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TN NOVA™ Storage Licensing and Airplane crash test

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ABSTRACT

The likelihood that an aircraft will crash on a storage cask containing used nuclear fuel is extremely small. However, some Regulators require that this potential accident is considered as a design assumption for storage. In accordance with the requirements of the ENSI, the Swiss Competent Authority, it is necessary to demonstrate that any used nuclear fuel interim dry-storage cask to be stored in Switzerland, in this case the TN NOVA™ storage system, is able to resist a simulated airplane crash test.

The TN NOVA™ system is one of the latest developments of TN International (TNI), an AREVA subsidiary, for AXPO Power AG, the largest Swiss Nuclear Utility. This system is expected to meet the used fuel assembly interim storage needs of the Leibstadt Nuclear Power Plant for its entire lifetime. The system meets the two necessary functions of transport and storage by means of three different components supported by two licenses:

- A sealed NUHOMS®-69BTH Dry Shielded Canister: This contains the used fuel assemblies and is loaded and sealed at the Nuclear Power Plant.
- A TN NOVA™ Overpack: The sealed Canister is loaded into this Overpack, which is used as a protective shell during storage. Together they comply with the Storage license which is reviewed and granted by the ENSI.
- A NUHOMS®-MP197HB Transport Cask: For transport, the sealed Canister is transferred from the Overpack into this Transport Cask. Canister and Transport Cask comply together with the Transport license which is reviewed and granted by the US Nuclear Regulatory Commission and is validated by the ENSI.

There is only one Transport Cask for multiple Storage Canisters and Overpacks.

This paper describes the main requirements for a Storage license in Switzerland and the aircraft crash test that was performed in 2010 in order to demonstrate the ability of the TN NOVA™ to withstand the impact of an airplane crashing into the cask at a speed of more than 800 km/h. The TN NOVA™ system successfully withstood this crash test, fully maintaining its leak tightness.

The TN NOVA™ product development has required specific design and numerical modeling resources from both US and French teams resulting in an excellent correlation between design calculations and test results.

The test was performed less than two years after the initial order was placed by AXPO Power AG.

INTRODUCTION

Within the framework of the contract signed between AXPO Power AG and AREVA TNI for the supply of multiple Storage casks for Leibstadt Nuclear Power Plant spent fuel assemblies, it is imperative that this innovative design fulfils the requirements of the ENSI, the Swiss Competent Authority. Therefore, the new TN NOVA™ cask (concept of a metallic TN NOVA™ Overpack and a sealed NUHOMS®-69BTH Dry Shielded Canister) has to withstand the most severe impacts, including a regulatory aircraft crash test.

This paper intends to provide an overview of the concept and the performance of the TN NOVA™ system under the conditions of a simulated airplane crash test. First the concept and the related operations are described, then the test itself along with its preparation and its success.

The airplane crash simulation test has proven the ability of the TN NOVA™ system to withstand the impact of an airplane hitting a cask at a speed of more than 800 km/h (approximately 500 mph). This success was demonstrated by a leak tightness test after the simulated airplane crash was performed.

BACKGROUND

This new system was developed in 2007 and, in response to a call for bid, offered to the Swiss utility AXPO Power AG for the storage of BWR spent fuel assemblies. The contract signed in January 2009 between AXPO Power AG in the name of KKL (Leibstadt Nuclear Power Plant) and TN International covers the conception, design and delivery of an innovative interim storage system: the TN NOVA™. This contract and its options aim at covering the power plant long term storage needs until the end of its life.

The TN NOVA™ system is the result of a TN International (France) - Transnuclear Inc. (USA) joint collaboration, combining the advantages of the NUHOMS® and TN® 24 systems, and providing a segregation of storage and transport functions:

- A sealed NUHOMS®-69BTH Dry Shielded Canister which contains a basket with the used fuel assemblies and is loaded at the Nuclear Power Plant while already placed inside
- A NUHOMS®-MP197HB Transport Cask which transports the loaded canister from the power plant to the storage facility. For storage, the sealed Canister is transferred from the Transport Cask into
- A TN NOVA™ Overpack which is then placed in the storage hall.

