NEW DUAL-PURPOSE CASK CASTOR® MTR 3 FOR DISPOSAL OF SPENT FUEL FROM RESEARCH REACTORS

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ABSTRACT

With more than 1500 loaded and emplaced casks and over 40 years of experience, GNS is one of the leading suppliers of casks for spent fuel worldwide.

Currently GNS is developing the CASTOR® MTR3, the direct successor to the CASTOR® MTR 2, for its customers Technical University of Munich, Helmholtz-Zentrum Berlin and Johannes Gutenberg-Universität Mainz, for the disposal of their fuel elements. This all-in-one transport and storage solution is able to carry fuel elements from TRIGA and MTR reactors and can be individually adapted to other fuel elements for research reactors from all over the world.

Currently, two cask bodies have been casted and are in production. Furthermore, the necessary drop tests have been conducted successfully and the final safety analysis report has been submitted to the German authorities.

The paper and presentation will focus on the cask design, the current status regarding the licensing process and the safety analysis.

1. Introduction

With its 40 years of nuclear experience GNS, world leading supplier of casks for spent fuel, intermediate level waste (ILW) and high level waste (HLW), offers services for management and disposal of spent fuel and all types of radioactive waste. More than 1500 spent fuel casks of the CASTOR® and CONSTOR® type with a storage period of up to 30 years and over 7,000 MOSAIK® casks for ILW are used today in a number of countries on four continents. The CASTOR® cask is especially optimized for high thermal loads, which allows the loading of spent nuclear fuel (SNF) with short cooling times and high burn-up. This makes GNS the world's top supplier for shielded transport and storage casks. Design and supply of treatment facilities and all kinds of engineering support round off GNS' portfolio.

GNS has not only developed casks for the disposal of fuel assemblies from NPPs, but also various casks for the disposal of spent fuel from research reactors. Already in the 1990s, the CASTOR® MTR 2 was designed for various fuel elements from research reactors. In total 18 CASTOR® MTR 2 casks are stored at the interim storage facility Ahaus (TBL-A), while others are still used as shuttle casks in Petten (Netherlands).

The CASTOR® MTR3 is the direct successor to the CASTOR® MTR 2 and was developed to accommodate further inventories. It is going to be licensed according to the current '96-IAEA regulations as a B(U)F-package.

2. CASTOR® MTR3

The transport and storage cask CASTOR® MTR3 is especially designed for the disposal of fuel elements from research reactors. Currently, a basket to accommodate five KKE7 fuel elements with highly enriched uranium fuel from the FRM-II reactor at Technical University of Munich (TUM) has been developed. Further baskets for fuel elements from other types of reactors (e.g. TRIGA, MTR) are envisaged and can be individually customized.

The transport and storage cask CASTOR® MTR3 mainly consists of a cask body with trunnions, a basket and a double lid system, see Figure 1. During transportation on public routes, the CASTOR® MTR3 is equipped with a pair of impact limiters, see Figure 2.

