# CASTOR® geo and the GNS CLU System
# Customized High Capacity Dry Storage Solutions

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## ABSTRACT

In recent years dry interim storage has become the most common solution for the disposal of spent nuclear fuel worldwide, both for operating reactors in order to gain space in the respective pools and prior to dismantling of reactors ready for decommissioning. Metal dual-purpose casks like CASTOR® casks provide a safe transport and storage option for decades. Here we report on the recently introduced CASTOR® geo and the new GNS CLU solution.

## INTRODUCTION

CASTOR® casks by GNS comprise a success story over four decades by now. Meanwhile almost 1500 CASTOR® casks have been loaded and safely transferred into interim storage worldwide, starting with the first CASTOR® dry storage systems by GNS in the early 80s. The CASTOR® footprint includes Germany, Switzerland and Belgium in Western Europe as well as several eastern European countries like Czech Republic and Lithuania and also countries outside Europe like South Africa and the US. Furthermore some sole transport casks of the CASTOR® design are in use in Finland, the Netherlands, Russia and Korea. This has made the CASTOR® cask system a well known and worldwide established trademark for the safe transport and storage of spent nuclear fuel and high-level waste.

All the different types of CASTOR® casks feature a common design philosophy that remained unchanged over the years. The casks feature a monolithic cask body made of ductile cast iron (DCI) which provides ideal conditions for heat dissipation compared to sandwich systems with neutron absorption on the surface. The neutron shielding of the CASTOR® casks is provided by means of polyethylene neutron moderators, filled in bore holes in the casks wall, thus not blocking any heat dissipation. Furthermore the 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 the double lid system is permanently monitored to observe leak tightness. All containment 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.

The longterm success is backed by the economic advantages of CASTOR® casks made out of DCI compared to cask made out of forged steel in the field of dual purpose casks and by its safety benefits compared to thin walled canister storage systems with metal or concrete storage overpacks. 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. Furthermore on GNS´ German home market usually very strong pool cranes are available which is in contrast to the internationally established lower crane capacities especially in dated plants, where defueling is required due to the shut down of those plants. In particular in those plants with small pool crane lifting capacities canister based storage systems offer handling advantages and classical dual purpose casks face some limitations.

Regarding the demand of a higher FA capacity per cask GNS has recently developed an evolution of the established DCI casks. The CASTOR® geo platform with all the well known safety features of the existing CASTOR® casks nowadays provides a significantly higher number of FA per cask compared to the casks utilized for the German NPPs.

Understanding the need for canister based systems for the dry fuel handling with lower pool cranes capacities in many especially dated plants worldwide, while experiencing the desire of many customers for a true dual purpose cask that provides all the safety features that have been established with those systems over the years, GNS developed an all new **C**ask **L**oading **U**nit – The CLU system.

## THE 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 designed to meet the individual requirements of costumers worldwide rather than focusing on the German market. CASTOR® geo casks are designed for storage and transport of both PWR and BWR FA (see Figure 1).

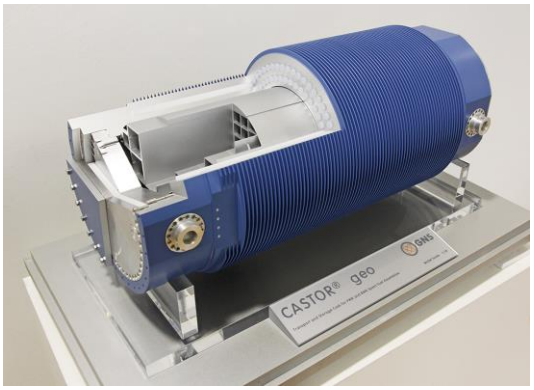


**Figure 1: A model of a CASTOR® geo cask**

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 allows for savings for the equipment needed for handling and dispatch of the casks and for training of the personnel.

CASTOR® geo casks are able to accommodate up to 37 PWR-FA or 69 BWR-FA respectively depending on the type of cask. GNS has signed contracts with two customers in Belgium and Switzerland for the delivery of three different PWR CASTOR® geo types in six reactors, resulting in three different types of the CASTOR® geo system in the development and licensing process. Furthermore GNS has developed a BWR version of the CASTOR® geo to accommodate up to 69 FA including up to 16 MOX FA per cask, which will be adjusted and customized for customer specific needs, while still based on standardized modules and components.

