ITALIAN-FRENCH EXPERIENCE IN THE DEVELOPMENT, LICENSING AND MANUFACTURING OF A NEW CASK FOR THE TRANSPORTATION OF USED FUEL FROM PIEMONTE NUCLEAR SITES

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ABSTRACT

In 2007, TN International was charged by SOGIN to transport the used fuel stored on Piemonte nuclear sites to La Hague for recycling. To perform those evacuations, the development and licensing of a new high capacity transport cask, the TN®117, was necessary. The shipments should start at the end of 2010, which means a very tight time schedule to design a new cask, to apply for a B(U)F certificate of approval complying with IAEA regulations (2005 Edition), and to manufacture two casks, associated operating tools and transport means.

The design of the cask started in April 2007 and more than two years has been necessary for the granting of the cask approval and its validation in Italy. The two casks, the handling and transport means and the operating tools have been manufactured in parallel from the end of 2007 to September 2010. Thus, design changes and optimizations have to be implemented in the procurement process during the licensing phase.

Thanks to this optimized time schedule the shipments will be able to start by the end of 2010.

INTRODUCTION

SOGIN, the Italian State Company founded in 1999 to ensure used nuclear fuel management and the decommissioning of the Italian nuclear power plants and nuclear research centers, signed, in April 2007, a contract with AREVA for the transport and recycling of used fuel stored at the Caorso and Trino nuclear power plants and at the Avogadro site. The international transport activities, coordination and cask supplies were entrusted to TN International (AREVA).

The operational compatibility of TN International used fuel transport casks with the Italian sites needed to be checked as a first step of the project. The capacities of Trino and Avogadro cranes are limited to 60t and the height of the entrance door at the Avogadro site is limited to 3200 mm. These constraints led the development and licensing of a new high capacity transport cask, the TN®117.

The deadline of the following tasks for making shipments by the end of 2010 necessitates the following tasks:

- Design of a new cask, with an optimized capacity considering limiting dimensions and weight constraints.
- Application for a B(U)F certificate of approval and validation in Italy,

- Manufacturing of two casks,
- Inventory and manufacturing of the associated operating tools, handling and transport means necessary both at the Piemonte sites and La Hague.

SEVERAL TYPES OF USED FUEL TO BE LOADED IN A CASK WITH MANY DIMENSIONS LIMITATIONS

The PWR UOX fuel assemblies and PWR MOX fuel assemblies were burnt in the Trino Nuclear Power plant and are now stored in the Trino pool. Different types of fuel assemblies have been stored at the Avogadro site:

- PWR UOX fuel assemblies and PWR cruciform assemblies burnt in the Trino reactor,
- BWR UOX/MOX fuel assemblies and BWR half pins burnt in the Garigliano reactor.

The PWR UOX fuel assemblies and BWR UOX/MOX fuel assemblies can be respectively divided in two sub-categories:

- PWR UOX fuel assemblies because of the different levels of enrichment and burn-up.
- BWR UOX/MOX fuel assemblies which are made of a mix of UOX and MOX rods falling into two types of assemblies: BWR UOX fuel assemblies and BWR MOX fuel assemblies.

In addition some of the BWR fuel assemblies were leaking.

Table 1 represents the different types of fuel to be loaded in TN®117 casks:

Categories	PWR MOX fuel assemblies	PWR UOX fuel assemblies		PWR UOX cruciform assemblies	BWR UOX / MOX fuel assemblies		BWR UOX half-pins
Array	15 x 15	15 x 15		cruciform	8 x 8		9 x 9
Nuclear power plant	TRINO	TRINO		TRINO	GARIGLIANO		GARIGLIANO
Sub-categories		(1)	(2)		MOX	UOX	
Maximum burn-up (GWd/tU)	38.6	17.6	38.6	42.1	40.8	40.8	14.3
Cooling time (years)	22	20	30	33	29		40
Max initial enrichment (U235)	0.72 %	4.5%		4 %	0.72 %	2.41 %	2.5 %
Maximum initial Pu / (U + Pu) content	6.8 %				6 %		
Leaking fuel assemblies	No	No		No	Some of them		No

Table 1: Different types of fuel to be loaded in TN®117 casks

Moreover, as the fuel assemblies were stored at two different sites (Table 2), the contents allowed in the transport license (Table 3) have been determined in order to optimize the number of shipments from each site.

