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GNS CASTOR® V Dual Purpose Casks: The Backbone for Spent Fuel Dry Interim Storage in Germany

Thomas Funke, Frank Jüttemann, Roland Hüggenberg, Jens Schröder
GNS Gesellschaft für Nuklear-Service mbH, Essen, Germany

ABSTRACT

The present concept for spent fuel management in Germany is dry interim storage and subsequent final disposal. For the case of spent fuel assemblies from commercial nuclear power plants in Germany CASTOR® V dual purpose casks essentially constitute the backbone for dry interim storage.

GNS has developed two types of CASTOR® V casks – CASTOR® V/19 and CASTOR® V/52 – licensed for both transport and interim storage of 19 PWR and 52 BWR spent fuel assemblies, respectively.

Since March 1997, when the first CASTOR® V/19 cask containing 19 PWR fuel assemblies was stored at the interim storage facility in Gorleben, more than 300 CASTOR® V have been loaded and put in storage.

To meet the customer as well as licensing requirements across these years, the initial cask design from the 1990s was continuously enhanced and optimized. Accordingly, the cask inventory parameters evolved from a heat load of 25 kW and initial enrichment of up to 4.05 wt-% U235 to a heat load of 40 kW and initial enrichment of up to 4.45 wt-% U235. MOX fuel assemblies may also be transported and stored in CASTOR® V casks. Currently, the initial enrichment of the spent fuel assemblies to be transported and stored in the CASTOR® V casks is going to be increased.

Moreover, periodical renewals of existing licenses as well as new applications kept cask design as well as proof of the design state-of-the-art. As a result, GNS is currently holding four type B(U)F-licenses for CASTOR® V casks.

Following the significant changes in political and legal boundary conditions in Germany 2011 an accelerated phase-out of nuclear power is demanded. This leads to new boundary conditions for the German electric power utilities and subsequently for the further CASTOR® V casks development. One challenge amongst others is to quickly remove spent fuel from shut-down plants. In order to achieve this, the cask inventory parameters are going to be extended and quivers to accommodate nonstandard fuel rods will also be developed and stored in CASTOR® V casks. Finally, cask manufacturing capacities are to be increased.

The presentation will give an overview of the specific capabilities of the CASTOR® V as dual purpose casks and an outlook to future developments.

1 INTRODUCTION

GNS has more than 30 years of experience in developing, licensing and manufacturing of casks for the transport and storage of spent fuel assemblies (SFA) and high active waste (HAW). The main cask type for storage of SFA from commercial nuclear power plants is the CASTOR® V. The casks of the CASTOR® V type family have been developed for transport and long-term interim storage of PWR and BWR SFA.

The CASTOR® V cask design was developed and licensed in Germany in the 1990s. In March 1997, three CASTOR® V/19, each containing 19 PWR SFA from Neckarwestheim NPP, were stored at the centralized interim storage facility in Gorleben. In March 1998, the second centralized dry interim storage facility in Ahaus received another three CASTOR® V/19 casks from Neckarwestheim NPP and three CASTOR® V/52 casks, each containing 52 BWR SFA from Gundremmingen NPP. Each cask holds about ten metric tons of heavy metal. All these casks serve as dual purpose casks for transport and interim storage.

15 years of storage have shown that the basic requirements, which are safe confinement, criticality safety, sufficient shielding and appropriate heat transfer have been fulfilled in each case. There is no indication of problems arising in the future. Of course, the customer as well as licensing requirements caused improvements of the cask design up to now.

2 DESIGN CHARACTERISTICS OF THE CASTOR® V

The CASTOR® V/19 cask is designed for 19 SFA from PWR. The CASTOR® V/52 is the well established product for 52 SFA from the German boiling water reactors. The basic design of both casks is similar and shown in Figure 1.

The cask body consists of a large cylindrical thick-walled casting including bottom made of ductile cast iron (DCI). On the outside wall, circumferential fins are machined in the body to improve the heat removal. For neutron moderation, axial bore holes are distributed uniformly in the cask wall and filled with polyethylene moderator rods. In addition, there are plates of polyethylene at the bottom end and on the underside of the secondary lid. Trunnions - made of stainless steel - are attached onto the cylindrical part bottom side and lid side for handling and lifting.

Corrosion protection of the cask cavity and the sealing surfaces is achieved by nickel coating. The outer surface of the cask, including the fins, is protected by a multilayer paint system, which can be decontaminated easily. The cask cavity is dried and filled with helium.

