CONSTOR® TRANSPORT AND STORAGE CASK FOR SPENT FUEL AND FOR HIGH ACTIVE WASTE

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ABSTRACT
The CONSTOR® is a steel-concrete-steel sandwich cask design. It was developed with special consideration to an economical and effective way of manufacturing by using conventional mechanical engineering technologies and common materials. The main objective of this development was to fabricate these casks in countries not having highly specialised industries for casting or forging of thick-walled metal casks. Nevertheless, the CONSTOR® concept fulfils both the internationally valid IAEA criteria for transportation and the requirements for long-term intermediate storage. The basic cask concept has been designed for adaptation to different spent fuel specifications as well as handling conditions in the NPPs. Adaptations have been made for spent fuel from RBMK and VVER reactors, and also for BWR spent fuel and high active waste.

So far, almost 40 CONSTOR® RBMK-1500 casks have been manufactured and delivered to Ignalina Nuclear Power Plant (INPP) in Lithuania. Two of these have been successfully loaded during hot trial tests and placed in storage.

Basing on this positive experience , the Lithuanian competent authority has granted the INPP-storage license, including the use of CONSTOR® RBMK-1500 casks in June 2001. The transport license in Czech Republic (Type B(U)F-85) for CONSTOR® RBMK-1500 has been issued also in June 2001. Furthermore the CONSTOR® has obtained the type B(U)F verification certificate from the Russian authority GAN.

THE CONSTOR® CASK CONCEPT

The CONSTOR® sandwich steel cask concept using heavy concrete as additional shielding material has been developed to achieve different goals.

The main goal 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 efficient and cost effective manufacture by using conventional mechanical engineering technologies and commonly available materials. Nevertheless, the basic requirement for this CONSTOR® concept was to fulfil both the internationally valid IAEA test requirements for safe transport and the safety criteria for long-term intermediate storage of spent nuclear fuel including accident and residual risk events at the storage site (examples for accidents: malfunction of crane, drop, collision of casks, earth quake.; examples for residual risk events: crash of aircraft, fire from aircraft crash, gas cloud explosion)

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 NPPs. 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 of strength behaviour and heat removal shows that the respective safety criteria are fulfilled.

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 shells is filled with heavy concrete for gamma and neutron shielding. The CONSTOR® design does ***not* rely** on the concrete for structural integrity. Inside the concrete, steel-reinforcement can be arranged to improve the strength and heat removal properties. The cask bottom has the same sandwich design as the wall. At the top end, the shells are welded to a ring made of forged steel. The trunnions for lifting and handling are attached to this ring.

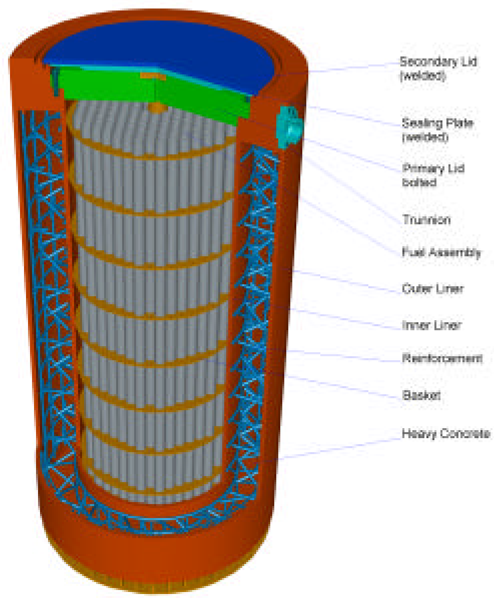

Figure 1, CONSTOR® Cask Design

The patented lid system (see Figure 2) is designed as a multi-barrier system in two versions. In the first version, the bolted primary lid fulfils strength and shielding functions. For temporary sealing, this lid is made leak-tight with the aid of an elastomeric 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 together with the inner and outer shell (including their bottom plates) constitute the double barrier system. In the second version, both the primary and the secondary lid are metal-sealed and bolted.