Categories / Location	PWR MOX fuel assemblies	PWR UOX fuel assemblies	PWR UOX cruciform assemblies	BWR UOX / MOX fuel assemblies	BWR UOX half-pins
TRINO	**X**	**X**			
AVOGADRO		**X**	**X**	**X**	**X**

Table 2: Storage location of the fuel to be loaded in TN®117 packaging

Categories / Content	PWR MOX FAs	PWR UOX FAs	PWR UOX cruciforms	BWR UOX / MOX FAs	Fuel holder of BWR UOX half-pins	Total of FAs loaded
Content 1	≤ 2	≤ 10				≤ 12
Content 2		≤ 12				≤ 12
Content 3			≤ 12			≤ 12
Content 4				≤ 12		≤ 12
Content 5		≤ 2	≤ 4	≤ 4	≤ 1	≤ 11

Table 3: Contents allowed in the transport license

One of the main challenges of the project was to load all of different types of used fuel assemblies in the same basket. Therefore, each dimension or characteristic of the cask was linked to the most conservative content. For instance:

- Section of the basket lodgments designed according to PWR fuel assembly cross-sections,
- Length of the cavity designed according to BWR fuel assembly length
- Weight of the content designed according to PWR fuel assembly weight
- Neutron shielding thickness designed according to PWR and BWR MOX fuel assembly source terms (content 1 and 4)
- Gamma shielding thickness designed according to PWR UOX fuel assembly source term (content 2)
- Boron content in the basket material for criticality safety analysis designed according to PWR fuel assembly initial enrichment (content 1 and 2)

In the same manner all safety analyses, such as thermal analysis, containment analysis, shielding analysis and criticality safety analysis had to be performed taking into consideration each radioactive content, including the different sub-categories of fuel.

TN®117: a compact cask

During the design phase of the cask, the project team had to face some important site constraints which were listed during the first steps of the project. The two main constraints were:

- The crane capacity with the resulting maximum weight of 60 tons for the loaded cask without shock absorber, the cavity filled with water;
- The height of the entrance door at the Avogadro site with the resulting maximum height of 3200 mm for the cask on its transport trailer without its shock absorbers.

The first constraint resulted in the limitation the cask capacity, the limitation the dimensions of the cask cavity and the optimization of the ratio between the thickness of the steel (high density material) and the thickness of the resin (low density material) used for the shielding protection. This was done while keeping enough margin on the steel thickness in order to ensure the mechanical strength of the cask to fulfil the Accidental Conditions of Transport requirements as defined by the transport regulations.

The second constraint had an impact on several transport elements such as:

- The height of the road trailer
- The transport frame and the diameter of the shock absorbers
- The diameter of the cask

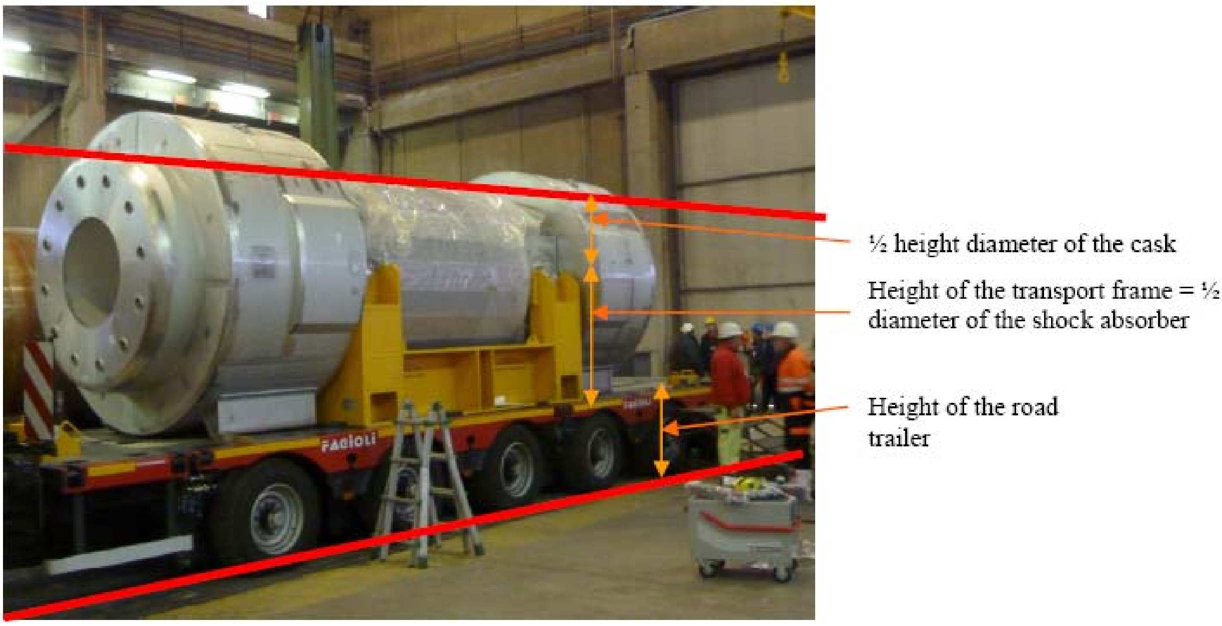

Figure 1: A limited height for the cask on its transport trailer

As the lorry defined a preexisting requirement, the diameter of the shock absorbers had to be limited, while maintaining satisfactory mechanical behaviour of the casks during regulatory drops. In order to allow the cask to go through the entrance door of the Avogadro facility, the diameter of the cask had also to be optimized at the following levels:

- the internal cavity of the cask while keeping the best capacity possible,
- the thicknesses of steel and resin while keeping a high performance of shielding protection,
- the length of the external cooling fins while keeping a good thermal performance of the cask.

