CASTOR® – 30 Years of Experience in Transport

Far beyond storage: particular challenges for transport & shuttle casks

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ABSTRACT

For more than 40 years the German company GNS Gesellschaft für Nuklear-Service mbH has designed and manufactured CASTOR® casks for the transport and storage of spent fuel assemblies, of which by now almost 1,500 casks have been loaded and stored worldwide. Any of these casks fulfil the function of dual-purpose casks by having granted type B(U)F approval certificates in compliance with the international regulations of the IAEA enabling the storage facility operators to easily transport the casks off-site without reloading at any time ("load-and-go" principle).

However, among the large variety of the CASTOR® type series, GNS has also developed specific casks for the transport and shuttle of spent fuel assemblies and high-level waste. As an example, from the years 1990 to 2003, in total 136 spent nuclear fuel transports were performed from German nuclear power plants to the reprocessing plant in Sellafield, UK, using the CASTOR® S1 cask. In Finland and Russia, for instance, other CASTOR® cask types are still in use for the frequent routine of on-site shuttle campaigns of spent fuel assemblies from reactor units to interim storage facilities for even more than 30 years now. A very recent and specific application of shuttling was the transfer of three quivers for damaged fuel rods between Units A and B at the German NPP Biblis loaded in a CASTOR® V/19. These quivers are designed by GNS as first of its kind solution for the disposal of PWR and BWR damaged fuel rods in Germany.

Since each loading and handling operation imposes considerably higher loads to the entire cask and its individual components as compared with those at the storage position, especially the use as shuttle casks impressively proves the robustness and durability of the CASTOR® cask technology, even for transports under extreme conditions for various purposes.

This presentation will provide an outline of the GNS cask types which have already been in transport operation for an exceptionally long period in a number of countries all over the world.

1. Introduction

With its more than 40 years of experience, the GNS Group is specialised in the transport, storage and disposal of spent fuel from nuclear reactors and high-level wastes from reprocessing. Furthermore, GNS offers efficient solutions for tasks of the disposal of radioactive waste, particularly the safe processing, packaging and storage of intermediate level waste and residual materials that arise from the operation and dismantling of nuclear power plants.

Due to the German concept of dry interim storage of spent fuel in dual-purpose casks, GNS developed the CASTOR® cask about forty years ago which was a complete novelty at that time. Today, the CASTOR® family with its various, continuously developed type series is an internationally well-known trade mark and a synonym for nuclear safety, reliability and innovation. Even though CASTOR® casks are generally designed for both transport and long-term dry interim storage some types exclusively serve for the transport and onsite shuttle of spent fuel assemblies and high-level waste in numerous applications in various countries.

2. Cask concept: protection goals and technical features

The main idea of the dual-purpose casks by GNS is, that all the protection goals that have to be fulfilled during transport as well as for decades of dry interim storage are covered by the cask itself. During the entire storage period the casks need to have a type B(U) transport approval certificate in accordance with the IAEA Regulations for the Safe Transport of Radioactive Material SSR-6. This certificate allows for transport on public roads, railway and sea including inland waters and is granted by the competent authority provided the applicant can demonstrate that the cask design will meet the following protection goals under routine, normal and accident conditions:

- Safe enclosure of the radioactive contents
- Shielding of radiation
- Dissipation of the decay heat from the radioactive material
- Guarantee of sub-criticality
- Safe handling operations

A series of tests to prove the robustness of the package under accident conditions of transport comprises several scenarios (Figure 1). Back in the year 1978, GNS performed the first drop tests with a prototype cask called CASTOR® Ia which already had the same basic safety features as the new generation being in use nowadays. In the following, more than hundred tests have been carried out by GNS with cask prototypes or scale models within the safety assessment in terms of mechanical and thermal impacts. Even tests going beyond the safety requirements of the regulator have been successfully conducted in the past, e. g., explosion of a rail tank wagon or missile impact tests simulating an aircraft crash.