## Current Examples of Different Cask Types

The first of the new PWR CASTOR® geo casks is the CASTOR® geo24B. The cask is able to accommodate 24 FA of which a maximum of 8 FA can 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 filled with water during handling inside the reactor is 117 Mg. The mass in transport configuration is somewhat higher due to the attached shock absorbers.

The second cask in the series of new CASTOR® geo casks is the CASTOR® geo21B. This cask is longer and slimmer compared to the CASTOR® geo24B to accommodate longer FA. To keep 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. 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 of the cask filled with water during handling inside the reactor is 126 Mg.

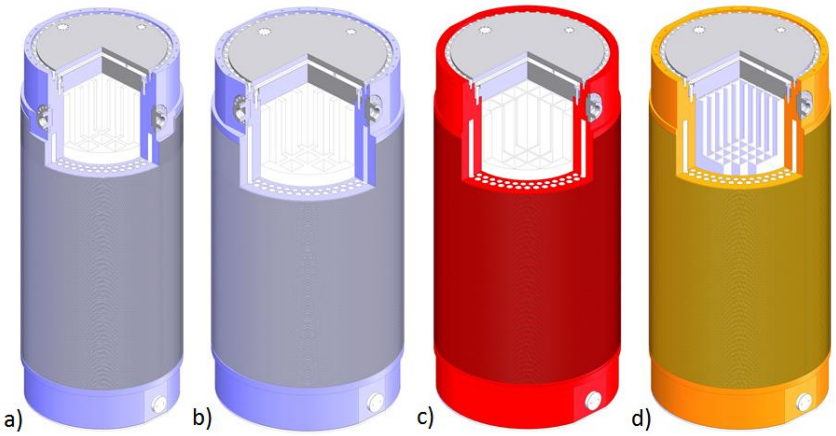


**Figure 2: Different types of CASTOR® geo casks.**
**a) CASTOR® geo21B for 21 PWR FA**
**b) CASTOR® geo24B for 24 PWR FA including up to 8 MOX FA**
**c) CASTOR® geo32CH for 32 PWR FA including up to 8 MOX FA**
**d) CASTOR® geo69 for 69 BWR FA including up to 16 MOX FA**

## THE GNS CLU SYSTEM

Canister based concrete dry storage systems have been established especially in the US over the last decades. The main issue of those systems during storage is the Chloride Induced Stress Corrosion Cracking (CISCC) of the welding seams of the stainless steel canisters. This issue occurs in particular at storage sites on the sea shores as maritime environment with its salty atmosphere foster the SCC, since the canisters are directly exposed to this aggressive atmosphere. The concrete shielding in those dry storage solutions is vented and does not serve as a barrier or even containment. To prevent the SCC issue, many customers worldwide have a growing demand for metal cask systems like CASTOR® casks which are not vulnerable to this issue. However, conventional classical metal casks feature certain minimum masses that are to heavy for many pool cranes especially at dated NPPs.

The development of the CLU system had three distinct goals. Firstly it should provide a solution to limited crane capacities that are otherwise only accessible with a conventional canister system. Secondly it should follow the development of the CASTOR® geo concept and further reduce the complexity of licensing processes. Finally we were looking for a fully retrievable solution, i.e. none of the lids should be welded to provide easy re-opening of the casks.

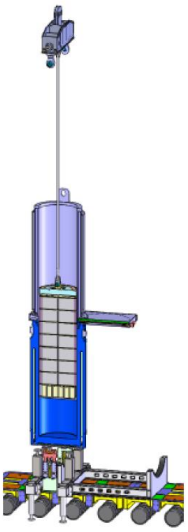

**Figure 3: The GNS CLU System with the lock to transfer in the canister from the transfer cask CLU into the CASTOR® cask**

