Proceedings of the 17th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2013-08-02 August 18-23, 2013, San Francisco, CA, USA

USED FUEL ASSEMBLY TRANSPORTCASK TN®G3 FAMILY

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ABSTRACT

TN International has extensive experience in domestic (in France) and international transport of used fuel assemblies (in France about 2,400 fuel assemblies are transported each year). Compared with the first transport cask designs of the early 1980s, the fuel characteristics (enrichment, burn-up) have significantly evolved. Meanwhile, the requirements of the regulations and the Competent Authorities have also significantly increased.

To deal with these evolutions and continue to satisfy customer needs for the transport of used fuel assemblies over the next 40 years, TN International has developed a new generation of transport casks. The TN®G3 cask family has been designed with four main purposes:

- Transport a wide scope of fuel types, with high enrichment (up to 5%), high burn-up (up to 70,000 MWd/tU), even with a short cooling time (as low as 2 years). Such content results in high radiation sources, especially neutron sources for high burn-up fuel. Used MOX fuel can also be transported. The TN®G3 cask is designed to mitigate the radiation level surrounding the package.

- Secure a design compliant with the highest safety level requirements. In particular, the TN®G3 design includes a double leaktight barrier complying with the latest IAEA regulations. The leaktightness of the barriers will be demonstrated by a drop test campaign with a package model including, in particular, the delayed impact effect.

- Minimize changes of interfaces with the hosting facilities (nuclear power plants and recycling facilities in France) and transport means (trucks, wagons…). Most of the heavy tools are unchanged for the operation of the casks, such as the cask lifting yoke, the transport skid, or the skirt to prevent contamination during pool immersion.

- Integrate TN International’s 50 years of experience in the shipment, operation and maintenance of transport casks into the design. The TN®G3 cask is also compatible with the latest NPP design such as the EPR™ reactor.

This paper presents the TN®G3 cask family, and the technical solutions to comply with this challenging scope of work.

INTRODUCTION

TN International has extensive experience in domestic (in France) and international transport of used fuel assemblies (in France about 2,400 fuel assemblies are transported each year). Compared with the first transport cask designs of the early 1980s, the fuel characteristics (enrichment, burn-up) have significantly evolved. Meanwhile, the requirements of the regulations and the Competent Authorities have also significantly increased.

To deal with these evolutions and continue to satisfy customer needs for the transport of used fuel assemblies over the next 40 years, TN International has developed a new generation of transport casks.

The TN®G3 cask family has been designed to cover a maximum of Nuclear Power Plant (NPP) needs. As described in Table 1, three different packages are part of the TN®G3 family to cover NPP differences in terms of:

- Fuel rod length: from short fuel assemblies (less than 3.5 m) to long fuel assemblies (almost 5 m for 14-foot long rods in active length).

- Lifting capacity of the facility crane.

Table 1: TN®G3 package family

	Short fuel rod length	Medium fuel rod length	Long fuel rod length
Light weight cask	TN®17MAX		
Medium weight cask	TN®-G3 S		
Heavy weight cask	TN®-G3 L		

All three casks have the exact same designs and components. Only dimensions may differ between them. Hereafter, this presentation will refer only to the TN®G3 design as a generic design applicable to the three different packages.

DESCRIPTION OF THE TN®G3 DESIGN

The TN®G3 package is composed of:

- Body made of a cylindrical thick-walled forged shell made of cryogenic carbon steel. A thick forged cryogenic carbon steel bottom is welded by full penetration to the shell. The steel vessel is surrounded by a neutron absorbent material, Vyal B, developed by TN International. This layer is protected by an external shell equipped with external thermal fins.
- Ports on the cask body itself give access to the cavity. They are used for draining and drying operations.
- Closure system consisting of two leaktight lids compliant with the double leaktight barrier definition of the regulations [1].
- Impact limiters, one at each end of the cask to absorb shock energy in case of accident during transport.
- Basket to receive used fuel assemblies.

The general view of the package is shown in Figure 1.

