DEVELOPMENT OF A NEW DUAL-PURPOSE CASK

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ABSTRACT

TN International (AREVA Group) has proposed for more than 20 years the TN®24 cask family which features by forged steel casks used both for the transport and storage of used fuel. Thus more than 20 versions of TN®24 casks have been designed for more than 20 customers in Europe, in the United States of America and in Japan which have ordered more than 300 casks. The PWR or BWR fuel characteristics may have various enrichment value up to 5%, various cooling time down to 2 years and various burnup up to 60 000 MWd/tU.

Facing the current international trend towards expanding used fuel interim dry storage capabilities with higher performances especially in term of used fuel characteristics and long term storage, TN International decided to launch an extensive innovation process to create the new generation of transport and storage casks.
The TN®DUO solution is the result of an extensive process to develop innovative and cost effective dual-purpose cask.

The purpose of this paper is to present this experience, and furthermore to underline the main advantages of the TN®DUO dual-purpose transport cask.

INTRODUCTION

As from the 90's TN International has developed the TN®24 family of cask to both transport and store nuclear used fuel. Many different versions have been designed, with many capacities and types of fuel, ranging from 21 PWR ones to 97 BWR ones. These dual-purpose casks have been delivered in Europe (Belgium, Switzerland, Germany and Italy), in the United States and in Japan to safely perform the interim storage of used fuel elements.

The increasing demand for massive forged pieces such as the ones use for the TN®24 body brought uncertainties on the availability and price on the TN®24 body. More generally, the overall cask needed to be redesigned to optimize all the costs.

Hence, in order to be more cost effective and to take into account new safety constraints TN International decided to launch an intensive innovation process using design to cost and

creativity methods. This process has lead to a new family of dual-purpose cask, which is called TN®DUO.

INNOVATION PROCESS

Innovation is a process of change which is managed and finalized in a pre-determined environment; this increases the chance of creating inventions and successfully introducing them into societal practice (technical but also economic, industrial, business, social and cultural). In order to permanently provide good and economical solutions through innovation, a structured innovation process must be defined. Designer teams really involved in innovation always set up innovation process.

The innovation process set up by TN International is presented in the paper [1].

The use of innovation methods by a dedicated team has lead to several innovations which have been applied in the new brand of design: the TN®DUO.

TN®DUO CASK: THE NEW LINE OF DUAL-PURPOSE CASK

The TN®DUO dual-purpose cask was first developed to transport and store the BWR used fuel of a Swiss operator. Considering other customers needs, TN International decided to adapt this concept to PWR fuel assemblies.

This article focuses only on the PWR cask, and highlights the main innovations and characteristics of this new container.

Overall presentation

The TN®DUO cask has been designed to safely transport and store used fuel assemblies. The transport cask has been designed to meet type B package requirements of the transport regulations issued by IAEA 2005 regulations [2].

The TN®DUO dual-purpose cask is constituted by:

- A cask body constituted of several pieces of forgings, closed by 2 bolted lids (body),
- A neutron shielding and heat rejection system, surrounded by a rolled steel plate (outer shell),
- A basket to host the used fuel assemblies,
- The shock absorbers in transport configuration, or an anti-aircraft crash cover in storage configuration.

The TN®DUO dual-purpose cask is presented in the figure 1.

