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Dual Purpose Casks in Operation

AREVA TN Experience

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Workshop on the Development and Application of a Safety Case for Dual Purpose Casks for Spent Nuclear Fuel

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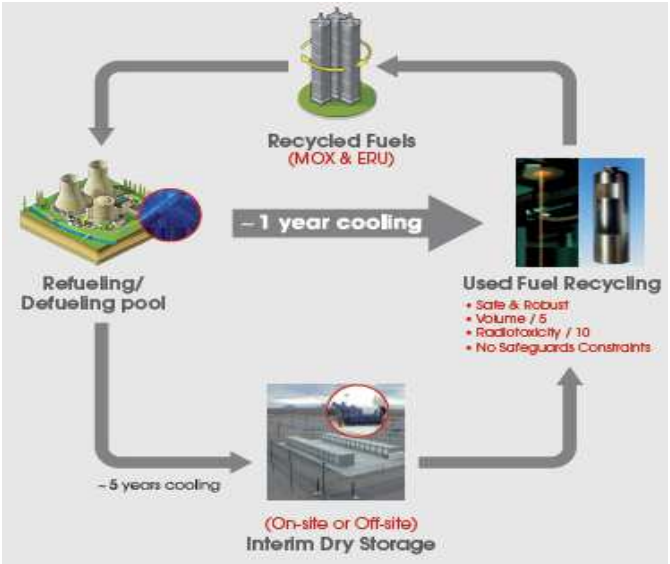
Summary

- Used Nuclear Fuel Management
- AREVA TN Dual Purpose Cask (DPC): TN®24 cask
  - Basic concept
  - Operations on storage facility and before transport
- Storage Safety Evaluation
  - Accident conditions during storage
  - Burnup credit & Criticality evaluation
  - TN®40 lessons learned
- Aging consideration for TN®24 cask
- Conclusion

Used Nuclear Fuel Management

Closed cycle in France

- At reactor : cooling, radioactive decay.
- Transport from NPP to La Hague Reprocessing plant
- Wet storage before reprocessing
- Resources for ERU fuel assemblies, for MOX fuel and for future generation IV reactors



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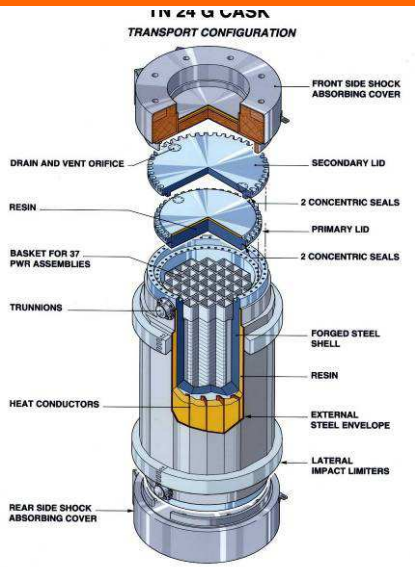
Used Nuclear Fuel Management

- **Open Cycle**
- **Interim storage of used fuel, basic principle**
  - Limited time, 30 to 40 years
  - Allow for used fuel cooling
- **Different systems to store used fuel designed by AREVA**
  - In use for decades
  - Safety records : experience covering more than 30 years

Metal casks (TN®24):



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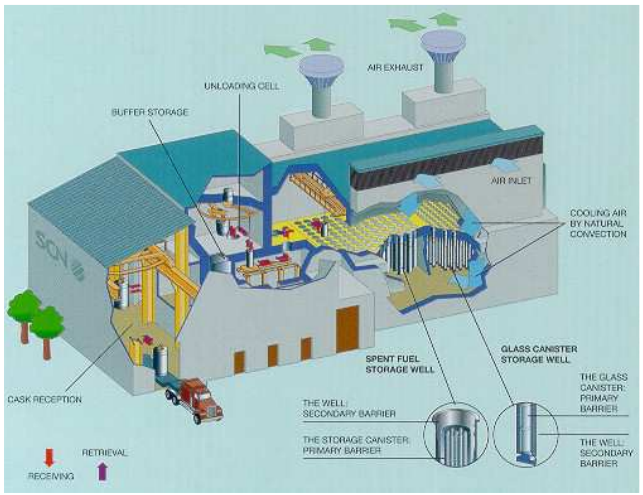
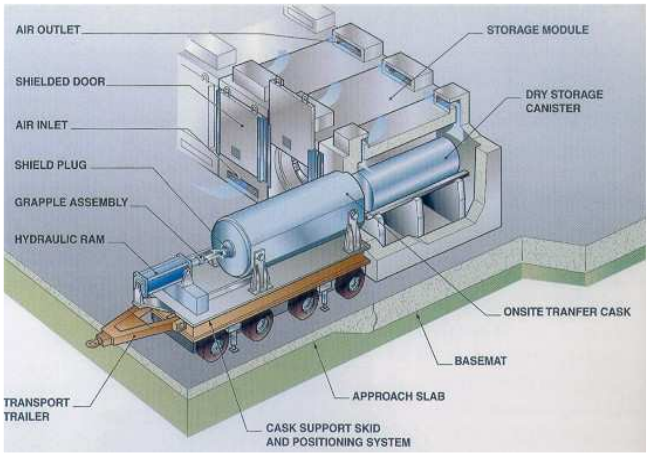
Vaults (Cascad type):