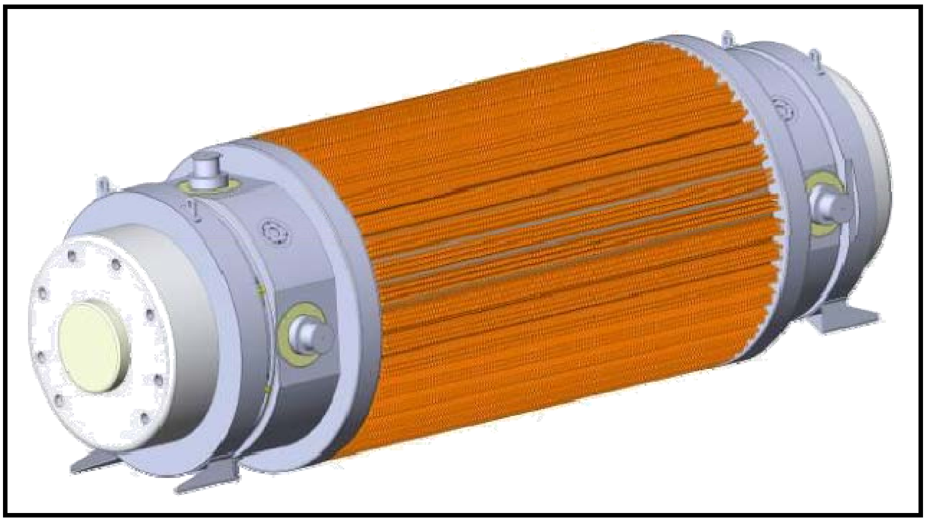

Figure 1: TN®G3 general view

Such a design is the result of an optimization between:

- the content characteristics: radiation level, thermal heat…
- the safety requirements,
- the interface limitations in facilities and operations for loading/unloading.

These aspects are further developed hereunder.

TN®G3 PACKAGE CONTENT

TN®G3 packages are designed to transport Pressurized Water Reactor (PWR) and Boiler Water Reactor (BWR) used fuel assemblies. The main fuel characteristics are described in Table 2.

Table 2: TN®G3 content characteristics

	PWR
Maximum enrichment	5 %
Maximum burn-up	70 000 MWd/tU
Minimal cooling time	2 years

These fuel data are maximum values which should cover generations of fuel for the next 40 years.

<u>Neutron sources</u>

Because of the high burn-up, the neutron sources for shielding are very high. For example, the increase of burn-up from 46 GWd/tU to 62 GWd/tU results in more than doubling the neutron sources. Also, neutron sources decrease very slowly with cooling time.

To accept high burn-up, the TN®G3 package is totally surrounded by a layer of neutron absorbent material, including the cask bottom and the primary lid to protect workers during cask operations in NPPs.

This material, called Vyal B, is a specific material developed by TN International. Its high hydrogen and boron content makes a very efficient neutron shielding barrier.

Cooling time

The TN®G3 package is designed for content necessitating a short cooling time. Such content is characterized by high thermal power and high gamma source levels.

The thermal power for high burn-up and short cooling time goes up to 5 kW per fuel. To dissipate such a heat load without damaging the fuel claddings or the package seals, the TN®G3 design is composed of a high conductive basket made of high conductivity aluminium. The forged shell is also equipped with copper conductors screwed on the vessel and going through the neutron absorbent resin. They form an outer shell in copper. Finally, outer copper fins welded onto the outer shell have been specifically designed to evacuate the thermal load.

For gamma radiation shielding, the TN®G3 package is made of a thick carbon steel vessel. The outer copper shell, designed for thermal purposes, also adds significant gamma shielding. To increase the protection of workers during cask operations, the lid shielding has been reinforced with tungsten plates, a very high density material (around 19 compared to 7.85 for steel).