Based on customer needs, inland transport before and after at least 40 years of storage, the transport and storage functions have been segregated. This segregation results in only one Transport Cask being required for multiple Storage Canisters and Overpacks.

The priority of this project was to develop a safe, flexible and cost-effective system in compliance with the transport and storage regulatory requirements. To this end, the design of the TN NOVA™ Overpack has been optimized using thick steel plates instead of the traditional large metal forgings. Its octagonal shape also allows simplification of the manufacturing supply chain.

Each function (storage and transport) is supported by a separate license, issued under different regulations:

- Storage for the TN NOVA™ Overpack, reviewed and granted by the ENSI
- Transport for the NUHOMS®-MP197HB Transport Cask, reviewed and granted by the US Nuclear Regulatory Commission and validated by the ENSI.

The NUHOMS®-69BTH Dry Shielded Canister is licensed for both Storage and Transport.

Furthermore this separation of storage and transport licenses provides freedom for independent product evolutions due to either regulatory changes or product optimization for the Overpack or the Transport cask.

STORAGE LICENSING

The ENSI G05 Swiss regulation for the licensing of any spent fuel storage cask makes it compulsory for the storage system to withstand a simulated aircraft crash test.

In addition to the regulatory requirements, the system must fulfill the contractual requirements of a canister capacity of 69 spent fuel assemblies with a maximum burn-up of 70 GWd/MTU. Furthermore, the canister, in particular its internal arrangement, must be able to accommodate a large variety of fuel types.

The TN NOVA^{TM} storage system is constructed of two main components with specific functions:

The Dry Shielded Canister (DSC) through its double lid design ensures the containment of the spent nuclear fuel assemblies. The DSC internal arrangement provides criticality control, as well as heat transfer. The closure lids are welded at the end of the loading, using the AREVA Automated Welding System (AAWS). At anytime the spent fuel assemblies can be retrieved by opening the DSC with a cutter device.

The TN NOVA^{TM} storage Overpack provides structural protection for the DSC during storage and shielding following ALARA principles. As a result of its storage in a vertical position and the air gap between the TN NOVA^{TM} Overpack and the DSC it is well cooled using natural convection. Furthermore, the Overpack is equipped to provide handling capability to the system.

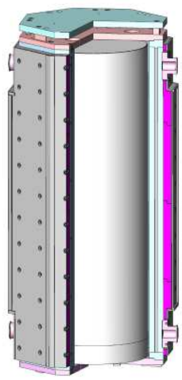


Figure 1: TN NOVA^{TM} Overpack and Dry Shielded Canister 69BTH

PRINCIPLE OF OPERATION

During the loading operations in the fuel pool of the nuclear power plant, the spent fuel assemblies are inserted into the stainless steel Dry Shielded Canister (DSC), which were previously placed in the MP 197 HB transport cask. The DSC is vacuum dried and then seal welded and transported inside a MP 197 HB cask from the nuclear power plant to the storage site.

Once at the storage site, the DSC is transferred horizontally from the transport cask into the TN NOVA™ Overpack, using a hydraulic ram.