The lid system consists of two independent lids to realize the double barrier system which is required to fulfill the German long-term storage criteria. The primary lid and the secondary lid are made of stainless steel and sealed by metal-O-rings and fastened by bolts. The space between the lids is filled with helium at a pressure of 6 bars. This pressure is permanently monitored during storage.

In order to accommodate the SFA, a basket consisting of square tubes for positioning of each fuel assembly is installed inside the cask cavity. The materials are steel for structural reasons and borated materials for neutron absorption. The necessary heat removal is realized by aluminum or copper plates.

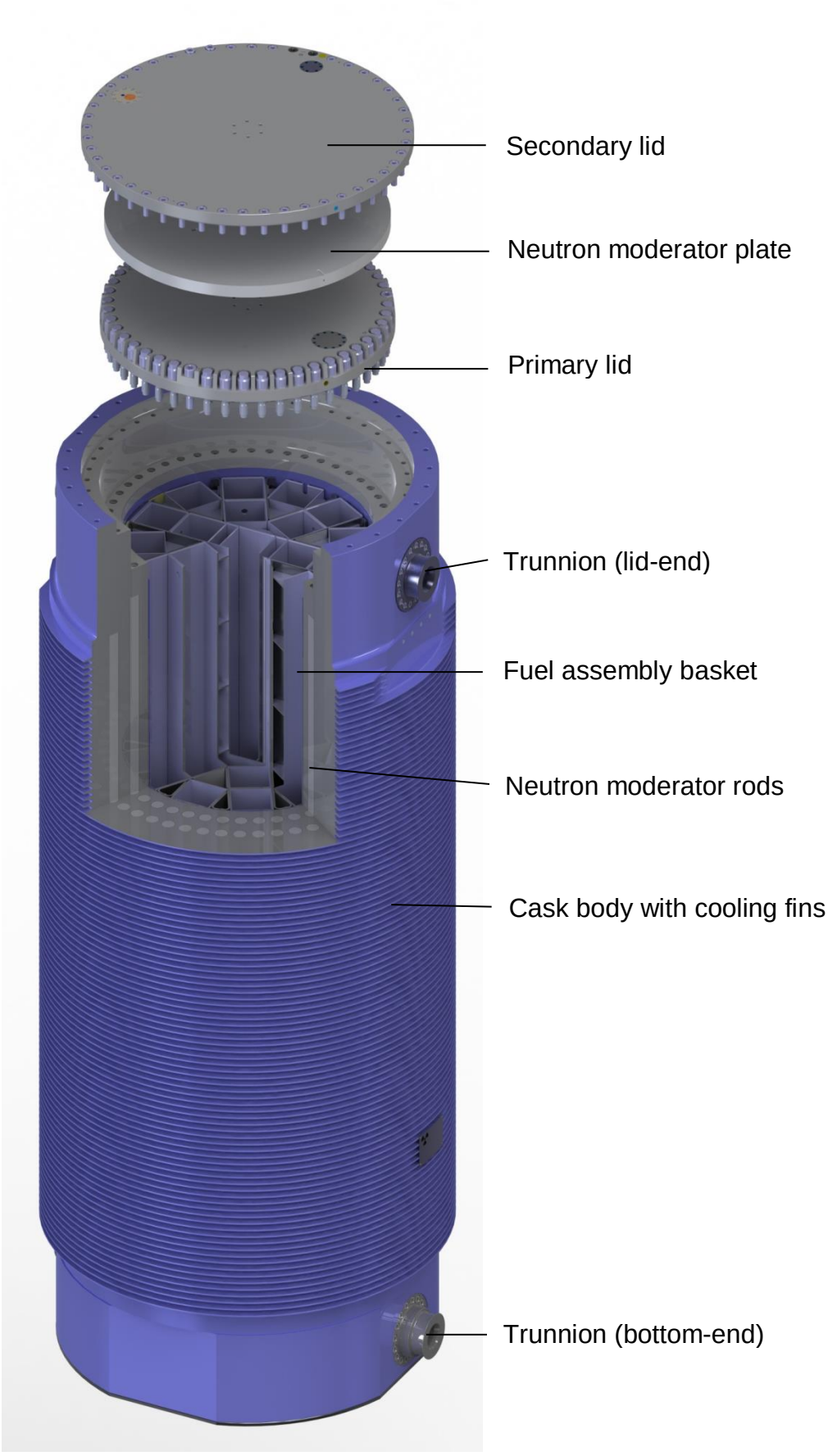

Figure 1: Design Features of the CASTOR® V/19

For fulfillment of the IAEA-criteria for transport of type B(U)-packaging, impact limiters are intended, which are bolted onto the lid side and the bottom side (see Figure 2).