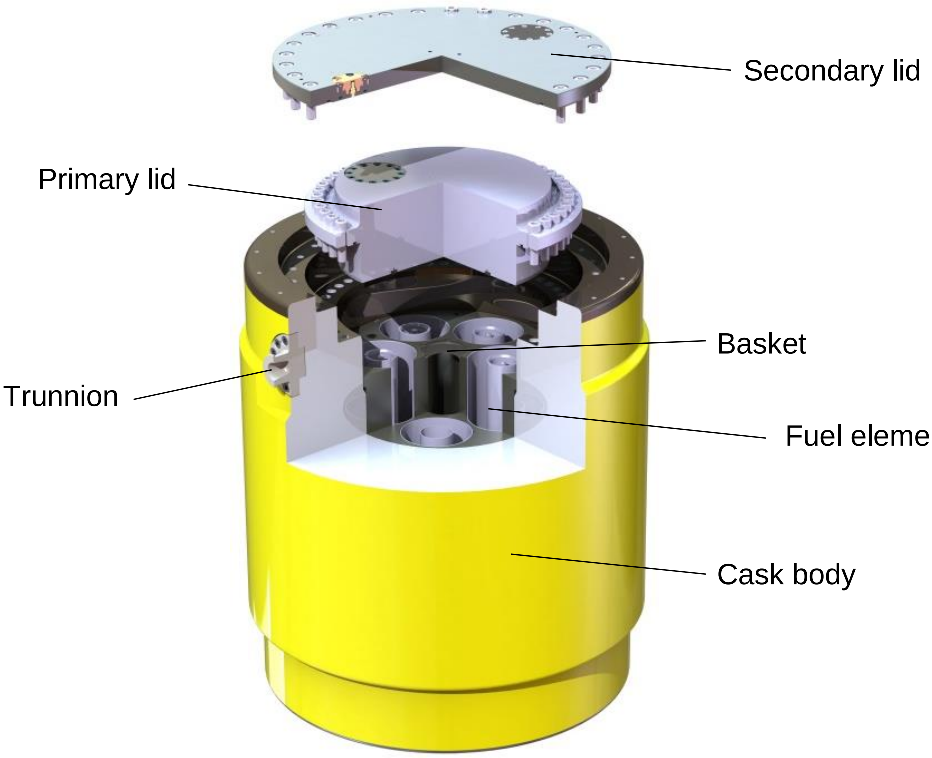

Figure 1: CASTOR® MTR3 exploded view

The monolithic cask body is made of ductile cast iron. Furthermore, an electroplated nickel coating is applied to the cask cavity and the sealing surfaces to protect against corrosion and wear. For handling operations, two trunnions made of high-tensile stainless steel are mounted to the cask body. They are designed according to KTA 3905 section 4.3, which ensures that a failure during handling can be ruled out.

The basket is placed inside the cask cavity. The main structure of the basket is made of aluminium discs for optimized heat dissipation. The aluminium discs are held together by prestressed rods. Additional measures to ensure sub-criticality are installed in the basket, also for accident conditions of transport: Tubes of borated stainless steel are placed inside the fuel elements' central tubes as well as outside, surrounding the fuel elements for neutron absorption. Metallic filters prevent the dispositioning of fuel particles to criticality sensitive positions.

The double lid system, consisting of a primary and a secondary lid with silver coated metal seals, ensures leak-tightness during transport and storage. The required leak-tightness is proven with a Helium leak-tightness test.

During transportation, primary and secondary lid form two redundant sealing barriers. During storage, both lids act together as a double sealing barrier to guarantee the safe enclosure. For protection against environmental influences, a protection plate is installed on top of the secondary lid. The surveillance of the leak-tightness of the double lid system is realized by a pressurized inter lid space, monitored by a pressure switch connected to a storage monitoring system. For the hypothetical case of a leaking primary lid, the double lid sealing barrier can be restored by welding a repair lid to the cask body on top of the secondary lid. This repair concept has been proven for all CASTOR® types, but during the total storage period of all CASTOR® casks, which accumulates to more than 18.000 years, it never had to be applied.

The fuel elements from the research reactors of TUM, Helmholtz-Zentrum Berlin and Johannes Gutenberg-Universität Mainz will be stored at TBL-A. The CASTOR® MTR3 casks are designed for at least 40 years of interim storage. Three casks can be stacked on top of each other in the interim storage facilities to minimize the use of space.

The certificate of approval of the CASTOR® MTR3 will allow for transport on public roads, railway as well as inland waters. For transportation, the loaded cask is equipped with a pair of impact limiters (top and bottom). The impact limiters are made of wood encapsulated by metal sheets. The wood absorbs the kinetic energy by deformation and limits the decelerations during accident conditions of transport (9 meter drop). During transportation, the cask stands in an upright position and is placed inside a transport frame. The transport frame has standard dimensions of a 10 ft container and is fixed to the transport vehicle by ISO corners, see Figure 2.

Due to increased safety requirements for the transportation of radioactive material, additional protection against disruptive actions or other interferences by third parties (“Störmaßnahmen oder sonstige Einwirkungen Dritter” - SEWD) may be necessary. The transport equipment of the CASTOR® MTR3 is already prepared to meet the SEWD regulations.

Table 1 gives an overview of the main features of the CASTOR® MTR3.

Outer dimensions	Storage configuration 1.5 m (diameter) x 1.6 m (height) Transport configuration 2.4 m (diameter) x 3 m (height)
Inner dimensions	0.72 m (diameter) x 0.92 m (height)
Mass	16 t (Storage configuration) 24 t (Transport configuration)
Cask body	Monolithic; ductile cast iron
Trunnions	2 pieces; Stainless steel
Lid system	2 stainless steel lids with metal seals