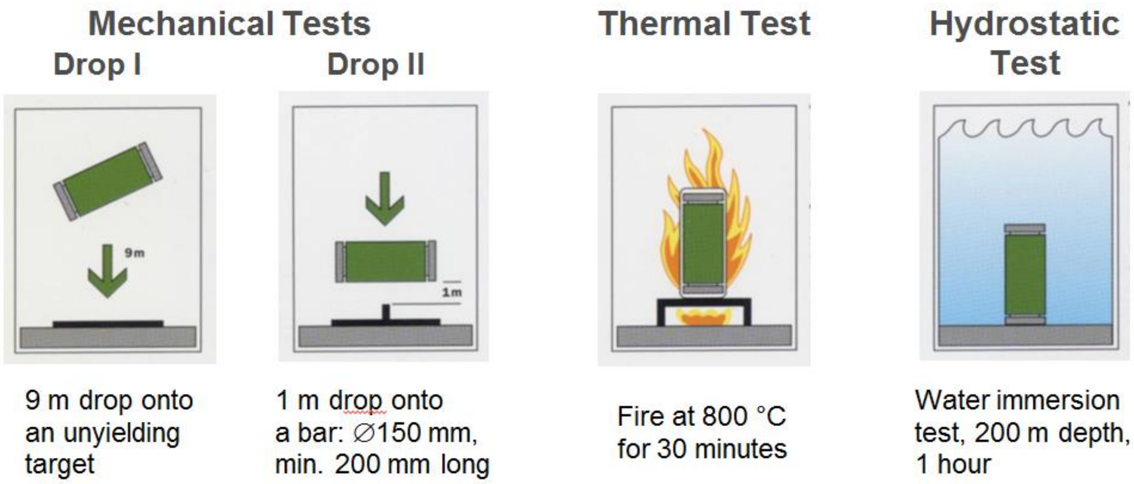

Figure 1: IAEA Test Conditions for Type B(U) packages

In order to maintain the transportability of the cask during its transport period on public routes, periodic inspections are stipulated in accordance with the regulatory requirements in the following intervals:

15 transports, but not later than 3 years

60 transports, but not later than 6 years

These inspections comprise visual checks, surface crack and leak-tightness tests etc. according to the approved step plan listed in the cask's approval certificate and may result in the exchange of some individual parts such as bolts, trunnions or gaskets, if required. Each replacement is thoroughly documented and added to the cask log book.

It is the special CASTOR® design and its essential components which ensure the perpetuation of the safety functions (Figure 2).

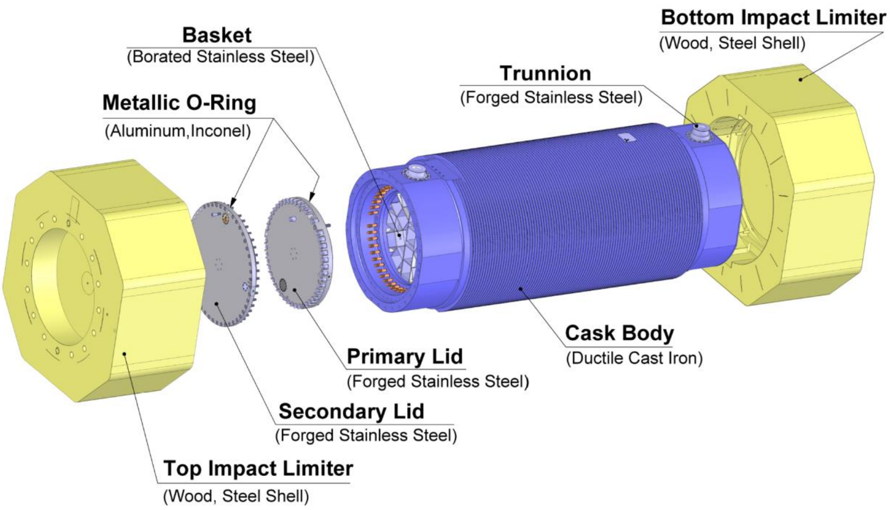

Figure 2: CASTOR® in transport configuration (with impact limiters)

All casks of the CASTOR® family consist of a monolithic cask body made of ductile cast iron (DCI) which is closed by a bolted lid system. The cask body and the lid system form the main shielding and the containment of the radioactive inventory. The most specific component is the fuel basket, which is especially designed to meet the geometrical and physical requirements of the loaded fuel assemblies. In the transport configuration additional impact limiters are bolted to both ends of the casks.