Canister based systems (Nuhoms®):



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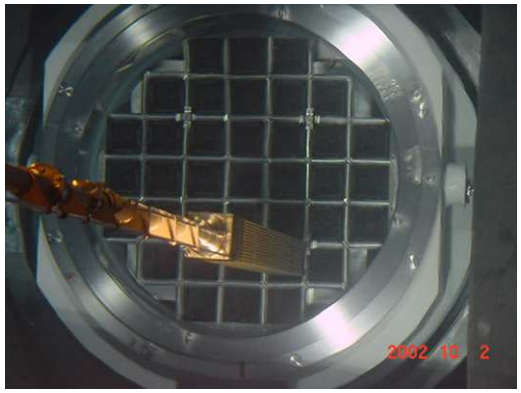
Track Record of AREVA TN Experience

- **AREVA TN is an experienced provider of storage technology in the world**
  - **USA**
    - First NUHOMS® system loaded at Robinson ISFSI in March 1989
    - First TN®24 cask loaded at McGuire in 1988 (in 1984, the TN®24P has been loaded for tests)
  - **Japan**
    - First TN®24 cask loaded at Fukushima Dai-ichi NPP in 1995
  - **Belgium**
    - First TN®24 cask loaded at Doel in 1994
  - **Switzerland**
    - First TN®24 cask loaded at Zwilag in 2000
  - **Armenia**
    - First NUHOMS® system loaded at Medsamor NPP in 2000

- **More than 300 TN®24 casks loaded**
- **More than 750 canisters systems loaded**

AREVA TN Dual Purpose cask: TN®24 cask

- **TN®24 cask: A dual purpose transport and storage packaging**
  - **Shielding of radiation:**
    - Vessel in forged steel providing the main gamma shielding
    - An external layer of neutron shielding resin covered by an outer steel shell
  - **Safe enclosure of radio-active material: the steel body and the lids equipped with metallic gaskets make the containment**
  - **Leak tightness: the high efficiency of the containment barrier is demonstrated through the permanent monitoring system**
  - **Sub criticality of the package: Basket made of Boronated aluminum and stainless steel**
  - **Removal of decay heat: Copper heat conductors**
- **Proven Technology, passive system**
- **System widely used in the USA, in Europe and in Asia.**
  - **More than 20 versions designed**
  - **More than 300 casks loaded since 1988**



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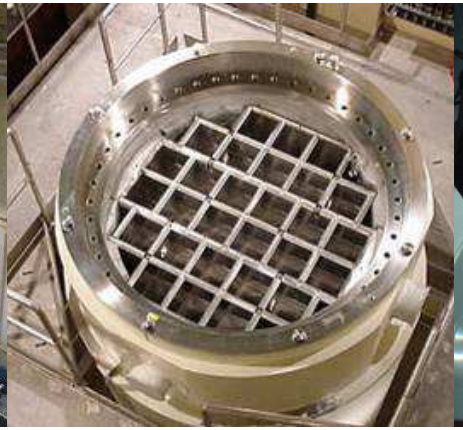
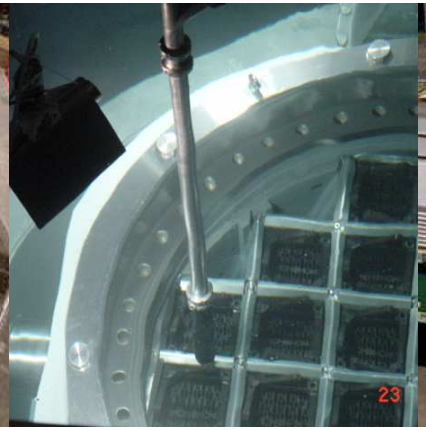
TN®24 dual purpose casks loading operations




TN®24 Operations on Storage Facility

Surveillance Requirements

- **Visual Inspection: Every 6 months an external visual inspection of the outside surface**