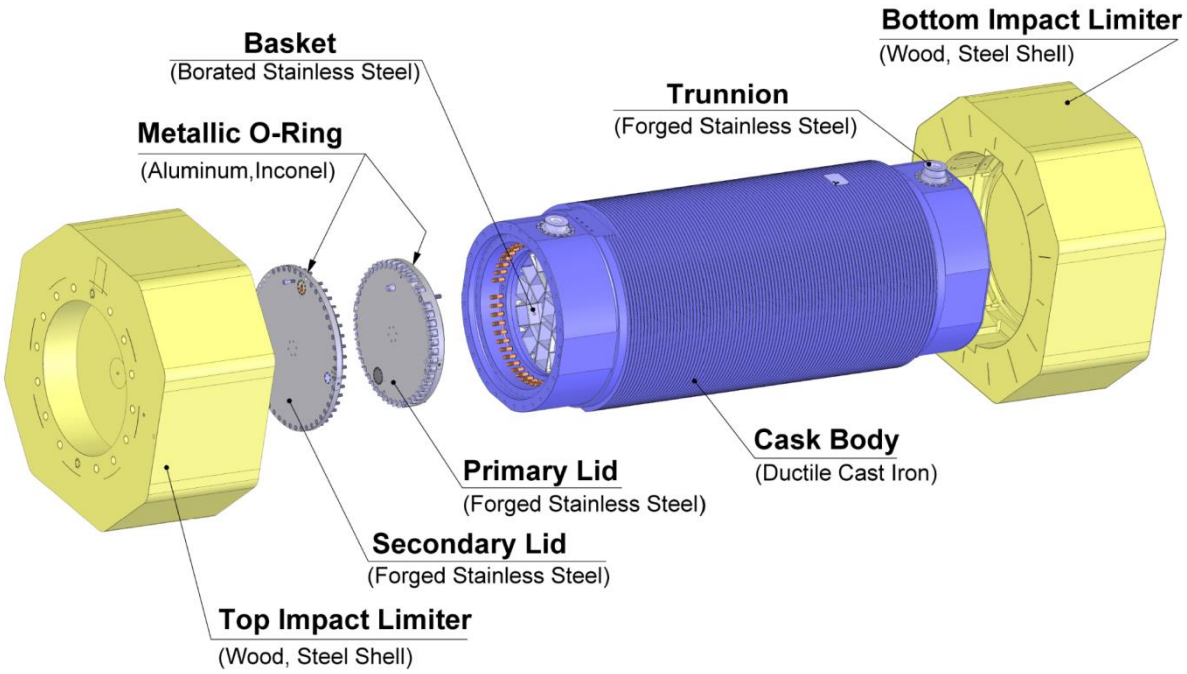

Figure 2: Design Features of the CASTOR® V/19 (Transport configuration)

The dimensions of the CASTOR® V/19 and CASTOR® V/52 are as follows:

	CASTOR® V/19	CASTOR® V/52
Overall height (without impact limiters):	≈ 5860 mm	≈ 5450 mm
Overall height (with impact limiters):	≈ 7530 mm	≈ 7120 mm
Outer diameter:	≈ 2440 mm	≈ 2440 mm
Cavity height:	≈ 5025 mm	≈ 4550 mm
Cavity diameter:	≈ 1480 mm	≈ 1480 mm
Cask weight loaded (transport config.):	< 150 Mg	< 150 Mg

3 CHALLENGES DUE TO POLITICAL CONDITIONS

3.1 PROHIBITION OF TRANSPORTS TO REPROCESSING PLANTS

Until 30th June 2005, the management of spent nuclear fuel in Germany was based on two pillars, i. e. reprocessing and direct disposal. From that day on, any delivery of SFA to reprocessing plants was prohibited so that the direct disposal of unreprocessed SFA is the only available option in Germany today.

Prior to this deadline, reprocessing of SFA was the preferred way in spent fuel management. The high active waste from nuclear fuel reprocessing is loaded, transported and stored in CASTOR® HAW-casks at the centralized dry interim storage facility in Gorleben. Apart from the preferred way of nuclear fuel reprocessing, a smaller number of spent fuel assemblies was loaded into CASTOR® V dual purpose casks for dry interim storage.

