The new CASTOR® geo - A Comprehensive Solution for Transport and Storage of Spent Nuclear Fuel, MOX and Damaged Fuel-17202

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ABSTRACT

Dry interim storage has become a common solution for the disposal of spent fuel in recent years. However, in particular the complete defueling of NPP prior to decommissioning and dismantling will dramatically increase the demand worldwide especially for non-standard fuel. Here we present the new dry storage system by GNS for international markets with its capability to also store MOX and damaged spent fuel.

INTRODUCTION

Dry interim storage systems for spent fuel assemblies have been in use worldwide for more than three decades by now. Starting with the first CASTOR® dry storage systems by GNS in the early 80s, this proven and reliable technology has enhanced the safe storage of spent fuel in countless NPP worldwide. More than 1250 CASTOR® casks have been loaded and safely stored over the past decades all over the world, including Germany, the US, South Africa and several eastern European countries. This made the CASTOR® cask system a well known and internationally established trademark for the safe transport and storage of spent nuclear fuel and high-level waste.

The sound operational record is backed by a common design philosophy that remained unchanged for various CASTOR® cask types. The casks feature a monolithic cask body made of ductile cast iron with machined cooling fins to improve the heat dissipation. Neutron shielding is provided by means of polyethylene neutron moderators, filled in drilled bore holes in the casks wall. This is a major benefit in safety compared to neutron moderators that are attached to the outside of the cask wall, when it comes to thermal accidents. The CASTOR® casks are closed by a bolted double lid system. Both independent lids are sealed with metal gaskets that are suitable for longterm interim storage. During storage both lids are permanently monitored to observe leak tightness. All cask components score with the complete absence of any welding seams, a potential weak link in many other dry storage systems on the market.

Another striking advantage of the CASTOR® design philosophy is its true dual-purpose design. The casks do not require any additional overpack for storage or transportation but rather fulfill the demands on shielding and safe enclosure set for a dual purpose system by itself. The only difference between storage and transport is the surveillance of leak tightness (in case of storage) and the shock absorbers (in case of transportation), respectively.
However, the existing designs of the established CASTOR® types and especially its fuel baskets for the spent-fuel assemblies (FA) were mainly driven by extreme boundaries

and requirements in GNS´ German home market. The larger geometric dimensions of the German FA and higher burnups in typical German NPPs in combination with requested short cooling times, limited the number of FA per cask. This limitation is very much in contrast to the internationally increasing demand for storage systems with larger capacities in terms of accommodated FA per cask.

Facing the challenge of the demand of higher FA capacities per cask, GNS introduces a new transport and storage system, the CASTOR® geo. The CASTOR® geo includes all the well known and established safety features of the existing CASTOR® systems, while it is able to accommodate a significantly higher number of FA per cask.

THE NEW CASTOR® geo

The new CASTOR® geo cask system is a product line based on standardized modules and components featuring different cask dimensions and basket designs. The cask system is constructed to meet the individual requirements of customers worldwide rather than focusing on the German market. CASTOR® geo casks are designed for storage and transport of both PWR and BWR FA.

A high degree of standardization between the different cask types of the CASTOR® geo system allows for savings in terms of time and funds especially for licensing. Even though different regulators will still review the respective documents independently and separately, major parts of the safety cases remain unchanged. The approach of standardization also yields to savings for the equipment needed for handling and dispatch of the casks and for training of the personnel. Finally the weights of the individual cask types are optimized according to internationally established crane capacities and can be further customized to individual needs.

Actual Examples of Different Cask Types

CASTOR® geo casks are able to accommodate up to 37 PWR-FA or 69 BWR-FA respectively with a maximum initial enrichment of approx. 5 wt-% ^{235}U, up to 74 GWd/MTU average burn-up and more than 40 kW heat load.

At the moment there are four different types of the CASTOR® geo system in the development or licensing process, respectively. Three different cask types for PWR reactors and one cask type for BWR reactors, customized for the specific needs, while still based on standardized modules and components.