Lid system

For most applications the cask body is closed by a double-lid system, consisting of the primary and secondary barrier, which form two redundant sealing barriers (Figure 3). Each barrier comprises a main lid, the primary lid and the secondary lid respectively, which covers the cavity of the cask body and small lids which close the service orifices within the main lids. Both the primary and the secondary lid are sealed by metal gaskets. All lids and covers are made of forged stainless steel. A moderator disc made of polyethylene is placed in the inter-lid space.

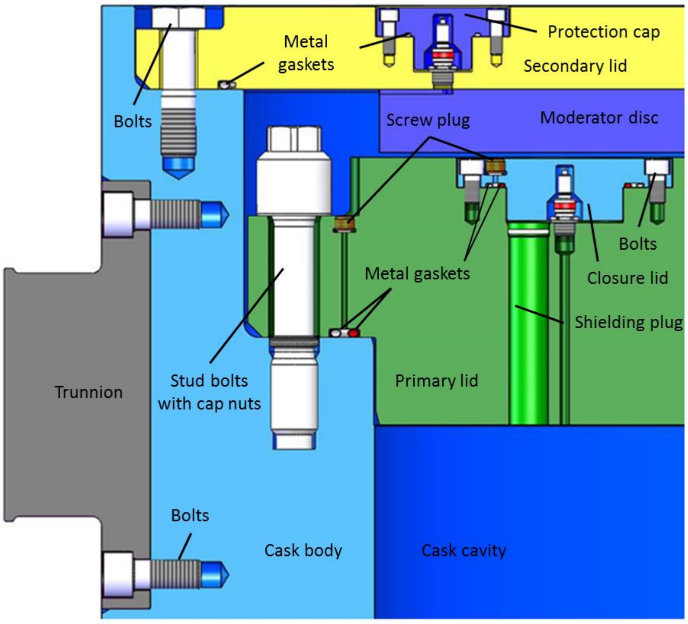

Figure 3: Lid system of CASTOR® cask - transport configuration

Fuel Basket

The design of the fuel basket is based on a structural skeleton, which carries the mechanical loads acting under operating and accident conditions. It forms the frame to position the fuel and the additional shielding components in the basket. The skeleton consists of stainless steel discs braced on several levels by means of spacer tubes and held together by tension rods and nuts (Figure 4). Each disc has square openings which define the position of the FAs. Receptacles made of borated aluminium plates are inserted into these openings. The boron in the aluminium sheets acts as neutron absorber material.

Both, the arrangement of the FAs and the boron content of the receptacles plates maintain the subcriticality of the FAs under all conditions. Shielding elements are arranged on the intermediate levels between the steel discs of the structural skeleton, filling the empty space between the fuel receptacles and the outer diameter of the basket. Additional aluminium heat conduction plates are positioned between the individual levels of receptacles. These plates transfer the heat from the centre of the basket to the outer shielding elements. Thus the shielding elements contribute to the heat dissipation by equalising the circumferential heat flow.