After the deadline for delivery of SFA to reprocessing plants, dry interim storage in CASTOR® V dual purpose casks became the sole option for spent fuel management. The nuclear power plant operators' obligation to ensure the interim storage of the SFA originating from their operation at the nuclear power plant sites (decentralized dry interim storage) has been laid down in the amendment to the German Atomic Energy Act of April 2002.

The German facilities for the interim storage of SFA are two centralized dry storage facilities in Ahaus and Gorleben – both operated by GNS, twelve on-site storage facilities close to the reactor, and two local interim storage facilities at Greifswald (ZLN) and Jülich. The twelve decentralized on-site storage facilities close to the reactor were constructed and taken into operation stepwise, the first facility in December 2002 and the latest in April 2007. In addition, the NPP Obrigheim has applied for the Obrigheim on-site interim storage facility.

Figure 3 shows the location of the interim storage facilities in Germany, figure 4 an example view into an interim storage facility.

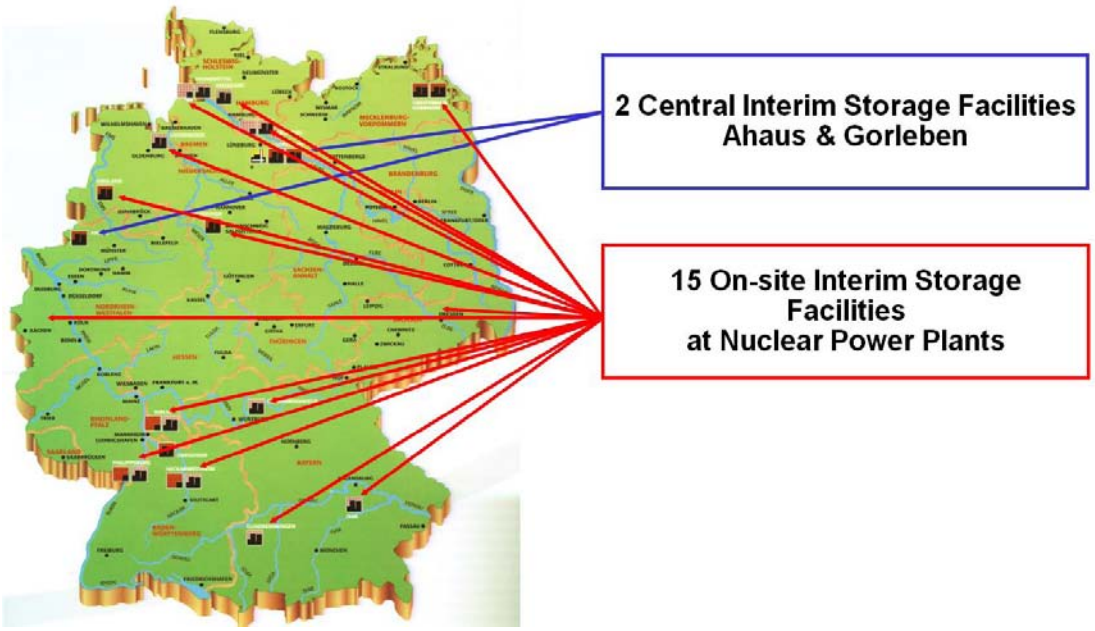

Figure 3: Spent Fuel Storage Facilities in Germany

Figure 4: Interim storage facilitiy Gorleben

Tab. 1 gives an overview to the overall number of CASTOR® V casks already loaded and stored in interim storage facilities.

Table 1: Number of loaded CASTOR® V casks in German interim storage facilities

	Until July 2005	Until January 2010	Until June 2013
Loaded CASTOR® V casks	83	247	336

3.2 GERMAN DECISION FOR ACCELERATED NUCLEAR POWER PHASE-OUT

The new political situation action in Germany demands an accelerated nuclear power phase-out. In March 2011, the German Federal Government decided to shut down eight German nuclear power plants (NPP) immediately. Therefore, only nine NPPs are still in operation. The Federal Government decided to end the use of nuclear energy for commercial electricity generation in Germany until the end of 2022.

This leads to new boundary conditions for the German electric power utilities and subsequently for the further CASTOR® V casks development, e.g.:

- Specific inventory from shutdown plants, such as high enriched SFAs with very low burn-up (< 10 GWd/MTU)
- Removal of nonstandard nuclear fuel from reactor pools of shutdown plants.