SAFETY REQUIREMENTS

Double barrier design

The TN®G3 design complies with the latest requirements of IAEA regulations [1] for the definition of double leaktight barrier. For criticality analysis, water inleakage inside the cask cavity shall be considered according to the IAEA regulations [1], except in cases with a double leaktight barrier. This assessment of “water exclusion” can thus allow the criticality analysis to be done without any reconfiguration of the fuel (the fuel is modelled in the most penalising configuration).

To comply with the double leaktight barrier definition, the TN®G3 package is composed of:

- A thick wall body in a high quality standard material subject to high requirements and qualification against brittle fracture.
- Two independent lids to close the cavity
- Two independent plates to close each of the lateral ports.

The leaktightness of the lids and port plates are demonstrated in Accident Conditions of Transport according to the regulations [1]. A 1:3 scale model of the package will be used to perform the drop tests in the most severe configurations that may challenge the leaktightness of the barriers. Indeed, the specific configuration of the delayed impact will be physically tested on the model.

Delayed impact

As described in the paper by Gordon S. Bjorkman, Jr. [2], the delayed impact is a new configuration for the lid-end drop consisting of keeping the maximal gap between the content and the lid, even during the drop fall, until the impact of the package on the target. The content impacts the lid with a certain time delay resulting in dynamic load amplification. This configuration is described in Figure 2.

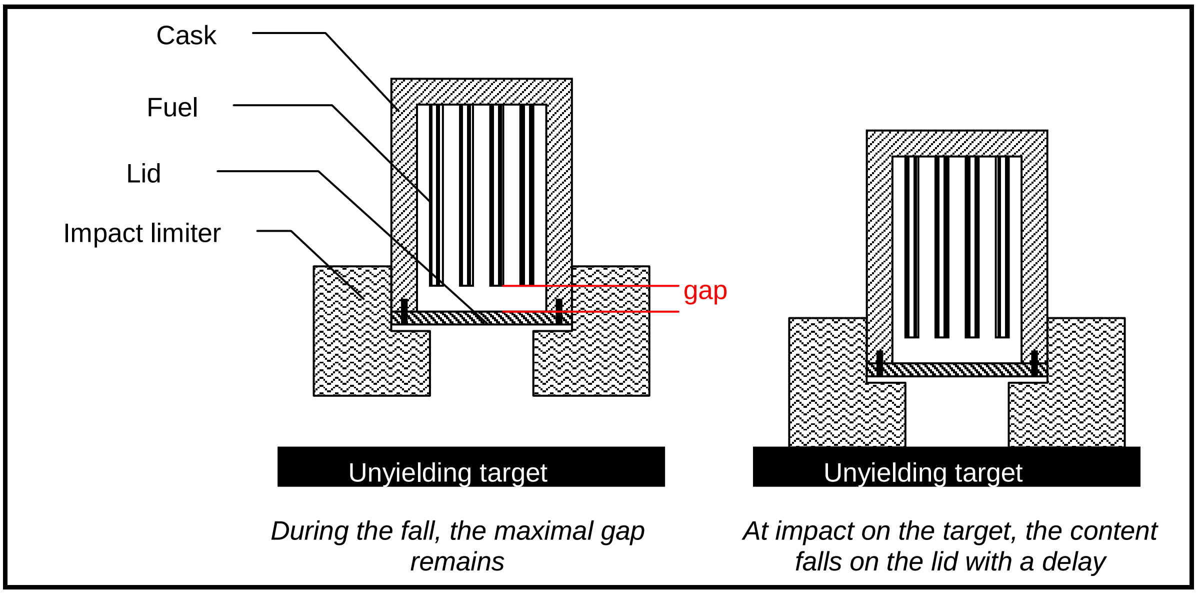

Figure 2: TN®G3 delayed impact configuration

The consequence of this configuration is that while the lid starts to decelerate during the crush of the impact limiter, the content continues to fall inside the cavity. The speed difference between the lid and the content results in a dynamic amplification of the load on the lid and its bolts.

To prevent any bolt deformation, the TN®G3 primary lid is equipped with an impact limiter on its internal surface.

