Challenges for transport and storage

IAEA Technical Meeting on Back End of the Fuel Cycle Considerations for Small Modular Reactors

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22-sept-2022

Unrestricted

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Content

1. Package design requirements for transport

2. Front-end transport packages

3. Back-end transport and storage packages

A great diversity of materials

Diversity of reactor technology implies diversity of fuel technology

- **Physical form**
- **Fissile content**
- **Radioactivity**

Fuel types

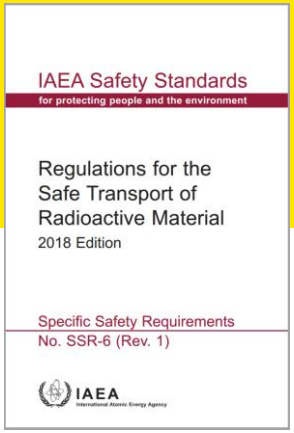
- **Oxide/ceramic fuels with cladding**
- **TRISO fuels**
- **Metallic fuels**
- **Liquid fuel salts**

Fissile material

- **LEU** **≤ 5% enriched U-235**
- **LEU+** **[5%;10%] enriched U-235**
- **HALEU** **[10%;20%] enriched U-235**
- **HEU** **≥ 20% enriched U-235**
- **Mixed U & Pu (oxide, metal, or salt)**
- **Thorium (oxide, metal, or salt)**

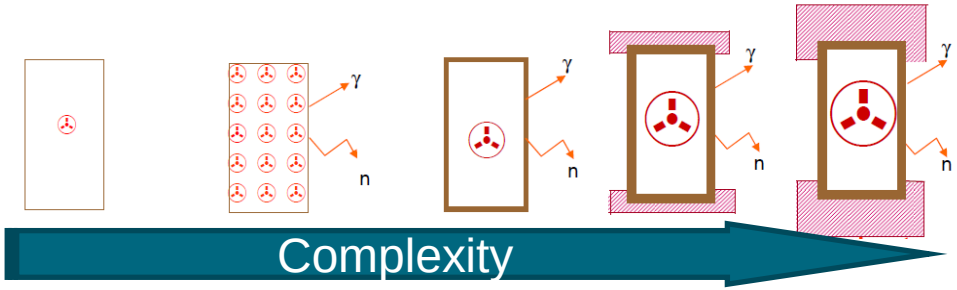
“ How to transport these materials ? ”

Transport regulations



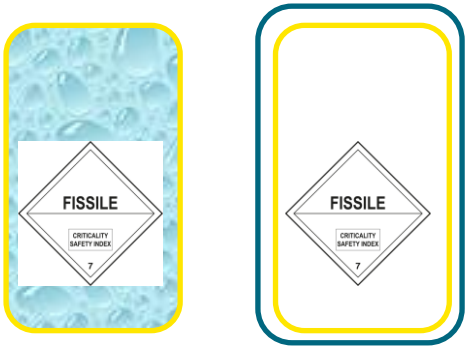
National regulations based on IAEA Safety Standard

Radioactive material characteristics (radioactivity, fissile material) => defines the type of package => defines the safety requirements and tests



Design features for fissile material

- **Assumption of water ingress inside the package shall be considered in the criticality analysis**
- **Unless the package is double barrier design => complexity of design and operations**



Front-end package design

Package design of fresh fuel with high fissile content shall be considered as well as all its by-products from the manufacturing chain

- **For example, UF6 transport with enrichment higher than 5% (HALEU…)**

Simple barrier design (water ingress)

- **With high fissile content (HALEU, high Pu content) subcriticality may reduce the payload capacity**
- **Example of a fresh UO2 powder package (French license)**

Enrichment	UO2 powder
e ≤ 5%	74.5 kg per cavity
5%< e ≤ 10%	16.5 kg per cavity

-78%
payload

- Package designed for 5% enrichment may not be optimized for higher fissile content

Double barrier design (water exclusion)

- **Enhanced payload => reduction of package numbers and transport cost**
- **Complexity of the design and additional operations (closure, leak tightness test…)**

Fresh fuel existing packages

Diversity of form, weight depending on the content

Simple barrier design

- **Criticality control by geometry and poison material**

Impact limiter and fire insulation materials

Light or no shielding

Fuel integrity protection

UF6 cylinders


MOX fuel assembly


MOX powder


UO2 powder

Back-end transport and storage

Heavy cask due to shielding requirements with high density materials (steel, lead…)

Large cask with impact limiters for transport

Compatibility with the loading facility process (weight limits, interfaces…)

