CONSORT –SPENT NUCLEAR FUEL
STORAGE AND TRANSPORT CASK SYSTEM

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ABSTRACT
Previously, GNB of Essen, Germany developed the CASTOR series of ductile cast iron container systems for the storage and shipping of spent nuclear fuel (SNF). The CASTOR system has been accepted and deployed internationally by GNB. However, GNB recognized that it needed to develop a new SNF container option for Eastern European markets where fabrication capabilities and financial resources are more limiting. Thus, GNB developed the CONSTOR system (steel-concrete-steel sandwich cask) which incorporates the advantages of the CASTOR system, but at an inexpensive cost.

The CONSTOR system was developed specifically for storage/transport of SNF from Russian RBMK reactors, but can be utilized for other Russian type reactor fuel. Advantages of the system include its ease of handling and loading, bolted lid design as has been proven with the CASTOR as well as heavy shielding capacity and inexpensive fabrication costs. The system meets the regulations of the IAEA for Type B(U) packages and has been approved for use by GAN, the Russian licensing authority. In addition to its use in the Russian reactor market, the CONSTOR has application for SNF at U.S. utility and DOE sites.

INTRODUCTION
In the 1980’s, GNB introduced the first generation of SNF storage and transport systems to the international market via its CASTOR dual-purpose cask system. CASTOR is a ductile cast iron cask that has been licensed for storage/transport throughout Europe and for storage in the U.S. Currently, there are 26 CASTOR systems deployed at the Virginia Power Surrey ISFSI and hundreds of CASTOR systems have been sold internationally. The CASTOR system continues to be a major cask for SNF management throughout Europe.

Fabrication of the CASTOR system is expensive and requires the type of casting/machining facilities which are readily available in most Western countries. Many Eastern European countries have a need for SNF management, but do not possess the casting facilities nor have the financial resources to manufacture the CASTOR system. Thus, GNB embarked on a program to develop and deploy a SNF system that could (1) meet the technical requirements for storage/transport of the Eastern European SNF, (2) be fabricated in Eastern Europe using facilities in those countries, and (3) provide an affordable SNF system for those Eastern European clients. This development
program resulted a second generation of SNF dual-purpose cask system—the CONSTOR system.

**THE CONSTOR SYSTEM—OVERVIEW**

The CONSTOR sandwich cask concept using heavy concrete as the basic shielding material has been developed by GNB together with the Russian company CKTI to achieve several goals.

One of the main goals was to use the CONSTOR as a multipurpose cask for both transport and dry storage and, in principle, also for final disposal.

A further goal was the effective and cost effective manufacturing by using conventional mechanical engineering technologies and common available materials. Another intent was to fabricate CONSTOR casks in countries not having highly specialized heavy industries. Nevertheless, the basic requirement for this CONSTOR concept was to fulfill both the internationally valid IAEA safety and test requirements for safe transport and long-term intermediate storage of spent nuclear fuel, including hypothetical storage site accident conditions (drop, fire, gas cloud explosion, side impact). The CONSTOR basic concept has been designed for adaptation to different spent fuel specifications and loading capacities, as well as different handling conditions in the nuclear power plants (NPP’s). Recently, adaptations have been made for spent fuel from the RBMK and VVER reactors and also for BWR spent fuel.

In the following, the design elements and structural materials of the basic design, taking as an example the CONSTOR RBMK cask, will be presented. An overview of the analyses and the results for radiation shielding, for strength behavior and for heat removal shows that the safety criteria were fulfilled. Afterwards, some principles concerning manufacturing will be given and at the licensing-related aspects are discussed.

**CONSTOR Cask Design**

The cask body of the CONSTOR RBMK (see figure 1) consists of an outer and an inner shell made of steel. The space between the two liners is filled with heavy concrete for gamma and neutron shielding. Inside the concrete, steel reinforcement is arranged to improve the strength and heat removal properties. The cask bottom has the same sandwich design as the wall. At the lid end, the shells are welded to a ring made of forged steel. The trunnions for lifting and handling are attached at this ring.