The crush of this impact limiter reduces the load on the lid and its bolts. The technology of the internal impact limiter complies with severe constraints:

- It is not made of a material containing hydrogen. Otherwise, radiolysis from the radioactive content radiation may produce explosive gas (hydrogen) in the cavity.
- It is stable in a wide range of temperatures, as the temperature of the inner surface of the lid may reach up to 200°C.
- It is thick enough to absorb the content drop energy, but not too thick so as to keep the total thickness of the lid within a range acceptable to the facilities, especially the AREVA La Hague recycling plant.

After much optimization and numerous tests, the lid impact limiter has been successfully designed and tested on drop test mock-up. It will be validated during a drop test with a 1:3 scale model. The drop test will be performed taking the delayed impact effect into account, meaning that the content of the scale model will be maintained on the bottom surface until the impact of the package on the target.

FACILITIES INTERFACE AND OPERATIONS

Compatibility with facilities

The TN®G3 package will be used in different Nuclear Power Plants and in the AREVA La Hague recycling plant. Each facility has its own specificities. To be compatible with various operation processes, the TN®G3 cask has the same interface geometry as the existing TN International packages which are widely received in facilities today.

This is true for trunnion gauges, but also for the primary and secondary lids. Thus, the TN®G3 packages are compatible with operation processes such as immersion of the cask in the loading pool, as well as operation processes consisting in docking the cask with a pool or a dry cell through a leaktight airlock system (case of the AREVA La Hague recycling plant).

The TN®G3 cask is also equipped with three lateral ports on the cask body itself: one on the top end for ventilation, two in the bottom for drainage and drying. They also provide access to the cavity without opening the lids or when the cask is docked in an airlock system.

Finally, to minimize changes of interfaces with the hosting facilities (nuclear power plants and recycling facilities in France) and transport means (trucks, wagons…), most of the heavy tools are unchanged for the operation of the casks, such as the cask lifting yoke, the transport skid, or the skirt to prevent contamination during pool immersion.

Total dose in operations

The TN®G3 package will replace the fleet of TN®12/2 and TN®13/2 casks, presently used for spent fuel transportation in France. A comparison of the total dose during operations to complete a loading operation cycle has been performed.

The comparison is based on:

- The content radiation sources: the fuel characteristics in the TN®G3 package result in higher neutron and gamma sources than in the existing package. Indeed, the TN®G3 package is to be used for next 40 years. Even for future fuel, the total dose for the loading cycle should be decreased.
- The cask shielding capacity of each package: 3D shielding models have been performed in different configurations, both with or without a secondary lid, or when the cavity is both filled with water or in dry conditions.
- The duration of the operations and number of workers needed for each operation.

The result is that the TN®G3 package will reduce the dose for operations from 10% to 30% depending of the operation process in NPPs, even with a higher radiation level of the sources than the current radiation level for the existing packages.

Trunnion protection

The TN®G3 cask is equipped with 6 trunnions: 4 on the top end and two on the bottom. They are used as tie-down points on the transport vehicule, handling points in facilities and rotating points during cask tilting.

The trunnions are bolted onto the cask body. The bolt areas, and especially the bolt heads, require specific protection during immersion in the NPP pool to prevent contamination as this area is difficult to clean.

The TN®G3 trunnion bolt area is covered by a protective plate in stainless steel equipped with an elastomeric seal. Its leaktightness even during immersion ensures no inleakage of water in this area and prevents contamination.

CONCLUSION

The TN®G3 design family is a flexible spent fuel transport package family, able to accept a large diversity content types of up to 5% enrichment, up to 70,000 MWd/tU burn up, with a minimal cooling time of 2 years.

REFERENCES

[1] IAEA Safety Standards, "Regulations for the Safe Transport of Radioactive Material," N° TS-R-1 2009, Edition.

[2] SMiRT 20-Division 5, Paper 1941, "*The Effect of Gaps on the Impact Response of a Cask Closure Lid*," Gordon S. Bjorkman, Jr.