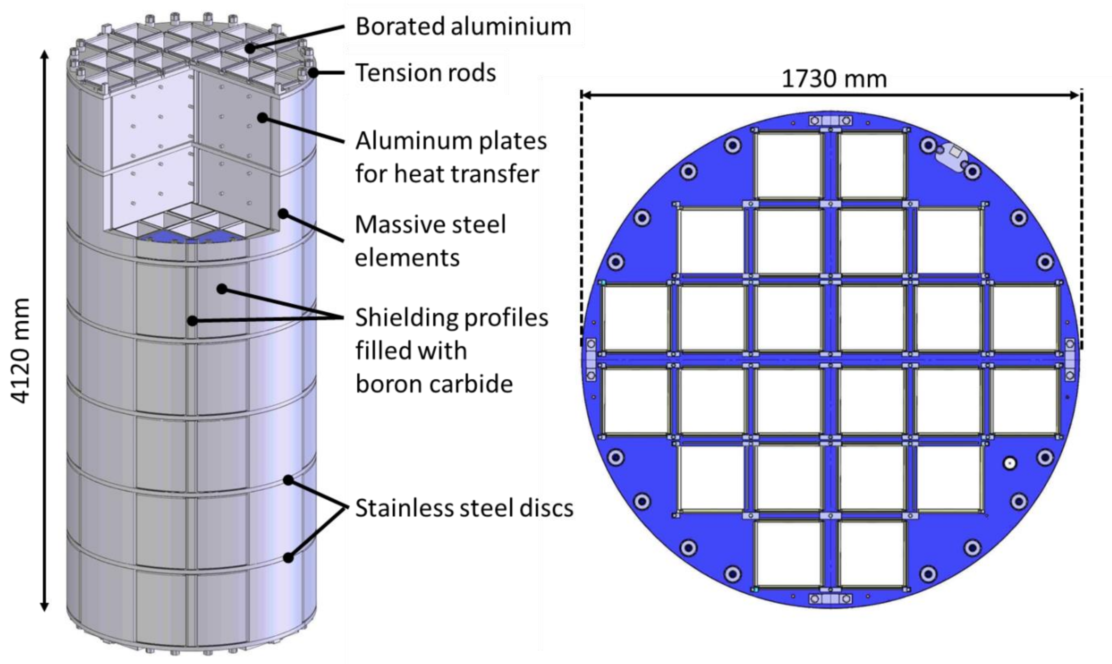

Figure 4: Main components / cross-section of the CASTOR® geo24B fuel basket

Impact limiter

Before being transported on public routes, the lid-end and bottom-end impact limiter are bolted to the cask body in order to protect the cask and its inventory under accident conditions (Figure 5). The impact limiters consist of a welded steel cage filled with defined layers of wood to dissipate impact energy. The impact limiters are equipped with additional steel plates that protect the lid system and the cask bottom, respectively, from direct mechanical impacts.

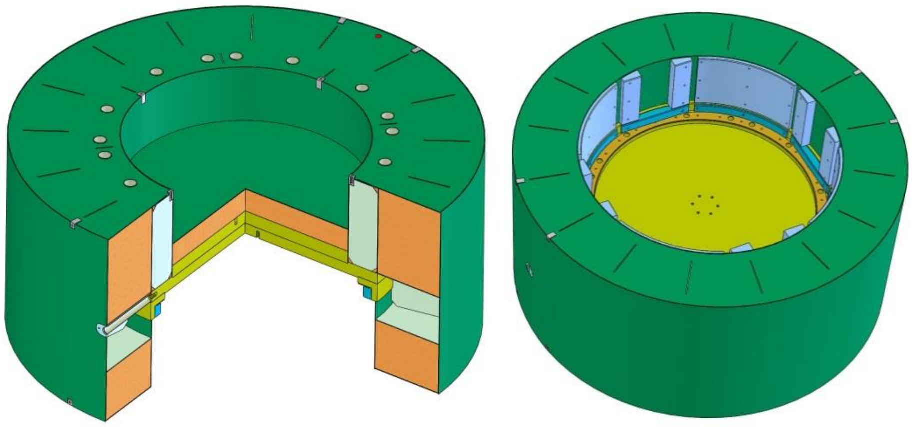

Figure 5: Example of Impact limiters

German Projects

1. Transports with CASTOR® S1 cask

One of the first casks GNS developed especially for the transport and shuttle of spent fuel assemblies is the cask type CASTOR® S1 (Figure 6). It was designed for the transport of up to six PWR FAs or up to 17 BWR FAs. Starting with the successful cold commissioning at THORP in 1989, from the years 1990 to 2003, 136 spent nuclear fuel transports were performed from the German nuclear power plants Unterweser, Gundremmingen, Grohnde, Lippe-Ems, and Biblis to the reprocessing plant Sellafield in the United Kingdom. A total of approx. 1120 FAs have been transported with the fleet of four CASTOR® S1 casks, in the so-called “wet” mode, i.e. with water inside the cask during shipment.

Figure 6: Handling of a loaded CASTOR® S1 at the German NPP Unterweser

Depending on the available transport connection of each power plant the casks were transported either by railway only or by a combination railway/road and reloaded on a specially constructed ship (Figure 7) between the seaports of Barrow (England) and Dunkirk (France).