The lid system (see figure 2) is designed as a multi-barrier system. The bolted primary lid fulfills strength and shielding functions. For temporary sealing, this lid is tightened by help of an elastomer seal. The sealing plate and the secondary lid are welded to the forged steel ring after loading and servicing of the cask. These two welded lids represent together with the inner and outer shell (including their bottom plates) the double barrier system.
The welding of the shells and the lids was made by a qualified welding technique used by the German POLLUX cask final disposal system according to a certified QA-plan and checked by a special QC-program have the same properties as the basic material. Consequently, a leak tightness monitoring system is not necessary for the CONSTOR cask during the long-term interim storage.

Special shock absorbing steel elements have been designed at the bottom end of the cask to guarantee the safety at hypothetical storage site drop accidents. During public transport, steel covered wooden shock absorbers will be attached to the bottom and the lid sides of the cask in order to fulfill the IAEA safety criteria. The RBMK spent fuel bundles are positioned in a basket inside the cask. The capacity of the standardized basket 32M is 102 bundles (half fuel assemblies). In an optimized basket, the capacity can be essentially increased. The total mass of the CONSTOR RBMK cask, including impact limiters, loaded with the 32M basket, is approx. 96 500 kg.

**Cask Materials**

For the cask metal parts, a weldable steel material has been chosen which has excellent properties against brittle fracture and fatigue at temperatures down to -50 °C. The mechanical properties of the steel are sufficient to guarantee the required strength.

The long-term corrosion protection is guaranteed by
- special anticorrosive paint system (inside and outside)
- dried inert gas atmosphere inside the cask
- hermetically sealed concrete space between the inner and outer shell.

The heavy concrete is based on barite minerals and steel granules and bounded by normal cement (see fig. 3). After hardening of the cement, the concrete will be tempered to regulate the free water content. The mechanical properties are comparable to B35 concrete. The long-term behavior and the properties of this heavy concrete under irradiation during a storage time of 50 years have been checked [1]. It could be shown that the highest possible total neutron and gamma fluxes which have been considered at VVER 1000 fuel are approximately three orders of magnitude less than such fluxes where the concrete strength slightly begins to decrease.

**Cask Content and Safety Analysis**

In case of CONSTOR RBMK cask, the fuel has the following specifications:

- Enrichment (average) 2.0 wt.% U 235
- Burn up (average) 20 GWd/t
- Cooling time 5 to 10 years
- Heat capacity per cask at mixed loading ≤ 7.65 kW

Adaptations of the CONSTOR cask design have been made for spent nuclear fuel assemblies with U 235 enrichments up to 4.0 wt % and a burn up of 50 GWd/MTU. The
total heat capacity of the cask can be increased up to 20 kW. For all above-mentioned fuel specification, the total dose rate at the surface is approx. 200 µSv/h.

The analyses of nuclear and thermal behavior as well as of cask strength according to IAEA examinations requirements (9-m-drop, 1-m-pin drop, 800 °C-fire test) and of the cask behavior during accident scenarios at the storage site (drop, fire, gas cloud explosion, side impact) were carried out by means of validated and benchmarked calculation methods and programs. In a special experimental program, the mechanical and thermodynamic properties of heavy concrete were examined and the reference values required for safety analyses were determined.

The strength analysis has shown that the mechanical stresses under both normal operational and test/accidental conditions are below the respective allowable stresses. The results of the safety analysis after drop tests according to IAEA-regulations as well as after a 1-m-drop at the storage site were confirmed by means of a test program using a scaled CONSTOR cask model [2]. The post-test inspection program of the model cask has shown that the cask integrity and leak tightness were maintained after the series of 6 drop tests.

The maximum temperatures which were calculated for operational and for fire conditions are presented in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Normal operation (°C)</th>
<th>Fire (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer cask surface</td>
<td>78</td>
<td>484</td>
</tr>
<tr>
<td>Fuel cladding</td>
<td>339</td>
<td>355</td>
</tr>
<tr>
<td>Concrete temperature</td>
<td>105</td>
<td>187</td>
</tr>
</tbody>
</table>

A more detailed analysis of the thermal behavior of the cask can be provided upon request.