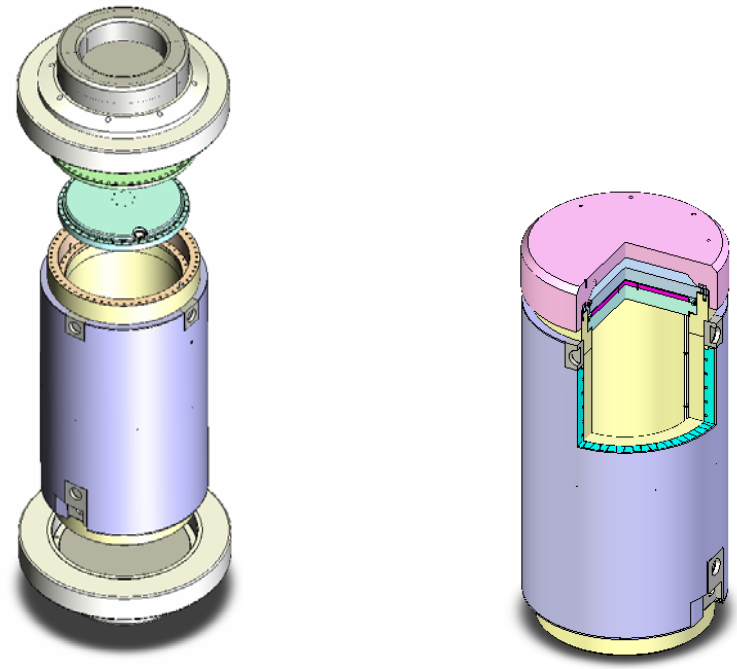

Figure 1. View of the TN®DUO in transport configuration and in storage configuration

The safety of the cask is mainly ensured by the mechanical properties of the cask body and the lids equipped with its shock absorbing covers in transport conditions.
The cask body is constituted of forged carbon steel, with high mechanical properties and good ductility at low temperature. It guarantees the gamma shielding as well, and the transfer of the decay heat.

Two pairs of trunnions on the forged vessel are used to handle safely, tilt and block the flask during transport and to handle safely the cask in the interim storage facility.

The first application of the TN®DUO cask is designed to transport and store PWR fuel assemblies (typically AREVA AFA 3G 17x17-12' or Westinghouse 17x17-12' or similar assemblies). The typical allowable content for this application is given in the table 1.

Table 1. TN®DUO used fuel typical content

TN®DUO cask	**PWR content**
Capacity	28 - 32 PWR FA w/ control components
Fuel Enrichment	5%
Max. Burn-up	65 GWd/tU
Decay Heat	32 kW

In storage configuration, a monitoring system including three pressure sensors are located on the side of the cask.

An anti-aircraft crash cover is fitted on the top of the cask and protects the package in case of airplane crash.

For the transport, the TN®DUO is equipped with shock absorbers which are suitable for rail and road utilization.

TN®DUO Items Review

- **Body**

This body is made of several pieces of forgings. This shell is closed by a primary lid and a secondary lid. Both lids are equipped with gasket, and form the double barrier required to match the safety criteria.

The grade of steel is chosen to ensure high mechanical properties and to prevent from any risk of brittle fracture. A brittle fracture analysis is carried out and all the drop scenarios are tested with calculations to ensure the safety of the cask. TN International must guarantee that the mechanical properties and integrity of the body are conserved at -40°C.

- **Outer shell**

The outer shell of the TN®DUO dual-purpose cask is made of:

- Aluminium heat conductors
- Resin blocks
- Trunnions
- The external shell

The TN®DUO outer shell is presented in the figure 2.

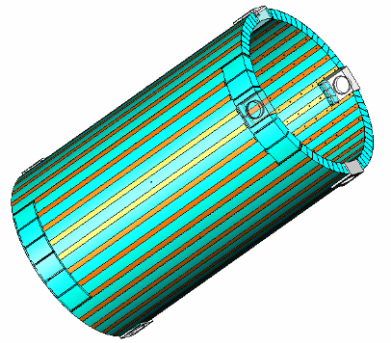

Figure 2. View of the TN®DUO outer shell

The aluminium conductors are designed to reject the adequate amount of heat, according to the customer's fuel data. The geometry, the fastening process and the fasteners type are all tested with mock ups and validated with calculations. The stake is to ensure the maximum surface contact between the body and the aluminium conductors, and a small and representative gap between the aluminium shapes and the external shell. Thermal tests run on a mock up have already validated the calculated heat rejection capacities of this design.

Resin blocks are inserted into the aluminium shapes, and designed with assembling gaps so that there are no unacceptable neutron leakages.

The external shell enables to complete the shielding and to close the resin/aluminium part of the cask.

The trunnions are fixed on the shell to enable the handling of the cask.

- **Basket**

The basket provides compact spacing of the used fuel according to the type of fuel. It is set in the cavity and:

- mechanically supports fuel assemblies,
- maintains sub-criticality in transport conditions, during fuel loading and unloading operations, and in storage conditions
- transfers the fuel decay heat to the cask body

Two baskets have been designed for this version of TN®DUO cask. The basket is constituted of steel and metal matrix composites (MMC) with boron. The MMC contains the highest B4C ratio, providing the latest technologies in the field which ensure the sub-criticality of the radioactive content.