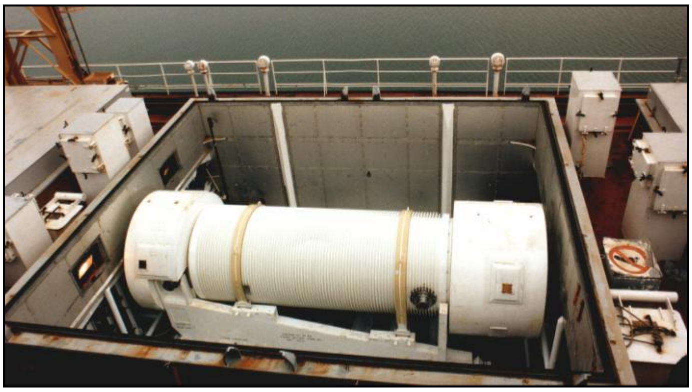

Figure 7: CASTOR® S1 during shipment

These four CASTOR® S1 casks, with their 136 shipments of spent fuel to reprocessing, have substantially contributed to the spent fuel management programme in Germany at that time.

2. Onsite Transports with CASTOR® casks

In the early 1980ies some German utilities already started shuttle operations between the units of a nuclear power plant, using CASTOR® casks of the first generation (Figure 8), usually in wet configuration. Some of these are still in use as truly reliable workhorses. In recent time, also GNS' most famous transport and storage cask types, the CASTOR® V/19 for PWR fuel and the CASTOR® V/52 for BWR fuel, have been widely used for transfer campaigns within the plants Gundremmingen and Biblis. Meanwhile, the total number of onsite transports in Germany has reached the significant figure of nearly 250. (Table 1).

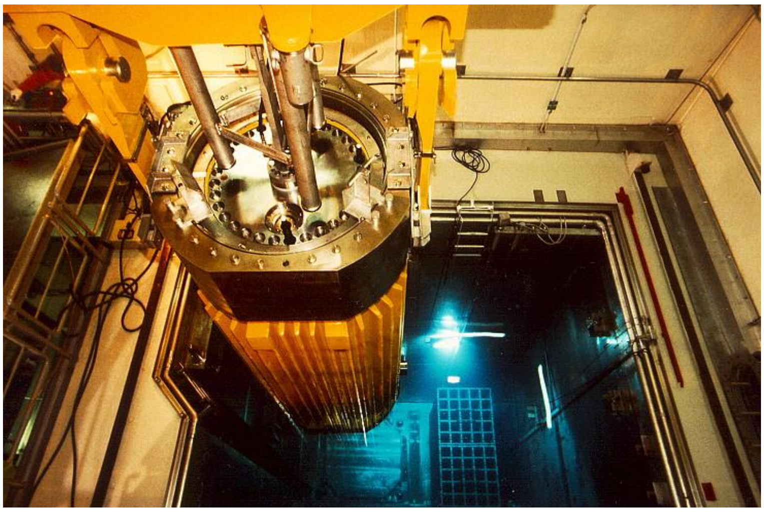

Figure 8: CASTOR® Ib after loading

Table 1: Onsite transport operations in Germany

Onsite Transport			*Intention*	*CASTOR®-Type*	*Inventory*	*No. of Transports*
From	*To*	*Mode*				
GKN Unit I	GKN Unit II	Wet	Complete Transfer for Loading and Dry Long-Term Storage in CASTOR® V/19	CASTOR® IIb	8 PWR-FA	108
KKP Unit 1	KKP Unit 2	Wet	Transfer for Loading and Dry Long-Term Storage in CASTOR® V/52	CASTOR® Ic	8 - 16 BWR-FA	22
KWO	External Cooling Pond Onsite	Wet	Assurance of Plant Operation	CASTOR® Ib	4 PWR-FA	96
KGG Unit B	KGG Unit C	Wet	Extended Use of 1-Cycle-FA from Unit B at Unit C	CASTOR® V/52	22 BWR-FA	5
KWB Unit A	KWB Unit B	Dewatered	Total Clearance of Unit A from Fissile Material	CASTOR® V/19	3 PWR-FA	1

International Projects

1. CASTOR® TVO

One of the first casks GNS had delivered for the purpose of onsite shuttling is the CASTOR® TVO for the nuclear power plant Olkiluoto owned by the Finish energy company Teollisuuden Voima Oyj (TVO) which by now can draw on more than 30 years of operational experience to customer's full satisfaction. By means of this cask spent fuel originated from OL1 and OL2 is transferred to the intermediate storage facility called KPA on a special trailer in a frequency of approximately four transports a year (Figure 9).