Table 1: CASTOR® MTR3 main features

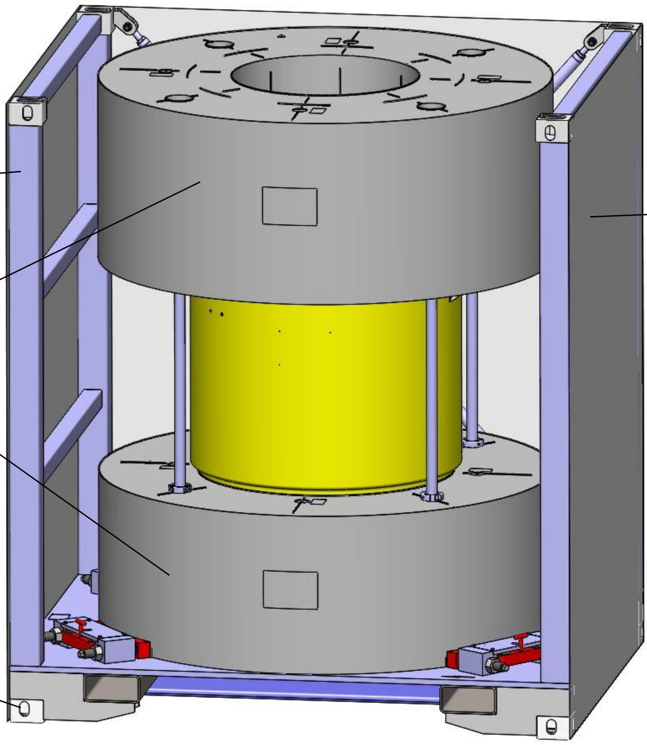

Figure 2: Transport configuration CASTOR® MTR3 with impact limiters on the transport frame (front and top side of the cover are not shown)

3. Mechanical analysis and verification by drop tests

The mechanical analysis of cask components for accident conditions of transport was performed by fully dynamic finite element calculations using LS-DYNA. Cask components and impact limiters were modeled in detail. In order to verify the calculation models, three full-scale drop tests were performed in cooperation with “Bundesanstalt für Materialforschung und –prüfung” (BAM).

The following tests were performed at either maximum or minimum design temperature: A 9.3 meter side drop test at -40 °C (see Figure 3) in sequence with an 1 meter pin drop test at ambient temperature, a 9.3 meter vertical drop test on the lid system at -40 °C and a 9.3 meter slap-down drop test onto the lid side with the impact limiter heated to 80 °C. Cask and impact limiters were equipped with numerous accelerometers and strain gauges to measure local accelerations and mechanical loads. In total, the signals of about 80 sensors were recorded during each drop test. The remaining shift of the lids and the deformation of the impact limiters were determined by photogrammetry after each drop test. After each drop scenario, the sealing barriers of primary lid and secondary lid where examined by a helium leak-tightness test, resulting in leakage rates significantly below the permissible value of the regular leak-tightness test before transport.

Figure 3: 9.3 meter drop test at BAM test area Horstwalde, Berlin

In comparison of drop test and FE simulation, the measured signals of acceleration and strain correspond well with those derived from the simulation. In Figure 4 the signal of an accelerometer in the slap-down drop test is plotted next to the result from simulation. The characteristic course of the experimental signal (the sharp peak at the very beginning followed by decreasing oscillations, rise to a plateau and moderate fall towards zero) is reproduced very well by the simulation. Also, the magnitudes of the peaks and the plateaus as well as the time duration are in good agreement.

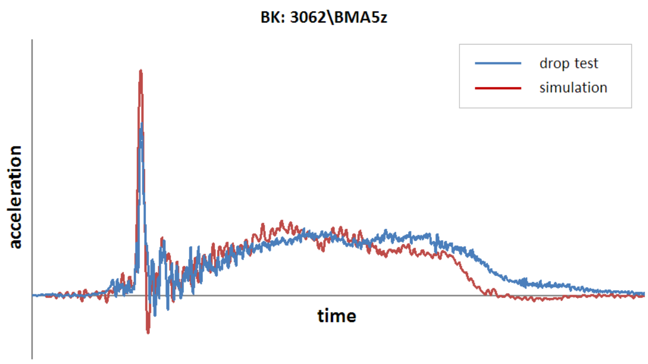

Figure 4: Accelerometer signal from slap-down drop test in comparison to FE simulation

Even details of the buckle-formation in the impact limiter could be reproduced by the FE-simulation, see Figure 5.