Monitoring Requirements

- **Leak monitoring**
  - Monitoring of the interspace between the lids (or gaskets) which is filled with pressurised helium
  - The leak system is connected to the 3 pressure sensors in order to permanently control the pressure in the lid interspace (or gasket interlids).
  - The leak system warns the operator if the overpressure interspace decreases significantly
- **Radiation Monitoring**
  - No continuous radiation monitoring required during storage
  - Dose rate measurements on Cask after installation
  - Radiation monitoring (at storage building, at ISFSI fence, site boundary…) based on utility requirements

TN®24 Operations before transport

Preparation for transport after storage

- Remove protective cover
- Perform leaktigthness test
- Check non-contamination of the cask
- Visual inspection of the handling attachment points
- Place shock absorbers and impact limiters (after checking)
- Perform regulatory controls for transportation

Licensing Management for the Dual Purpose Casks

Transport Licensing

- Generally Transport license is valid for 5 years
- Renewal of the Transport license every 5 years according to the applicable transport regulations

Storage Licensing

- The validity of the storage license depends on the national regulations
  - Storage period: 10-y, 20-y, 40-y or more
- Storage license could be conditioned to the granting of the Transport license
  - In some countries, the transport license is required to be maintained over the whole storage period
  - In other countries, the transport license is required only for the loading operation and for the transport activities (transportation before the storage period and after the storage period).

Storage Safety Evaluation
Accident Conditions

Main Accident Conditions during Storage

Cask drop

- Hypothetical drops resulting of a failure during operations outside the reactor site building.
- E.g. drop of cask without impact limiters
  - 3.4 m height onto a shock absorber placed on the concrete slab
  - 30 cm height onto the concrete slab

Cask flooding

- The cask must withstand loads from forces developed by the probable maximum flood including hydrostatic effects and dynamic phenomena

Fire

- “Envelope fire” of specific site conditions (e.g. based upon the limited availability of flammable material at the storage site)
- E.g. fire at 600°C during 1hour

Earthquake

- Risk evaluation of cask tip over
- Risk evaluation of cask displacement on the ground that could create collision between casks

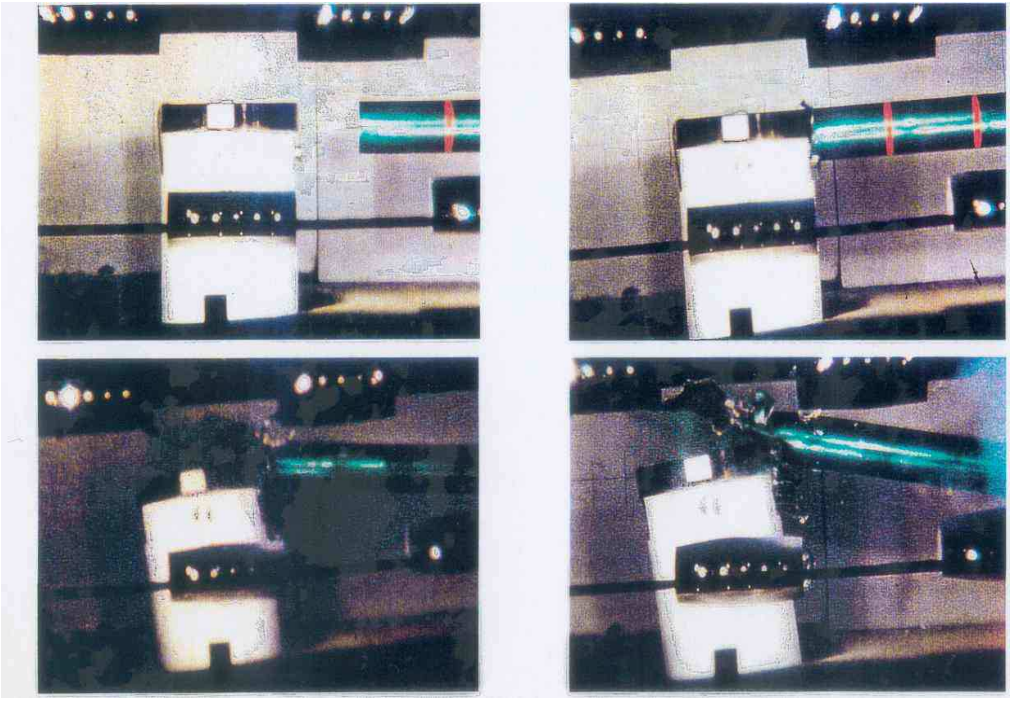
Cask burying

- In case of collapse of building

Aircraft crash

Stoarge Safety Evaluation of dual purpose cask in severe conditions

- **Testing on impact of a F16 Fighter on the TN®24D**
  - **Aircraft crash testing achieved successfully on cask specimen**