- 28 FA Basket

The 28 position basket is evolved from the basket of the TN24®DH cask which is licensed for transportation and storage.

- 32 FA Basket

This basket will make it possible to increase the cask capacity while using burn up Credit methodology. Two different designs have been tested in term of criticality, and enable to transport and store a biggest number of fuel assemblies with high burn up and relatively small cooling times.

- **Transport auxiliaries**

- Lateral Impact Limiters

New materials have been selected to significantly reduce the deceleration (i.e. g-load) within the cavity. This new system includes stainless steel tubes, welded together.

TN International realised several drop tests and numerical calculations; these calculations are currently still running. The stake is to find out a way to justify a repeatable behaviour for the lateral shock absorbers. This design is performed in association with suppliers and a mock up will validate the final concept once the calculations will be done.

The result of a drop test of a scale model is presented in the figure 3.

Figure 3. Picture of scale model of cask after lateral drop test

- Axial shock absorbing cover

The axial shock absorbers are made of carbon foam, an isotropic material. The qualification process of this material is almost done and its shock absorbing capacities are good.

The interest is to have a material which characteristics do not vary much with temperature and environment. This new material will be associated with steel parts and will help to solve the big angle drop tests and delayed impact issue.

- **Storage auxiliaries**

Depending on the national regulation and the customer requirement, the TN®DUO cask could be equipped in storage configuration with one or two lids (primary and secondary lids) bolted on the body.

- Monitoring system

The surveillance system used in storage is a very simple one consisting of a small pressurized vessel connected to three pressure sensors and the interspace between the primary lid and secondary lid if 2 lids are required. In case of only one lid is required, the interspace monitored is the space between the primary lid outer and inner gaskets.
The interspace is pressurized with helium and permanent monitoring of the pressure allows detecting any decrease of leak-tightness performance long before any release is possible. The pressurization of the monitored space ensures that no gas can flow from the inner cavity to the atmosphere.

- Anti-aircraft crash cover

If required by the national regulation or the customer requirement, the cask could be equipped with an anti-aircraft crash cover placed over the two bolted lids. An anti-aircraft crash cover is constituted of a big forged plate which protects the package in case of airplane crash.

Mass and dimensions

The main mass and dimensions for the PWR version of the TN®DUO dual-purpose cask are given here in the table 2.

Table 2. TN®DUO main characteristics

TN®DUO cask	PWR version
Weight of the transport auxiliaries (axial and lateral impact limiters)	~ 18,000 kg
Weight of the loaded cask	~ 130,000 kg
External diameter (transport configuration)	~ 3,200 mm
External length (transport configuration)	~ 6,500 mm

TN®DUO ADVANTAGES

While having high technical performances, the TN®DUO brings cost effectiveness to every design features and provides significant advantages:

- **A dual-purpose cask** (transport and storage) compliant with IAEA 2005 regulations.
- **New aluminium heat exchangers** to simplify the manufacturing: corrugated aluminium plates for the conductors are optimized to simplify cask assembly.
- **A new basket design** has been developed for the TN®DUO to optimize the existing 28 PWR assemblies basket to reach 32 PWR assemblies' capacity. This would ease the manufacturing and the assembly while improving the level of performance.
- **Resin blocks** are inserted into the heat conductors to optimize the overall assembling phase.
- **Efficient shock absorbers** are designed to minimize acceleration during accidental drop.
- **The TN®DUO incorporates the latest advances** of the TN International and subcontractors innovation concepts. For instance, for the basket, metal matrix composites contain the highest B4C ratio, providing the latest technologies in the field.
- **Smart design features** have been integrated in the TN®DUO to ease storage operations. The monitoring system is now located on the side of the cask and thus does not require removing the anti-aircraft crash lid.

REFERENCES

[1] Technological innovations for Spent Fuel storage, IAEA-CN- 178 / KN 22 International Conference on Management of Spent Fuel from Nuclear Power Reactors, 2010, Hervé Issard, (AREVA Group), Saint-Quentin-en-Yvelines, France.

[2] IAEA, Vienna 2005, Regulations for the Safe Transport of Radioactive Material, Safety Standard Series, N° TS-R-1, 2005 edition (revised)