Existing solutions like TN-EAGLE ® and NUHOMS EOS ® and systems, licensed for LWR fuel, can be adapted/modified for such needs

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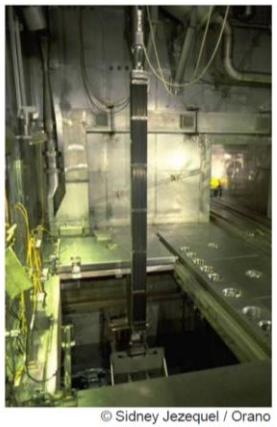

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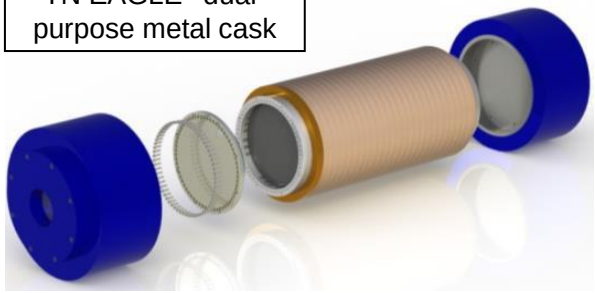
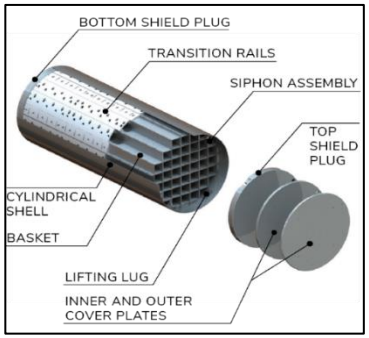
TN EAGLE® dual-purpose metal cask



EOS ® Canister and Basket



EOS ® HSM

EOS® Storage System

37 PWR / 89 BWR / 50 kW

Faster Offload from Pool

Optimize Spent Fuel Management

Innovative design

- **Patented Basket layout**
- **High performance materials**

State-of-the art methods

Proven horizontal storage

Next generation storage system

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TN Eagle Dual purpose Cask

Licensed in France for Transportation

Initial Application Submitted to NRC 12/2020 (RAI Response in Progress)

- **EOS® DSCs included as contents**

TN-EAGLE has TWO Models

- **TN EAGLE-STC (LC) (Large Canister)**
- **TN EAGLE-STC (SC) (Standard Canister)**

Versatile Universal Transportation Cask

Interim storage and transportation

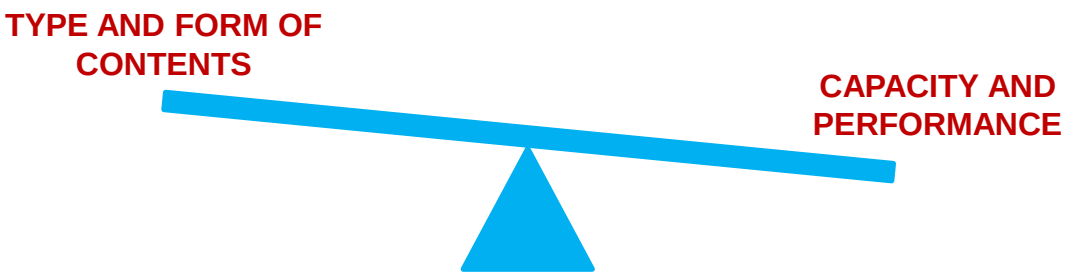
Fuel Type	Comparison with LWR fuel	Potential impacts
Oxide/Ceramic	Similar fuel form and materials Higher enrichment and burnup Advanced cladding materials	More demanding sub-criticality requirements
Metallic	Rodded form with shorter active fuel length Higher enrichment and burnup Sodium-bonding	Higher power density, thermal & radiation source terms, reactivity Additional processing prior to interim storage and transportation Fuel cladding integrity (accident conditions)
TRISO	Different fuel form with large graphite content Higher enrichment and burnup Very low power density	Possible to store/move large quantities Well-sized cylinders to manage sub-criticality
Liquid	Highly different fuel with significant change in physical/material characteristics during storage	Significant modifications needed, like: - Design features to deal with potential impact of phase change (between liquid and solid phases) - Corrosion resistant materials - Temperature and gas monitoring during storage - Fission gas getters

Conclusion

Interim storage and Transportation are critical parts of the overall front-end and back-end management

Licensed solutions must be available for the various fuel types to be transport

Anticipating the package solution is key to optimized transport scenario, and should be integrated early in the reactor design phase



“ Thank you for your attention ”