The results of heat removal analyses have been confirmed by an experimental heat transfer test and by an 800 °C fire test performed by using the a. m. CONSTOR cask model. The cask tightness and integrity were maintained after these tests.

**Fabrication Technology**

The fabrication technology has been tested with help of the scaled test cask, see figure 4. The model has been prefabricated in Russia with a Quality Assurance Program according to Western Standards for spent nuclear fuel casks. The completion has been done in Germany. It has been shown that the CONSTOR cask can be fabricated in an effective and economic way, according to the following strategy:

- Purchase of pre-assembled components, as for example, the cylindrical shells, large forged pieces, reinforcing components, lids and bottoms
• Assembling (welding) at the same locations where concreting is carried out
• Use of the essential concrete materials coming from their own country.

The concrete technology exclusively developed for this purpose excludes well-known demixing problems during fabrication and guarantees the formation of homogeneous heavy concrete free from cavities between the cask walls. The cask density can be adjusted according to shielding requirements by using of different amounts of steel shot.

**LICENSING OF THE CONSTOR**
In 1997, GNB began working with an Eastern European client who possessed Russian-made RBMK SNF. This client was willing to accept the licensing authority of the Russian government to qualify the CONSTOR system for storage of the RBMK fuel. GNB prepared the SAR and license application for submittal to GAN, the Russian licensing authority. After review of the license application, GAN approved the CONSTOR system in 1998. The client has place an order for forty (40) CONSTOR cask systems for their facility. Although the CONSTOR will be utilized by the client for storage, the CONSTOR meets the international regulations of the IAEA for Type B(U) packages for transport.

In working with the client and the Russian licensing authorities, GNB experienced several issues which will make future licensing efforts more efficient.

**APPLICABILITY OF THE CONSTOR SYSTEM**
In addition to the utilization of the CONSTOR cask system for Russian-made RBMK SNF (and VVER SNF), GNB is reviewing the applicability of the system to a Fast Breeder Reactor Fuel Project in Kazakhstan, and applicability to the U.S. SNF market.

The Aktau Facility in Kazakhstan has a need to move SNF from its facility to a final disposal site. The SNF will be moved by rail/truck to the disposal site. The characteristics of the SNF from the Fast Breeder Reactor readily meet the storage/transport capabilities of the CONSTOR cask. The client requires that the transport cask system meet the requirements of the IAEA; the CONSTOR system meets the IAEA requirements and has already been approved by a Russian regulatory agency as discussed above. GNB believes that the CONSTOR System is the most cost-effective cask for this project and will work with the client to propose its use.

In the U.S. market, GNB believes that the CONSTOR System is a technically acceptable and cost-effective system for the storage/transport of BWR fuel, as well as fuel stored at the DOE sites. The CONSTOR is capable of storing/transporting over 50 BWR spent fuel elements with the following characteristics: up to 3.5% initial enrichment; burnup of over 40 GWDt/MTU; and a cooling time of ten years. In addition to the utility BWR market, DOE possesses SNF which may be suitable for the CONSTOR system. One such site is the INEEL where DOE is storing SNF from several utilities. At this time, GNB is assessing its interest in pursuing the U.S. market for the CONSTOR cask system.
SUMMARY
Using of detailed analyses and tests, it has been shown that the CONSTOR cask concept can be used for the safe transport and storage of spent nuclear fuel. The concept can be flexibly adapted to different kinds of spent fuel specifications. It can be manufactured in countries with normal mechanical engineering equipment. There are a number of possibilities to increase the cask heat removal capacity and the number of fuel bundles per cask.

REFERENCES

Fig. 1  CONSTOR RBMK Transport and Storage Cask

Fig. 2  CONSTOR RBMK Lid System

Fig. 3 Specimen of Heavy Concrete for CONSTOR Casks

Fig. 4  CONSTOR RBMK Test Cask Manufacturing