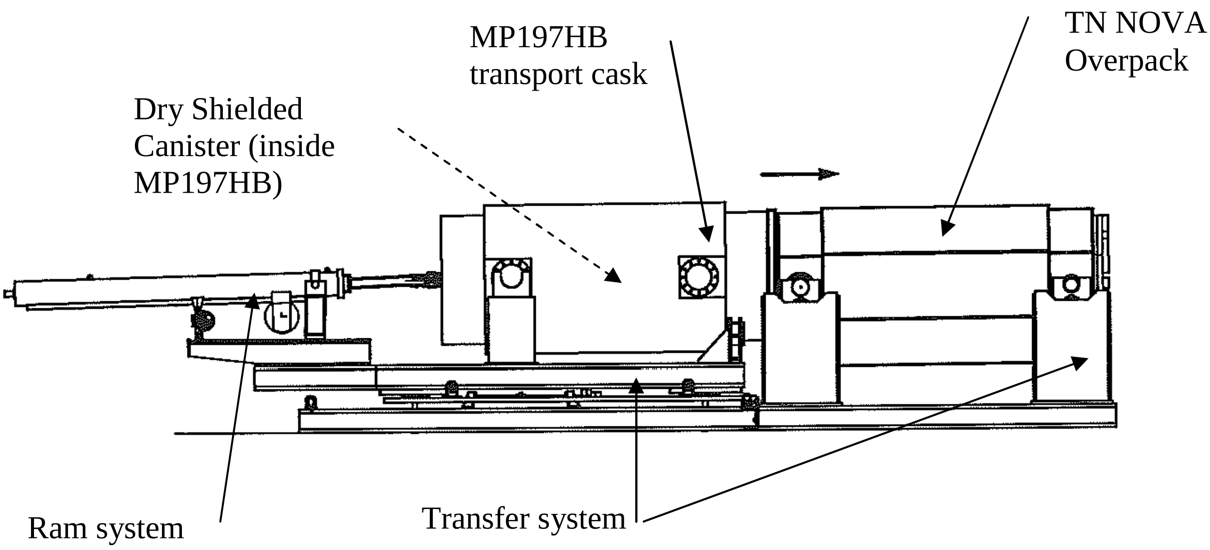


Figure 2: TN NOVA™ during Canister transfer

After transfer of the DSC, the TN NOVA™ is up-righted into a vertical position and transferred to its storage location.

SUCESSFUL SIMULATED AIRPLANE CRASH TEST OF THE INNOVATIVE TN NOVA™ CASK

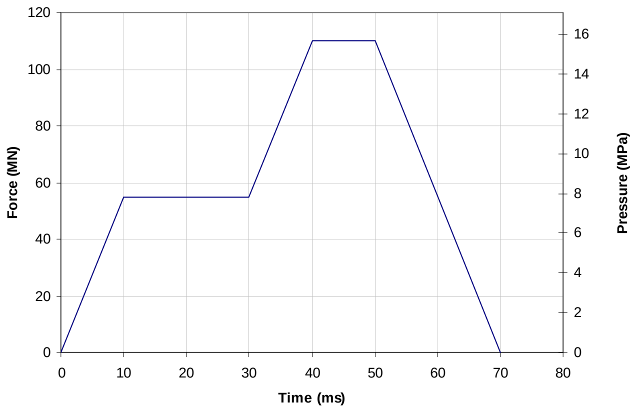
Design and Crash Test:

During the course of the Topical Safety Analysis Report development, one primary constraint needed to be considered in addition to other safety requirements: the withstanding of a defined aircraft crash test.
It was determined through the application of a defined load curve and validated by a successful leak tight test of the DSC.

The method used to justify the behavior of the TN NOVA™ storage system during an impact by a military aircraft is summarized hereafter.

The regulatory agency required that the load be considered for the aircraft crash test.
The military aircraft impact on a rigid wall is characterized, according to the Swiss regulation <1>, by:

- the loading curve in relation to time



- an impact surface area of 7 m^2
- a mass of 20 000 kg
- a speed of 215 m/s

The test was designed to demonstrate that the TN NOVA™ containment barrier, which is the DSC, remained leak tight after an aircraft crash.
The demonstration was provided by testing a scaled-down mock-up of the TN NOVA™ package for which similarities with full-scale behavior were established. The test also aimed at demonstrating the robust behavior of the TN NOVA™ overpack.