Storage Safety Evaluation
Burnup Credit

New application taking into account BU credit

- **Advanced safety demonstration on the criticality evaluation based on the use of a qualified Burnup Credit methodology including 9 actinides and 6 fission products (from 12 and 15 recommended by OECD)**

- **Qualification is based on:**
  - **demonstration of the similarity between a selected set of critical experiments (“Haut Taux de Combustion” (HTC) and Fission Product (FP) experiments, [AREVA and IRSN proprietary] and cask configurations**
  - **111 experiments from HTC and FP series was used to validate the criticality code package CRISTAL V1.0 applied for AREVA TN®24E dual purpose cask loaded with 21 irradiated UO2 fuel assemblies (minimum required average fuel assembly burnup of 12 GWd/tHM).**
  - **The similarity analysis was completed by various and numerous sensitivity analyses to confirm the application of the burnup credit on the TN®24E cask.**

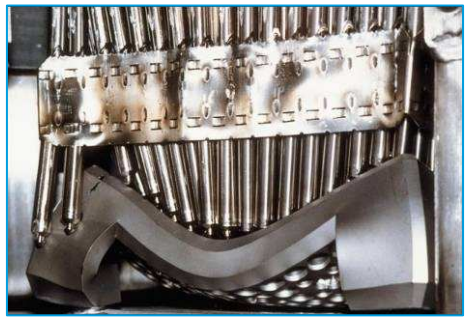
- **A validation of burn-up calculations for BUC for the TN®24E package has been approved by the German competent authority BfS.**

Storage Safety Evaluation
Criticality calculation

Assessment of Fuel Behavior (Regulatory tests IAEA SSR-6)

- **Fuel Integrity Project (FIP) for TRANSPORT**
  - **assessment of LWR Fuel Assembly mechanical behaviour in Accident Conditions and to confirm hypotheses for safety-criticality studies.**
- **FIP methodology, based on Mechanical tests on fresh and spent (BU ≈ 50 GW.d/tU) fuel rods samples, allows a complete safety assessment.**

PWR 17x17 fresh fuel assembly loaded in the FS 69 cask



BWR 8x8 fresh fuel assembly loaded in the FS 74 cask

1987 bending test on PWR fresh fuel pins

Criticality calculation based on assembly configuration

TN®40 lessons learned

- TN®40 was originally designed and licensed for storage only by AREVA TN Americas
- The transport license that was eventually granted for the TN®40 (CoC 9313) includes the following conditions:
  - Transport limited to central interim storage, geological disposal or recycling and No re-use for transportation afterwards
  - Higher strength bolts and higher preload will be required to maintain the seal
  - Prior shipment, leak testing of the entire containment boundary
  - Temperature survey on loaded package (compared to calculated outer temperature)
  - Neutron and gamma survey

Aging Considerations for TN®24 Cask

- **Mechanical behavior**
  - **Vessel in steel: mechanical properties are not significantly affected by aging**
- **Shielding of radiation**
  - **γ-shielding is provided by steel : shielding properties are not significantly affected by aging**
  - **Neutron shielding is provided by proprietary resin: shielding properties are affected by aging.**
    - Ageing effect is considered in the Safety analysis.
  - **Moreover, the dose rates decrease along time**
- **Safe enclosure of radio-active material**
  - **Steel body and the lids equipped with metallic gaskets make the containment**
    - Leaktightness metallic gaskets have been demonstrated along time
  - **High efficiency of the containment barrier is demonstrated through the permanent monitoring system**
- **Sub criticality of the package**
  - **Basket made of Borated aluminum and stainless steel**
  - **Mechanical and thermal properties affected by aging**
    - Ageing effect is considered in the Safety analysis
- **Removal of decay heat**
  - **Copper heat conductors**
  - **the heat load decreases along time**

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Actions to support storage extension

- **Aging management Program AMP**
  - **Interim storage safety functions shall be maintained in the long term**
  - **Degradation phenomenon shall be studied and mitigated (knowledge gaps)**
    - Cask component
    - Content
  - **R&D on storage systems, components and used fuel is addressing these safety questions**
- **AMP includes following programmes:**
  - **Prevention programme**
  - **Mitigation programme to slow the effects of ageing**
  - **Monitoring (condition & performance) and inspection programmes**
  - **Maintenance programme**
- **Special attention shall be paid on transportability after long term storage**

Conclusions

- **A large industrial experience and many safety studies show the ability of the interim dry storage systems to protect the public and manage safely and economically in the long term the used fuel from nuclear power reactors.**
- **Verifications are carried out to demonstrate that the fuel can be stored safely and can be transported after storage for the deployment of the back-end strategy: direct disposal or reprocessing and recycling**

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