The three different types for PWR CASTOR® geo casks will be utilized in six reactors of two European countries. The first of the new PWR CASTOR® geo casks is the CASTOR® geo24B (Figure 1). The cask is able to take up 24 FA of which a maximum of 8 FA might be MOX-fuel. The initial enrichment of the fuel is 4.5 wt-% ^{235}U and 7.7 wt-% Pu_{fiss} (Pu+U) respectively. The cask features a maximum average burn-up of 55 GWd/MTU and a maximum heat load of 33 kW. The maximum mass of the cask during handling inside the reactor filled with water is 117 Mg . The mass in transport configuration is somewhat higher due to the attached shock absorbers. It is 134 Mg .

The second cask in the series of new CASTOR® geo casks is the CASTOR® geo21B (Figure 1). This cask is somewhat longer and slimmer compared to the CASTOR® geo24B to be able to accommodate longer FA. To remain at the same handling and transport masses the cask takes up 21 FA, thus slightly less FA per cask. The nuclear parameters are also adjusted to the customer specific needs. The initial enrichment of the fuel is 4.4 wt-% ^{235}U with a maximum average burn-up of 55 GWd/MTU and a maximum heat load of 29 kW.

The third of these new PWR casks is the CASTOR® geo32CH (Figure 1). The cask accommodates 32 PWR FA with a maximum of 8 MOX-FA. The initial enrichments are 5 wt-% ^{235}U and 4.8 wt-% Pu_{fiss} (Pu+U) respectively. The maximum average burn-up is 74 GWd/MTU with a maximum heat load of 35 kW. The maximum mass in transport configuration is 150 Mg, while it is 135 Mg in storage configuration.

Besides the new casks for PWR fuel assemblies GNS currently designs a new cask for BWR fuel. The CASTOR® geo69 (Figure 1) will be able to accommodate 69 BWR fuel assemblies including up to 16 MOX FA.

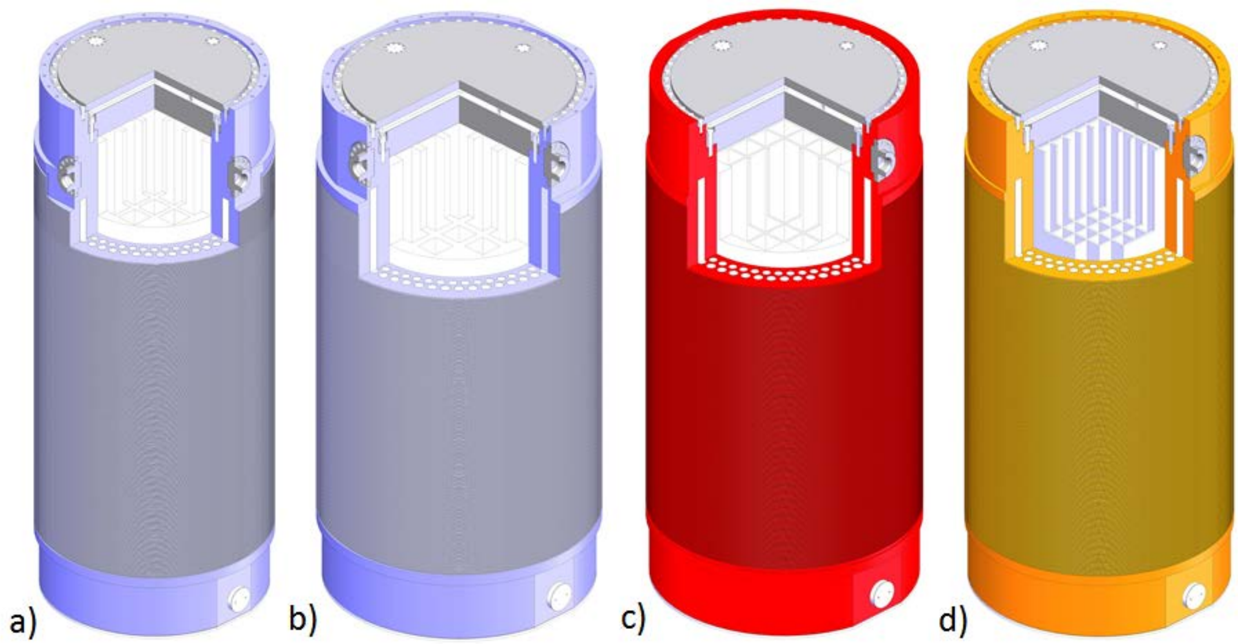


Figure 1: Different types of CASTOR® geo casks.
a) CASTOR® geo21B for 21 PWR FA
b) CASTOR® geo24B for 24 PWR FA including up to 8 MOX FA
c) CASTOR® geo32CH for 32 PWR FA including up to 8 MOX FA
d) CASTOR® geo69 for 69 BWR FA including up to 16 MOX FA