Despite these limiting constraints, the capacity of twelve fuel assemblies was made possible thanks to:

- the performance of the neutron poison in **Alcan's Al-B_4C** Metal Matrix Composite (MMC) used to design a very compact basket within the limited diameter of the cavity (1100 mm);
- the performance of the neutron shielding protection, Vyal B™ resin, whose optimized shielding properties and enhanced thermal properties (patent application N° WO 03/050822), allows the limitation of thickness;
- the heat dissipation system of the cask based on copper heat conductors in contact with both the internal and external shells, and with limited length cooling fins.

A TIGHT TIME SCHEDULE TO DEVELOP, LICENSE AND MANUFACTURE TWO CASKS

As the transports should start in 2010, which means three years after the contract signature, different means to reduce the time schedule have been planned by the project team to meet this goal:

- Design phase limited to one year, including the preparation of the safety analysis report.
- Cooperation with Italian Authorities at the beginning of the licensing phase, in order to reduce the time necessary between the granting of the French certificate of approval and its validation in Italy.
- Launch of the process for the specific transport authorizations with both French and Italian Authorities before obtaining the packaging license.
- Manufacturing of the two casks in parallel to the design and licensing of the packaging.
- Definition and manufacturing of the associated operating tools, handling and transport means necessary both at the Piemonte and La Hague sites in parallel to the fabrication of the two casks.

<u>A design phase limited to one year</u>

In order to succeed in this goal, the mechanical behaviour of the TN®117 has been based on the TN®24 GET drops tests. The TN®24 GET cask was licensed in France in 2001 following IAEA regulations (1985 edition) and validated in Italy in 2003. The TN®24 GET drop tests were performed in January 2000 with a 1:3 scale model at Laudun platform (see figure 2).

Figure 2: Vertical drop test of TN®24 GET scale model

The results of the drop tests demonstrated that both primary and secondary lids of the TN®24 GET remained leak tight after the drop cases considered by IAEA regulations.

TN®117 was designed with a similar geometry and similar shock absorbers (figure 3).

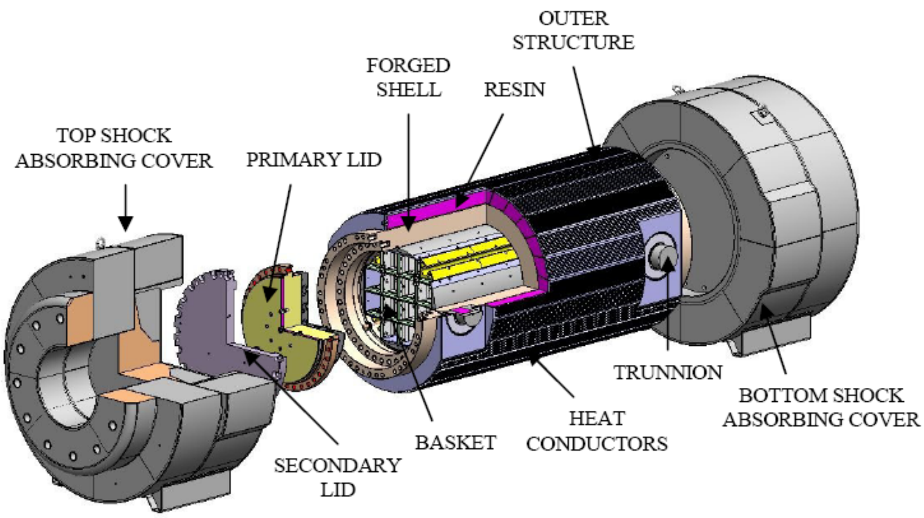

Figure 3: General design of the TN®117 packaging

These shock absorbers are made of balsa wood contained in stainless steel casings. The balsa wood is used as an absorbing material in every impact direction. The size of the shock absorber avoids the impact of the cask body. This prevents the trunnions from acting as rigid points on the forged shell of the body.

Both primary and secondary lids were demonstrated to be leak tight after the drop cases by numerical calculation. The model was benchmarked with the TN®24 GET drop tests results, as the designs of the casks are similar.

After one year needed for developing the cask, application for B(U)F certificate according to IAEA regulations (2005 edition) has been submitted to French Authorities in June 2008. More than two years of expertise have been necessary for approval which is expected to be granted in November 2010.

