportation of leaking fuel assemblies

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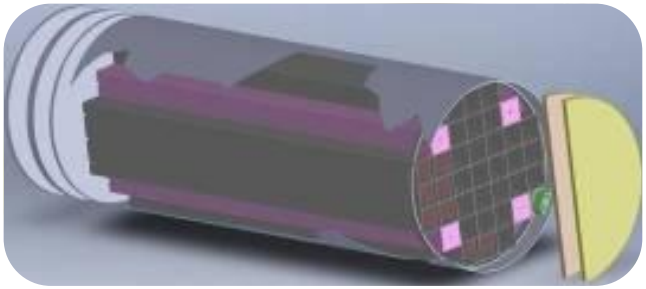
Interim dry storage in the US

- **Solution licended 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

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Interim Dry Storage
Safety assessment & Operational experience (both in the US)

Safety Assessment

Confinement

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

Radiolysis

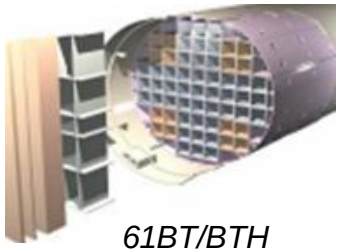
- No specific draining, drying & leaktight tests procedure for defective fuel

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

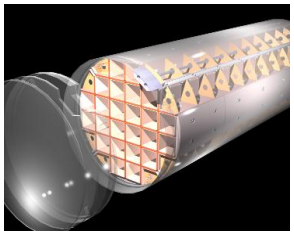
- Specific loading plan with defective fuel in dedicated basket compartment



61BT/BTH

61 BWR UFA

16 Leaking UFA



24PTHF

24 PWR fuel assemblies

8 Failed fuel cans

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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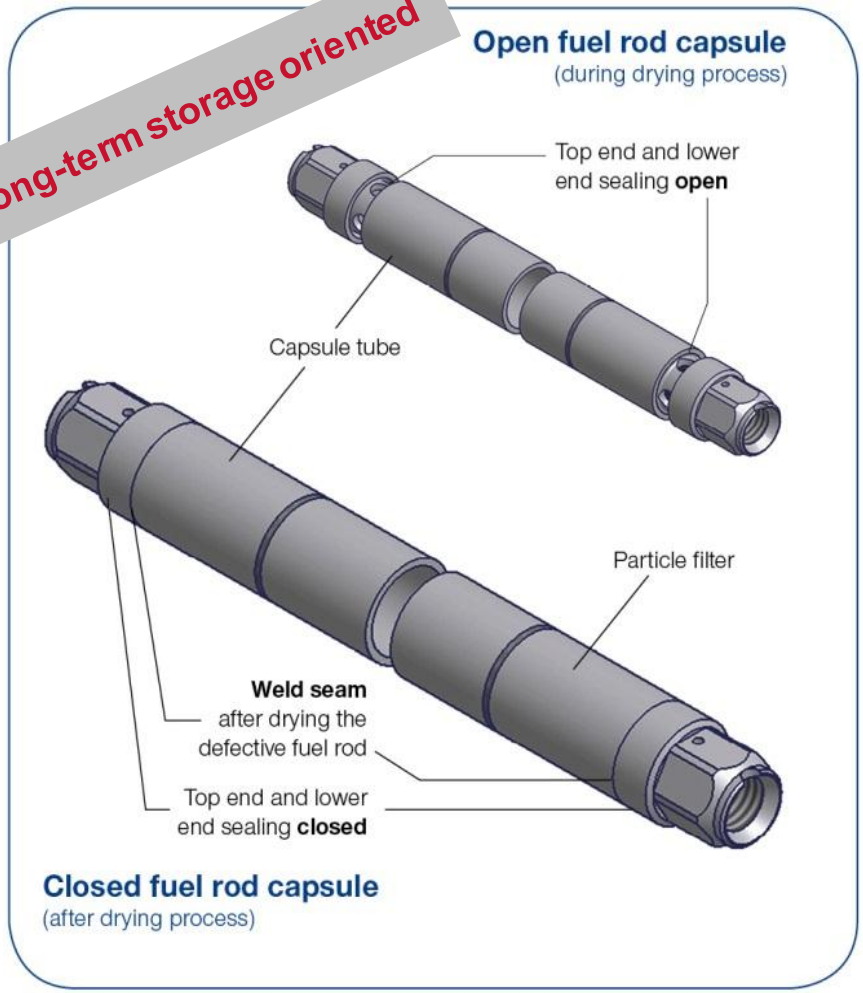
Long-Term storage of defective fuel rods
Welded fuel rod capsule