The CLU system is basically a canister with a standard CASTOR® geo basket inside a standard CASTOR® geo cask (see Figure 3) The CASTOR® cask serves as the containment and provides all safety features, which is a tremendous improvement compared to other conventional established storage overpacks made of concrete or metal, which have to be ventilated and where thin-walled welded canisters are the only containment during storage. Therefore the CLU system combines the advantages of canister based systems with the robustness and transportability of dual purpose casks, i.e. it provides smooth handling inside the plant and safety for transport and storage of a metal cask. The loading and dispatch of the fuel is performed entirely based on a canister which is later loaded into a CASTOR® cask for transport and dry storage. Figure 4 describes the handling in detail. The canister inside the CLU itself is loaded under water and subsequently dispatched on the reactor floor. After that the CLU is transferred to the waiting CASTOR® cask, placed at a truck lock of the reactor or even outside the containment, which is already prepared with a lock to transfer the canister from the CLU into the cask. As the loading of the cask even with smaller lifting capacities of the pool crane is therefore feasible, the first goal described above is met.

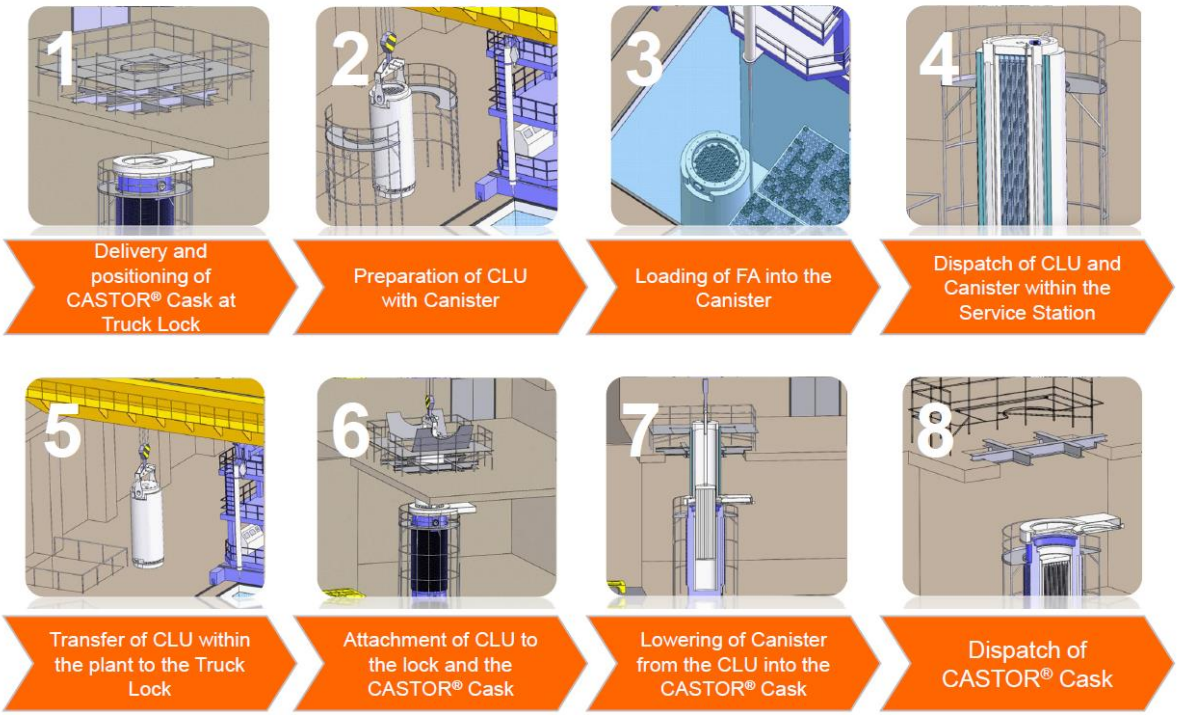


**Figure 4: The handling steps for the loading with the GNS CLU System.**

The canister consists of an inner basket and the canister containment itself. The baskets for casks of the CLU system are similar to the standard CASTOR® geo baskets. The cask bodies are also like the CASTOR® geo cask bodies, therefore the main components of this new system are re-utilized and do not have to be developed entirely new. Since only the loading procedure is different, while the casks are very much alike many of the numerical calculations and physical tests that have been used for the safety cases of the traditional CASTOR® cask are still valid. The second goal to minimize the complexity of the new system is therefore also met.