Figure 9: CASTOR® TVO during onsite transport

This cask type can contain up to 41 BWR assemblies after a cooling time of two to five years. The loaded cask weighs about 93 t without impact limiters. The transports are conducted in wet mode, with a total permitted heat load of 22 kW.

2. CASTOR® VVER 1000

Even three years earlier GNS supplied one cask of the type CASTOR® VVER 1000 to the NPP Novo Voronesh in the former Soviet Union (Figure 10). The first loading took place in May 1987. Today this cask is still in operation with about four to five onsite transports per year.


Figure 10: Shipment of CASTOR® VVER-1000

3. CASTOR® MTR 2

GNS has not only developed casks for the disposal of spent fuel from commercial nuclear power plants, but also special casks of minor dimensions for the disposal of spent fuel from research reactors (Figure 11). One of these casks is the CASTOR® MTR 2 that can accommodate different fuel baskets with MTR and also VVER-M and EK-10 fuel assemblies of Russian type. In the transport configuration shock absorbers are installed at the top and bottom ends of the cask resulting in a mass of the loaded cask of nearly 18 tons.

The CASTOR® MTR 2 complies with the international regulations of the IAEA for package designs of the type B(U) and is, for example, currently used to transport the fissile radioactive waste from NRG Petten to the interim storage facility HABOG at COVRA in the Netherlands. Therefore, the approval certificate has been validated by the Dutch competent authority. In the meantime, more than 40 transports have been performed since November 2003.

Figure 11: CASTOR® MTR 2 for research reactor fuel

4. CASTOR® KN12

In the year 2000, GNS as a joint venture with the company DOOSAN signed a contract with the electric power company Korea Hydro & Nuclear Power for the delivery of two transport casks of the type CASTOR® KN12 (Figure 12). Within the division of tasks at the time, GNS was responsible for the development and licensing of the cask, while DOOSAN was responsible for the manufacture of the casks. At the request of the Korean customers, the cask body was made of forged steel.

During the project the CASTOR® KN12 package design approval certificate was issued by the Korean authorities KINS, and two casks were manufactured and delivered for fuel transports at the Kori NPP. The project was completed in 2002. In the year 2006, GNS signed a license agreement with DOOSAN for the manufacture of three further casks of the type CASTOR® KN12 for use at two other power plants of Ulchin and Yonggwang. This project was completed with the delivery of the casks in December 2008. Details of the long-time cask operations at the three Korean nuclear power plants are given in Table 2.

Figure 12: The CASTOR® KN12 Transport Cask

Table 2: Transfer operations with CASTOR® KN12

Site	***Units***	***No. KN-12 Casks***	***Operation Period***	***Total No. of Operations***	***Average No. of Operations per each cask***
Kori	4	**2**	2002~	**123**	62.5
Hanbit (Yonggwang)	2	**1**	2009~	**19**	19
Hanul (Ulchin)	2	**2**	2009~	**64**	32

Special application: Onsite transport of Quiver-system

A very recent and specific application of shuttling was the transfer of three quivers for damaged fuel rods between Units A and B at the German NPP Biblis. For the disposal of special fuel rods which are characterized by damaged cladding or other defects GNS developed a technologically sophisticated solution for the needs of the German utilities, the so-called “Integrated Quiver-System”. This system was used to prepare and package damaged fuel rods under water in the spent fuel pond of Unit A at NPP Biblis. In total three of these quivers were loaded into a CASTOR® V/19 cask and then transported onsite from Unit A to Unit B end of 2016/beginning of 2017. The quiver technology can easily be adapted to different kinds and grades of damaged fuel rods for both national and international needs.

Conclusion and Outlook

The original impulse for developing the first CASTOR® casks was the revolutionary idea to establish casks both suitable for transport and dry storage. But from their very beginnings, some CASTOR® casks have not only been used for a single transport from the reactor building or a reprocessing plant to an interim storage facility but were used for numerous transports within more than three decades. With individual track records of up to several dozen loadings, multiple dispatch procedures and transport operations each, these cask are the best evidence for the durability, reliability and versatility of the CASTOR® cask family. And they prove to be reliable means for the upcoming transports from interim storage to future final repositories.