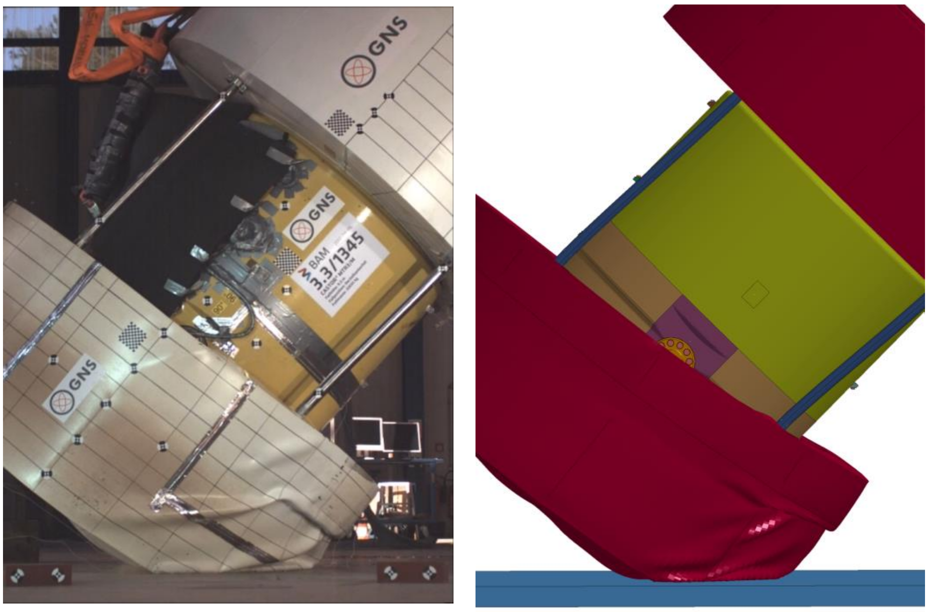

Figure 5: 9.3 meter slap-down drop test. Left: still image from high-speed video.
Right: Visualisation of corresponding FE-Simulation for the same time.

4. Handling and equipment

Since every research reactor facility has different boundary conditions (crane capacity, spacing of the reactor hall etc.), a unique set of equipment is designed and manufactured for each customer, enabling the CASTOR® MTR3 to be used in a wide variety of research reactors.

To identify the necessary equipment, a handling study is carried out. It investigates all the necessary steps for a successful cask loading, beginning with the delivery of the cask and the corresponding components to the reactor facility over the loading procedure[1] and subsequent drying to the installation of the impact limiters on the transport frame.

The equipment can be categorized into handling, processing and transport equipment.

The handling equipment is used for all handling operations with the cask itself, beginning with the unloading of the cask from the transport vehicle at the reactor facility. It usually consists of a lifting beam with corresponding storage rack, a lid setdown stand for the safe temporary storage of the lids during the loading procedure, a long lid lifting fixture for handling of the primary lid in the spent fuel pool and a short lid lifting fixture for handling of the secondary lid.

To support the workers during the processing of the cask, a working platform was designed. It surrounds the cask and allows for easy access to all necessary components. The processing equipment also includes the necessary appliances for drying of the cask cavity and the subsequent leak-tightness test.

The transport equipment consists of the transport frame for the safe transportation of the cask on public streets with a truck according to the certificate of approval. Depending on the

[1] The CASTOR® MTR3 was originally designed for underwater loading procedures, but dry loading is also possible.

inventory, an additional protection according to SEWD regulations may be necessary in order to meet the requirements of the transport license.

5. Licensing and procurement process

The CASTOR® MTR3 is a dual purpose cask for the transport and interim storage of spent nuclear fuel from research reactors and is going to be approved as a B(U)F-package according to IAEA ’96-IAEA regulations. The certificate of approval, obtained by GNS, will allow for transportation on public roads, railway as well as inland waters. The certificate of approval has to be prolonged every five years. The final safety analysis report for the certificate of approval has been submitted to the authorities end of 2017. The certificate of approval is expected to be obtained in September 2018.

The licensing procedure of the storage license is conducted by the “BGZ Gesellschaft für Zwischenlagerung mbH” (BGZ). The storage license verifies the suitability of the CASTOR® MTR3 as a save disposal method in compliance with the requirements of the TBL-A.

Usually, the procurement process for cask components starts after the certificate and license mentioned above have been issued. However, due to the urgent disposal needs of TUM, two CASTOR® MTR3 casks are currently in early production, meaning that their procurement process was started before the respective certificate and license were obtained. Their cask bodies have been casted already and the mechanical works have started. The procurement process for most of the components mentioned in chapter 4 has also started. The first CASTOR® MTR3 is expected to be delivered to TUM in the first quarter of 2019.

6. Conclusion

The CASTOR® MTR3 is a state of the art package solution for the safe disposal of fuel elements from research reactors which combines over 40 years of experience in nuclear services. The concept comprises not only the cask, but also the necessary equipment for all handling, loading and transportation operations. The safety analyses conducted during the engineering phase of the package design were verified by drop tests. The CASTOR® MTR3 represents a high-quality solution for the safe disposal of a wide variety of fuel element types.

7. Outlook

The certificate of approval for transport is expected for late 2018, the storage license for the beginning of 2019. The first hot loading of a CASTOR® MTR3 with fuel elements from the FRM II reactor is planned in the first half of 2019.

The CASTOR® MTR3 will also be able to accommodate other inventories. In the near future, new baskets for other fuel element types (e.g. TRIGA, MTR etc.) will be developed.