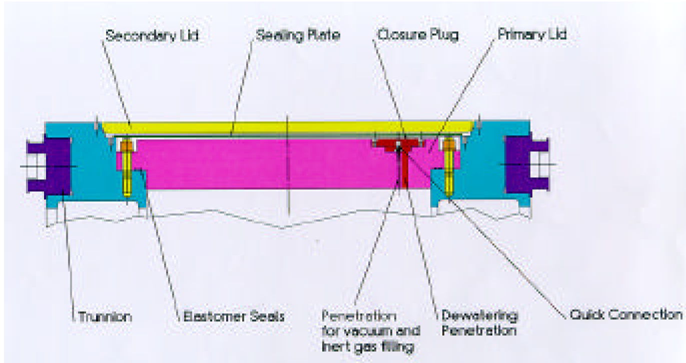

Figure 2, CONSTOR® Lid System

The welding of the shells and the lids is made by means of a qualified welding technique according to a certified QA-plan and checked by a special QC-programme. This guarantees that the welds have properties identical to the basic materials. 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 accidental storage site drop accidents. During public transport, wooden impact limiters will be attached to the bottom and the lid sides of the cask in order to fulfil the IAEA safety criteria. The RBMK spent fuel bundles are positioned in a basket inside the cask. The capacity of the basket is 102 bundles (half fuel assemblies). The total mass of the loaded CONSTOR® RBMK cask, including impact limiters, is approx. 96.5 MT.

The CONSTOR® basic design was adapted for VVER 440 type fuel assemblies. The respective cask has a capacity of up to 84 fuel assemblies with a total heat load of 21 kW. The loaded mass for transport including impact limiters is about 130 MT.

Also a CONSTOR® BWR adaptation has been developed for up to 69 fuel assemblies. The total mass in the transport version is about 134 MT. About 19 kW can be dissipated per cask under IAEA transport conditions.

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 -40 °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 space, filled with concrete between the inner and outer shell.

The heavy concrete is based on Barite minerals and/or steel granules and bounded by normal cement. After hardening of the cement, the mechanical properties are comparable to construction concrete grade B 35. The long-term behaviour and the properties of this heavy concrete under irradiation during a storage time of 50 years have been investigated, [1]. It was shown that the highest possible total neutron and gamma fluxes which have been considered from PWR/BWR fuel are approx. three orders of magnitude less than such fluxes where the concrete strength slightly begins to decrease. This investigations have been have been verified by asbuild encapsulated concrete specimens loaded by extensive gamma doses at HFR-research center at Petten site in the Netherlands.

To improve the heat removal properties, special heat conducting elements made of copper can be arranged in the concrete layer between the inner and the outer steel shell using these elements, the heat capacity of the content can be increased up to approx. 30 kW per cask.

SAFETY ANALYSES

The analyses of nuclear and thermal behaviour as well as of cask strength according to IAEA Type B test-requirements (9m drop, 1m pin drop, 800 °C fire test) and of the cask behaviour during accident scenarios at the storage site (drop, fire, gas cloud explosion, collision of casks) were carried out by means of qualified calculation methods and programmes.

The strength behaviour of the CONSTOR® cask was analysed by using the finite element code LS-DYNA, [2]. All possible drop orientations were investigated:

(1) 9m drop onto the IAEA target

(1.1) horizontal drop
(1.2) vertical drop
  a) bottom end
  b) lid end
(1.3) drop onto the corner
  c) bottom end
  d) lid end

(2) 1m drop onto the IAEA pin

As an example of the LS-DYNA analysis results, the outer liner stresses for 9 m drop on bottom edge is shown in Figure 3.