One challenge amongst others is to quickly remove spent fuel from reactor pools of shut-down plants. Besides the extension of the cask inventory parameters, the cask manufacturing and cask service capacities need to be increased significantly.

4 INVENTORY OF THE CASTOR® V CASKS

Originally, the CASTOR® V/19 was licensed for an initial enrichment of up to 4.05 wt-% U235 and a heat load of 25 kW per cask. The discharge burn-up for the homogenous loading was limited to 55 GWd/MTU. In a heterogeneous loading pattern, a loading with 4 MOX-FA or 4 special U-FA with a maximum burn-up of 65 GWd/MTU was possible.

The cask was licensed according to the IAEA-Regulation TS-R-1 "Safety Requirements for the Safe Transport of Radioactive Material" 1985 Edition.

Later on, the maximum heat load per cask was increased to 39 kW and by use of burn-up credit the initial enrichment was raised to 4.45 wt-% U235.

In 2010, the first approval according to the 1996 edition of the TS-R-1 was issued by the German competent authority BfS. Due to design improvements nowadays, up to 6 MOX-FA can be loaded into the CASTOR® V/19.

The CASTOR® V/52 was licensed for fuel with an initial enrichment of up to 4.25 wt-% U235 according to IAEA-Regulation TS-R-1 (1985 Edition). The discharge burn-up was generally limited to 55 GWd/MTU. In a heterogeneous loading pattern, a loading with 16 uranium-FA with a discharge burn-up of 65 GWd/MTU or 16 MOX-FA with a discharge burn-up of 50 GWd/MTU is possible. The maximum allowable heat load per cask is 40 kW.

Further extension of the cask inventory parameters for the operating plants is required and technically possible. Currently, further licensing procedures are ongoing to achieve e. g. further increased initial enrichment, more positions for MOX elements, spent fuel with high burn-up and the reception of quivers for special fuel rods.

5 GNS CASK MANUFACTURING CAPACITY

Following the increased cask demand, GNS has increased the production capacity to 80 casks per year. Therefore, the manufacturing processes were adapted and the manufacturing facilities were expanded (see figure 5).

Figure 5: GNS-Manufacturing plants I and II in Mülheim / Germany

6 GNS CASK LOADING CAPACITY

In addition to the increased cask manufacturing capacity, the number of possible cask loadings per year will be increasing as well.

GNS provides all services for cask loadings (Fig. 6). Service teams for cask handling are available which can load casks at five nuclear power plants simultaneously. Besides the personnel, the necessary equipment is also available.

The cask loading is performed on the basis of detailed handling sequence plans under the constant surveillance of experts from the competent atomic supervisory authority. The operation procedure during normal operation of the transport and storage cask is:

- Preparation of the cask for loading secondary and primary lids are removed, sealing area of the cask is protected
- Placement of the cask with the fuel assembly basket into the loading pool
- Loading of the cask with fuel assemblies (handling of the loaded basket within the cask only)
- Placement of the primary lid
- Removal of the cask from the loading pool
- Dewatering and drying of the cask cavity, filling with helium
- Helium tightness test of the primary lid
- Placement of the secondary lid
- Drying of the inter-lid space and filling with helium
- Helium tightness test of the secondary lid
- Preparation and transfer of the loaded cask out of the reactor building
- Transfer of the loaded cask to the nearby interim storage facility.

For the operation procedures in the reactor building, an adequate service place and supply with helium, nitrogen, pressurized air, electricity and water is required.

The cask surface is protected against contamination by the use of a contamination protection skirt. In addition, the outer surface of the cask body is protected by a closed multilayer paint coating, which is easy to decontaminate.

All handling procedures and equipment are designed and monitored to meet highest national and international standards and to ensure that drop accidents within or outside the reactor unit are excluded.

Figure 6: Cask loading and handling

7 SUMMARY

For SFA from commercial nuclear power plants in Germany dry interim storage in dual purpose casks and subsequent final disposal is the sole option for spent fuel management. With more than 300 casks loaded and over 15 years of operating experience, CASTOR® V casks essentially constitute the backbone for dry interim storage.

GNS' CASTOR® technology has been tested, approved and licensed worldwide for three decades. Customer as well as licensing requirements and operating experience bring forth continuous improvements of the CASTOR® technology. The CASTOR® cask family will be permanently optimized and adapted to customer-specific needs. As ductile cast iron is well-known and certified for several decades now, the CASTOR® V family is an economic solution for the dry interim storage of spent fuel worldwide.