The approach consisted of:
- determining the most damaging impact configuration of the containment system (DSC components) through finite element calculations
- determining the size of a projectile whose impact on the 1/3 scale mock-up of the package would be representative of the impact of an aircraft on the TN NOVA™ package (full scale)
- performing a calibration test for a preliminary experimental check of the load induced by the impact of the projectile on a near rigid target
- conducting the impact test in order to verify the expected behavior of the TN NOVA™ overpack with respect to the calculations and to subsequently measure the leak tightness of the DSC

Determining the most damaging impact was achieved by identifying several types of impact orientations:
- an axial impact on the center of the anti-crash cover
- lateral impacts at different locations and heights
- an oblique impact on the top of the overpack oriented toward the centre of gravity

The consequences of the impact were assessed via the strain induced on the DSC which provides the containment boundary.

The most damaging impact for the DSC was determined using the LS-DYNA computational code <2>. Several iterations were needed to obtain the final result.

It was demonstrated by calculations that lateral impacts were relevant for the aircraft impact test. The most damaging configuration was a top lateral impact on a specific rail. The weakest part was the weld of the top cover plate.
The impact test configuration adopted corresponded to this most damaging configuration.

A similarity analysis of the full scale TN NOVA™ package and its 1/3 scale mock-up was prepared for the TN NOVA™ Overpack and for the DSC in order to demonstrate that the mock-up was representative of the full scale package.

Prior to the impact test on the mock-up, a calibration test was performed on a defined near rigid target so as to validate the projectile impact assumptions. The curve of the impact acceleration of the projectile launched toward a near rigid target was measured and compared to the theoretical curve of the projectile impact acceleration used in calculations.

The projectile used was similar to the one used during the real impact.
For the projectile itself, the general aim was to reproduce the type of deformations induced by the impact of an aircraft determined by calculations.
From these calculations it was determined that the calibrated projectile needed to be made of an assembly of mechanically welded steel tubes of variable thicknesses and diameters.

The results given by the first test on a near rigid target were very encouraging as the measured data provided the similarity of the impact test with its calculated results. This positive step led to the start of the second step: impact on the mock-up itself.

The mock-up impact test was carried out in November 2010 in the CESTA experiment and research center near Bordeaux in the presence of the Swiss Competent Authorities and AXPO. The manufactured components were:

- a specific 1/3 scale mock-up of the TN NOVA™ Overpack package fitted with its anti-crash cover and loaded with the DSC mock-up which was representative of the full-scale TN NOVA™ package. This mock-up was manufactured by MECAGEST, an AREVA subsidiary.
- a calibrated projectile supplied by MECASTER, the impact of which was to simulate an aircraft crash.

The projectile of 300kg was launched from an air pressure cannon at a speed reaching 240m/s.

Figure 3: TN NOVA™ Mock-up for aircraft crash test

Figure 4: Impact of the projectile on the mock-up

CONCLUSIONS

The test was successful as the leak tightness of the canister was tested and proven.

This experiment took more than a year due to the time required to analyze the requirements, prepare calculation models, construct the one-third scale mock-up and the projectiles via a manufacturing process that had to be validated by the customer and the ENSI as well as to adjust the requirements with the experiment testing facility.

This important event in the project marked a major step in the design phase validating the technical viability of the storage system.

The implementation and execution of the test was a delicate step by step process, and its success confirmed that the TN NOVA™ system is safe and robust.
This was made possible by the joint know-how of TN International and Transnuclear Inc., two key companies of the AREVA Logistics Business Unit and thanks to the oversight of AXPO Power AG and ENSI representatives.

Current & Future Goals:

Our international project team is pursuing the project first to obtain the transport and storage safety licenses. Encouraged by the test result, preparations of the project to proceed to the manufacturing phase of the first components of the system are underway.

ACKNOWLEDGMENTS

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Figure 2: process patent pending,
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Figure 4:
CESTA

<1> : HSK-R102/d "Design Criteria for the Protection of Safety Equipment in Nuclear Power Stations against the Consequences of Airplane Crash, "1993, January.

<2> : LS-DYNA 3D, Version 971, Livermore Software Technology Corporation, CA.