There is one more striking difference between canister based systems and metal casks like CASTOR® casks. Metal casks are usually equipped with a bolted lid system while canisters usually feature welded lids. Even though there are some concepts to re-open such canisters after storage it is by far easier and safer to re-open bolted lids. Therefore the canister for the CLU system was designed for re-opening as well. The canister of the CLU system is equipped with a bayonet lock system with elastomeric or metal sealings to ensure a safe transfer inside the plant while it is handled within the CLU. Finally the third initial goal for a easy re-opening of the new system is also met.

## Transport

The transport of the casks of the CASTOR® geo casks as well as for the CASTOR® casks of the CLU system are 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 (see Figure 5). There are no other auxiliaries necessary for the formation of the transport package. Related equipment such as transport frames etc. are designed in

accordance with the respective transport vehicle.

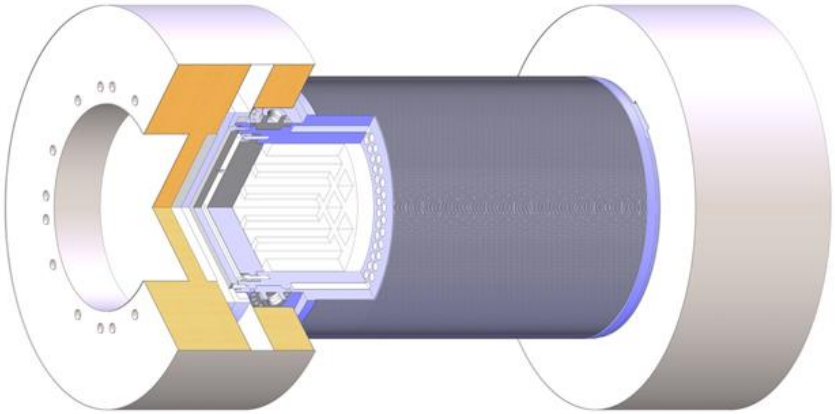

**Figure 5: A CASTOR® geo24B cask with shock absorbers. The shock absorbers for the CASTOR® geo casks are generally comparable and suitable for the different categories of transportation**

## Damaged Spent Fuel Disposal

For both the traditional CASTOR® casks like the CASTOR® V or CASTOR® geo types as well as the CLU system, GNS offers a solution for the management of damaged fuel, the GNS IQ® Quiver system. The PWR version of the GNS IQ® Quiver System has already received its transport and storage licenses for the CASTOR® V/19 which is the PWR cask mostly used for German customers. Furthermore the first loading campaign of the GNS IQ® Quiver System was successfully completed in November 2018 with the dispatch of three quivers at Unterweser NPP. Subsequently in February 2019 these Quivers have been loaded into a CASTOR® cask resulting in the important milestone for Unterweser NPP to be completely free of fuel. The second loading campaign at Biblis NPP was likewise successful. The loading of damaged fuel into dry storage systems has therefore reached the status of an industrial application.

## Type Tests of the new Dual Purpose Cask Systems of GNS

The CASTOR® geo32CH is dedicated for a Swiss NPP and has therefore to fulfill the Swiss regulatory requirements regarding interim storage. This is in particular related to airplane crash scenarios (military aircraft), which GNS intends to demonstrate by a physical test, i.e. a scaled cask will be hit by a projectile (impactor).

First of all a verification of the projectile is planned by a shooting on a rigid target. In a second step a shooting on the scaled cask itself is foreseen, which finally will be analyzed for the safety analysis report dedicated for the cask storage.

The accident conditions of transport for the package design approval of the CASTOR® geo casks will by derived by means of calculations, which are validate by the tremendous track record of drop test with CASTOR® casks performed over the last decades. However, an actual drop test for certain boundary conditions of the

CASTOR® geo32CH is also planned.

## CONCLUSION

With the CASTOR® geo and the GNS CLU System, GNS offers two different state of the art transport and storage solutions for spent nuclear fuel. With the first contracts signed for the CASTOR® geo cask and the first SAR already handed in at the respective competent authority these solutions will be fully utilized in the upcoming years.