# CONSTOR STEEL CONCRETE SANDWICH CASK CONCEPT FOR TRANSPORT AND STORAGE OF SPENT NUCLEAR FUEL

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## SUMMARY

A spent nuclear fuel transport and storage sandwich cask concept has been developed together with the Russian company CKTI. Special consideration was given 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 specialized industries. Nevertheless, this sandwich cask concept fulfills both the internationally valid IAEA criteria for transportation and the German criteria 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 NPP. Recently, adaptations have been made for spent fuel from the RBMK and VVER reactors, and also for BWR spent fuel.

The analyses of nuclear and thermal behaviour as well as of strength according to IAEA examination requirements (9-m-drop, 1-m-pin drop, 800 °C-fire test) and of the behaviour during accident scenarios at the storage site (drop, fire, gas cloud explosion, side impact) were carried out by means of recognized calculation methods and programmes. 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 results of the safety analysis after drop tests according to IAEA-regulations as well as after 1-m-drops at the storage site were confirmed by means of a test programme using a scale model.

The fabrication technology has been tested with help of a half scale cask model. The model has been prefabricated in Russia and completed in Germany. It has been shown that the CONSTOR cask can be fabricated in an effective and economic way.

## INTRODUCTION

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 different 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 industries. Nevertheless, the basic requirement for this CONSTOR concept was to fulfill both the internationally valid IAEA test requirements for safe transport and safety criteria for 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 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 sections, 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 behaviour and for heat removal shows that the safety criteria will be fulfilled. Afterwards, some principles concerning manufacturing will be given and at the end 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 multibarrier 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-programme 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, wooden impact limiters 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 asssemblies). 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 behaviour and the properties of this heavy concrete under irradiation during a storage time of 50 years have been checked (Hilsdorf et al., 1976). It could be shown that the highest possible total neutron and gamma fluxes which have been considered at VVER 1000 fuel are approx. three orders of magnitude less than such fluxes where the concrete strength slightly begins to decrease.

## CASK CONTENT AND SAFETY ANALYSES

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 HM |
| • Cooling time | 5 to 10 years |
| • Heat capacity per cask at mixed loading | ≤ 7.65 kW |

For the above-mentioned fuel specification, the total dose rate at the surface is approx. 200 μSv/h.

The analyses of nuclear and thermal behaviour 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 behaviour during accident scenarios at the storage site (drop, fire, gas cloud explosion, side impact) were carried out by means of recognized calculation methods and programmes. 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 a 1-m-drop at the storage site were confirmed by means of a test programme using a scale model (Dreier et al., 1998). The post-test inspection programme 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:

| | Normal operation (°C) | Fire (°C) |
|---|---|---|
| Outer cask surface temperature | 78 | 484 |
| Fuel cladding temperature | 339 | 355 |
| Concrete temperature | 105 | 187 |

A more detailed analysis of the thermal behaviour of the cask is described in the Conference Proceedings (Zubkov et al., 1998).

## FABRICATION TECHNOLOGY

The fabrication technology has been tested with help of the scale cask model (1 : 2), see figure 4. The model has been prefabricated in Russia and completed in Germany. It has been shown that the CONSTOR cask can be fabricated in an effective and economic way, according to the following strategy:

- Additional purchase of preassembled components, as for example, lengths of the cylindrical shells, large forged pieces, concrete armouring, 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 self-developed concrete technology avoids well-known demixing problems during fabrication and guarantees the formation of 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.

## CONCLUSIONS

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

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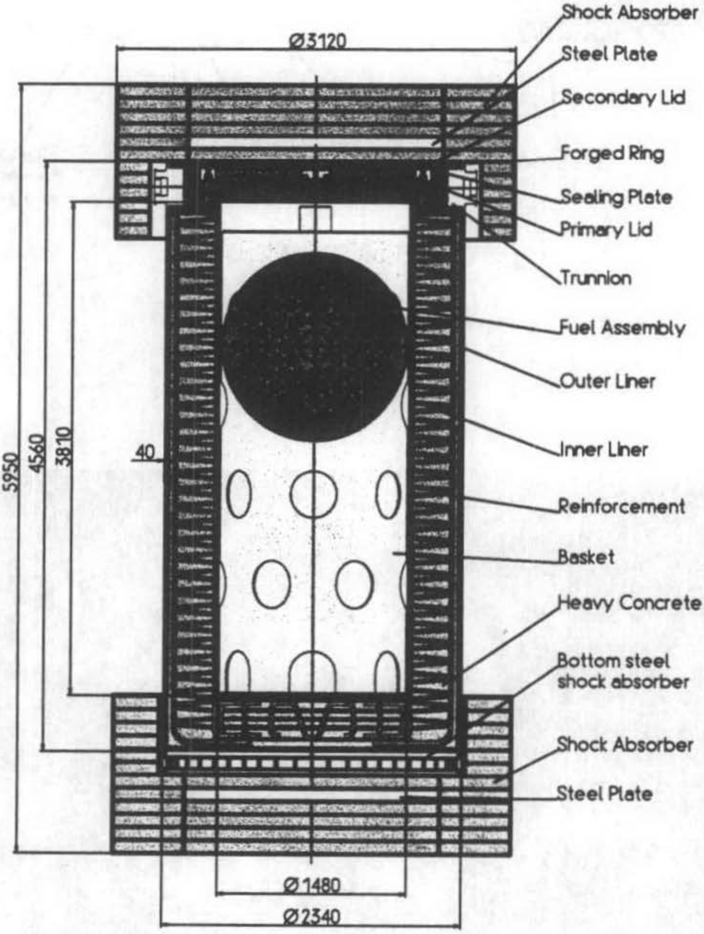