Development based on existing screwed fuel rod capsule

Long-term storage oriented



Reconstitution of the Fuel Rod enclosure (cladding) for retention of radioactivity during handling and storage

Best available technology regarding dry storage safety requirements

- **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*

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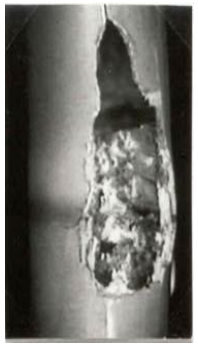
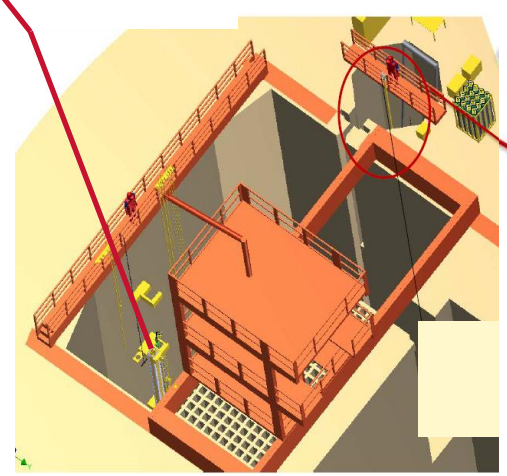
Long-Term storage of defective fuel rods Operations

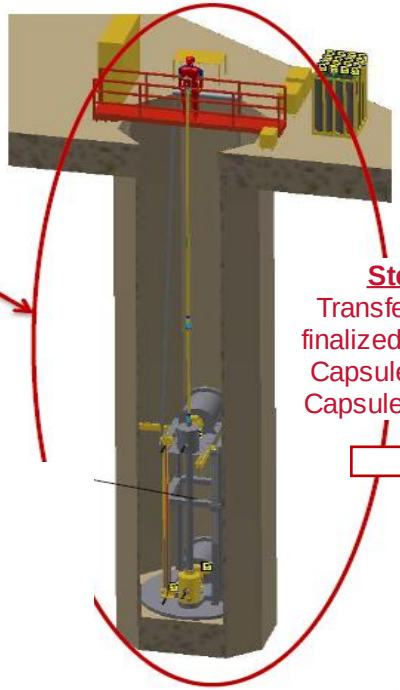
Step 1
Preparation* of the Defective Fuel Rod and transfer* into the Fuel Rod Capsule



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

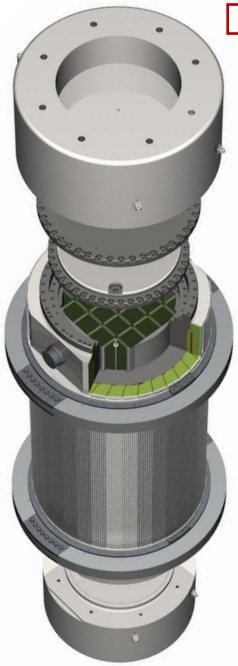


Step 4
Transfer* of the finalized Fuel Rod Capsule into the Capsule Canister

Dimension of a Capsule Canister is similar to a Fuel Assembly

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

Step 6
Transfer to the storage facility



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

** Operational experience available*
*** Non Destructive Testing*

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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**

Example of spent fuel transport and storage cask for which license will cover DFR* loaded in capsules: TN®24 SH cask

** Defective Fuel Rods*
*** Fuel Assembly/ies*

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”

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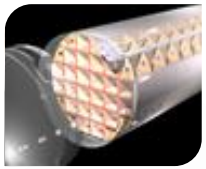
Conclusion

- **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)



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Thank you for your attention!

Questions?

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