Transport

The transport of the casks of the CASTOR® geo cask system is similar to the established transportation of the previous CASTOR® casks. Again the casks are generally able to be transported by road, rail, inland waters and sea. Two shock absorbers attached to the top and bottom respectively form the transport package in combination with the cask itself (Figure 2). There are no other auxiliaries necessary for the formation of the transport package. Related equipment such as transport frames etc. are designed in accordance to with the respective transport vehicle.

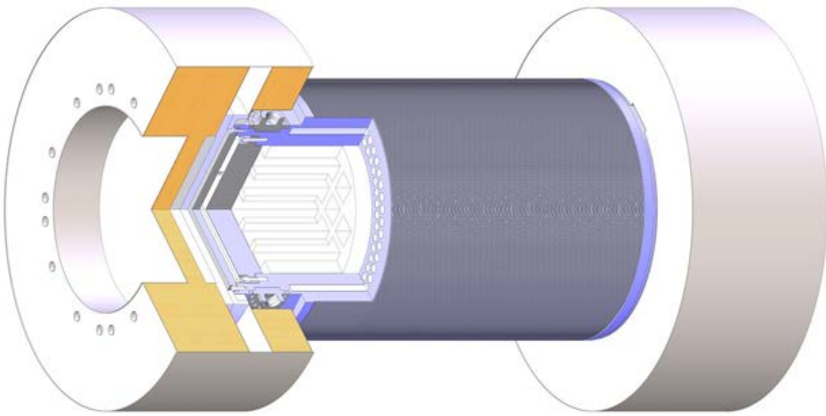


Figure 2: A CASTOR® geo24B cask with shock absorbers. The shock absorbers for the CASTOR® geo casks are generally comparable and suitable for the different categories of transportation

Mox Fuel Disposal

Since many dry storage systems are not licensed for MOX fuel, the shortage of systems capable to take up MOX-FA remains a challenge for many utilities. Therefore the existing CASTOR® design has two major advantages over many other dry storage systems. In addition to standard UOX spent fuel it is also able to take up MOX fuel from reprocessing plants. This achievement can also be found in the new CASTOR® geo product line.

The challenges in the storage and transport of MOX-fuel are higher heat loads and higher neutron source strengths compared to UOX-fuel of the same burn-up. Decay heats are roughly two times higher and neutron source strengths even up to seven times higher. The maximum number of eight MOX-FA in the CASTOR® geo24B cask type is therefore on the edge of the physically possible configurations.

However, the exact take up of MOX fuel is dependent on the customer-specific needs and might be slightly adjusted.

Damaged Spent Fuel Disposal

Complete defueling is a prerequisite for decommissioning and dismantling of NPPs. In particular the defueling of damaged spent fuel and the following dry storage remains a challenge, since most of the damaged spent fuel rods have been collected during the NPPs lifetime in the spent fuel pools. It was the aim to complement the existing dry storage technology for intact fuel assemblies with a comprehensive solution for damaged fuel rods comprising concepts for transport as well as for storage

Therefore GNS developed the Integrated Quiver System “GNS IQ” (Figure 3) for damaged spent fuel which complies with the requirements of the transport and storage cask CASTOR® V (for the German market) and CASTOR® geo (for the international market). The dimensions of the Quivers allow it to load them directly into the slots of the fuel baskets of the casks. The Quivers are designed like a “second cladding” and it offers especially leakers a way to be re-dried inside the Quiver. However, it was the aim of the Quiver project to develop a one-fits-it-all solution for all different kinds of damaged spent fuel, therefore other defects like deformations of rods, buckling of the FA skeleton or damages to the foot and head pieces or even certain kind of debris can be accommodated by the Quiver.