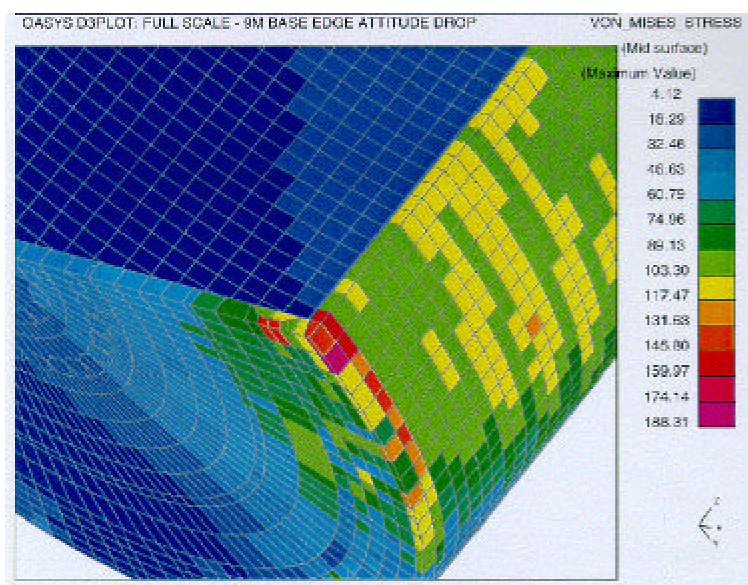

Figure 3, CONSTOR® 9m Bottom Edge Drop – Outer Liner Maximum Stresses

In a special experimental programme, 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 an assumed 1m drop at the storage site were confirmed by means of a test programme using a scaled model, [3]. The following tests have been performed under supervision of competent authorities and independent experts, such as BAM and German TÜV:

- 9m horizontal drop in transport configuration
- 1m pin drop onto lid side in transport configuration
- 1m pin drop onto side wall in transport configuration
- 1m pin drop onto bottom side in transport configuration
- 1m drop onto IAEA-target bottom orientation without impact limiters for transport
- 1m drop onto IAEA-target bottom edge orientation without impact limiters for transport

The post-test inspection programme of the model cask has shown that the cask integrity and leak tightness were maintained after this series of 6 drop tests.

The 1:2 scaled-down model cask for drop tests is shown in Figure 4.

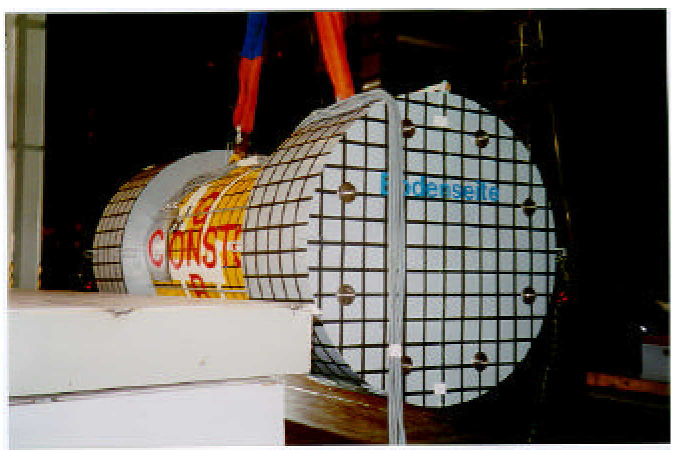

Figure 4, CONSTOR® 1:2 Model Cask

The thermal behaviour of the CONSTOR® cask was analysed for the normal transport conditions and for the IAEA fire test conditions. The respective analyses were performed by means of composed numerical-analytical methods (steady-state thermal condition) and numerical non-steady state methods (cask under fire conditions), [4]. The methods have been verified by experimental benchmarking programmes and by thermal tests and the 800 °C fire test using the 1:2 scaled-down model after performance of the 6 drop tests mentioned above. It has been shown that the calculated temperatures are in good agreement with the experiments. Furthermore, it could be verified that integrity and leak tightness remain was after cumulative loads of both, series of 6 drop tests and IAEA fire. In addition it could be shown that the shielding properties fulfilled the corresponding IAEA recommendations after the tests.

SUMMARY

Using 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. There are a number of technical measures to increase the cask heat removal capacity up to about 30 kW and the number of fuel bundles and/or fuel assemblies per cask respectively.

The cask can be manufactured in an economic way in shops with standard mechanical engineering equipment.

REFERENCES

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