<u>Manufacturing of the two casks in parallel to the design and licensing of the cask</u>

The manufacturing of the two casks has been performed in parallel to the licensing work from the end of 2007 to September 2010. Manufacturing of the thick carbon steel forgings started as soon as the dimensioning phase and the structural analysis were validated by TN International. Welding, cladding of the cavity and external part of the body and lid, assembly of the two bodies and manufacturing of the baskets started as soon as the whole design was validated internally and the safety analysis report was submitted to French Authorities.

This situation led the management of design changes decided during the expertise phase. Two main design changes affected the cask production:

- Lateral drop cases with impact along the trunnions area.

As mentioned above, the impact of the trunnions during drop cases needs to be avoided. To increase the remaining gap between the trunnion and the surface of impact after lateral drop case considering the boundary conditions (minimal crushing stress and maximal temperature of the shock absorbers), extra thickness was added on the lateral parts of the shock absorbers (figure 4). This extra thickness was added during the manufacturing phase.

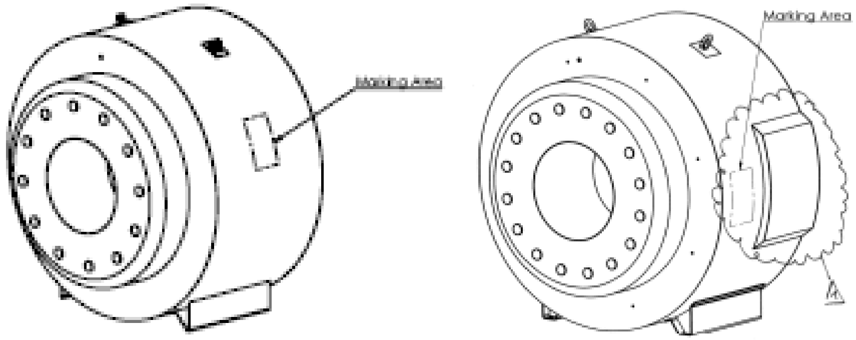

Figure 4: Previous design and current design of the shock absorbers

- Delayed impact of the cask content on the lid taking into account the most penalizing axial gap

In October 2009, French Authorities requested TN International to analyze the influence of the axial gap between the content (basket and fuel assemblies) and the cavity. The most damaging situation for the cask is the 9 m axial drop with impact onto the shock absorber. In this situation, French Authorities require in a conservative approach, to take into account the maximal gap between the content and the lid. This leads the content to impact the lid shortly after the impact of the cask on the target.

In order to demonstrate the leak tightness of the two lids, the design had to be modified in the following way:

- o Modification of the primary lid by adding extra thickness to reduce the overall gap of the content,
- o Adaptation of the basket length to accommodate the extra thickness of the primary lid, to enter in the cavity,
- o Limitation of the gaps between the fuel assemblies and the primary lid by adding spacers. The remaining gap is needed for thermal expansion during transport and for manufacturing and irradiation tolerances,
- o Increase of primary lid bolts strength to avoid any strain.

Leak tightness of the two lids was then demonstrated in the different boundary conditions (temperature of the shock absorbers and the cavity, axial gaps between the contents and the cavity, preload of the bolts) by numerical calculation considering, with a very conservative assumption, the assemblies and basket infinitely rigid.

The delayed impact analysis started when the two casks were nearly completely manufactured. The design modifications were selected taking into account the industrial constraints such as cost and time.

Finally these modifications were facilitated by the fact that, since beginning of 2009, TN International had a sister company, Mecagest specializing in the manufacturing of critical components such as shock absorbers and internal arrangements (baskets).

Manufacturing of the associated operating tools, handling and transport means

Keeping in mind the time schedule optimization, the operating tools along with the handling and transport means both for Piemonte and La Hague sites have been designed and manufactured in parallel to the casks production. Modifications of existing handling equipment (lifting beams and lorry) in Avogadro and/or La Hague were part of the project. Equipment such as transport frames, horizontal lifting beam, shock absorber lifting beam and orifice tools, were tested in the manufacturing shop of the cask in order to anticipate all the potential modifications of the tools due to interfaces.

CONCLUSION

TN International's experience in designing and licensing used fuel casks was a key aspect of this project, whose team faced many challenges: various radioactive contents, very stringent dimension and weight constraints and a tight time schedule.

Such challenges were overcome thanks to:

- a design basis and qualification well relying on the existing TN24 family,
- a wide knowledge in licensing and transporting all types of used fuel (BWR, PWR being UOX or MOX),
- an efficient project management based on appropriate change management associated with the use of innovative processes.

Thanks to the good relationship between all parties involved, the optimization of the time schedule was made possible, making this project a major success for all of the actors.