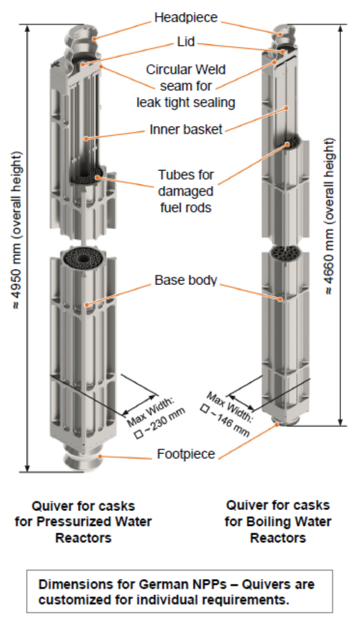
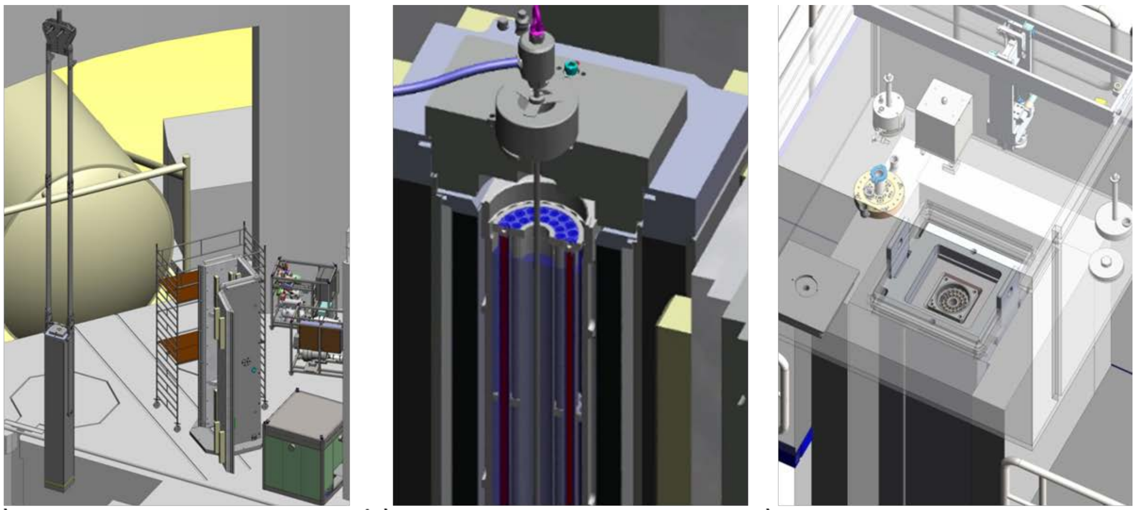


Figure 3: GNS IQ. A Quiver for dry storage and transport damaged spent fuel of PWR and BWR reactors.

In contrast to the regular dispatch and loading of spent fuel assemblies under water in the spent fuel pool, the dispatch of the Quiver is performed outside the spent fuel pool on the reactor floor. This approach is motivated by the use of a much simpler technology and increase in process stability, than it would be required if processing and especially drying and welding is done under water in the spent fuel pool. This also yields an increase in process stability. However, this approach requires some additional equipment especially in terms of shielding. Figure 4 describes the dispatch i.e. the drying of the fuel and the closure of the Quiver by means of welding in general. The dispatch of a Quiver is assumed to last not longer than one week and results in a collective dose of less than 3.7 mSv including independent inspectors.



a) b) c)

Figure 3: Schematic dispatch of the Quiver on the reactor floor level.
a): The damaged rods are loaded under water into the body of the Quiver, which is subsequently transferred into a so-called primary shielding that allows the Quiver to be taken out of the pool. After that the Quiver inside the primary shielding is lifted out of the pool into the handling station on the reactor floor.
b) Dewatering of the Quiver inside the handling station.
c) Subsequently a simplified hot cell is attached to the handling station. In there the drying and the welding of the Quiver take place. All work is carried out fully remote controlled. The picture provides a view into the simplified hot cell on top of the handling station

The Quiver for the PWR cask CASTOR V/19 is expected to receive its Type B transport license in spring 2017 and its first storage license at an interim storage facility of a German NPP in fall 2017. However, the first hot loadings and internal transport between different blocks of a multi-block NPP already took place in summer and fall 2016, respectively.

CONCLUSION

With the development of the new CASTOR® geo cask system GNS provides state-of-the-art high capacity dry storage cask system for customers worldwide. Together with the newly developed GNS IQ Quiver systems, it provides a comprehensive solution for the dry storage of spent UOX fuel, MOX fuel and even damaged fuel.