Fig. 1 CONSTOR RBMK Transport and Storage Cask

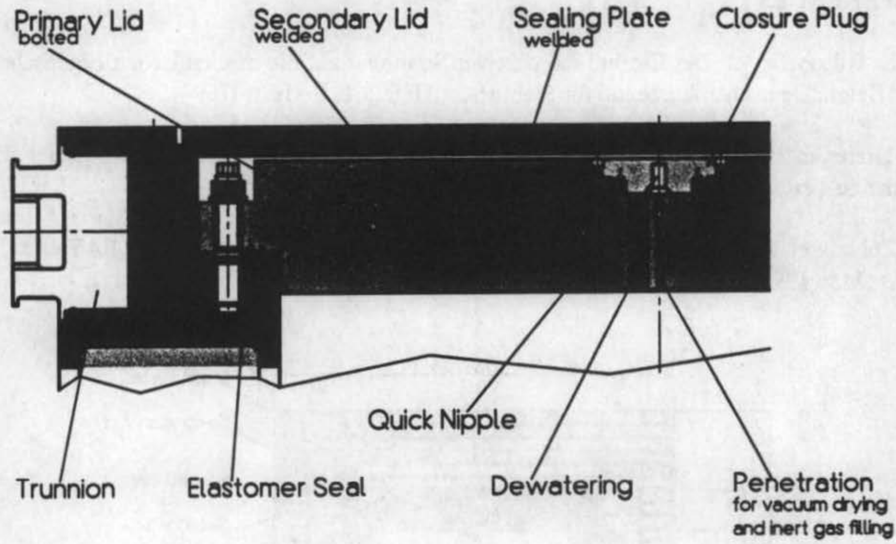


Fig. 2 CONSTOR RBMK Lid System

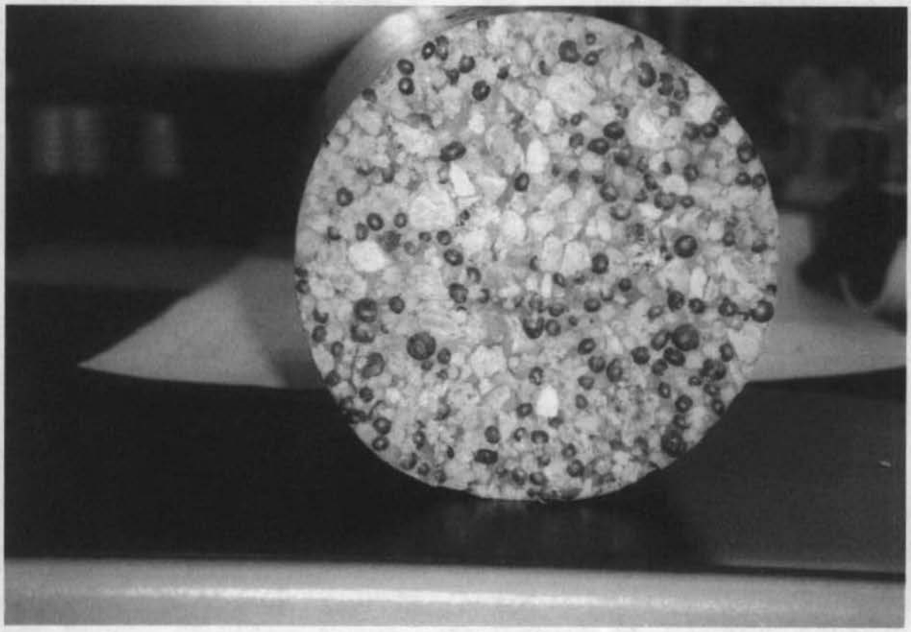

Fig. 3 Specimen of heavy concrete for CONSTOR casks

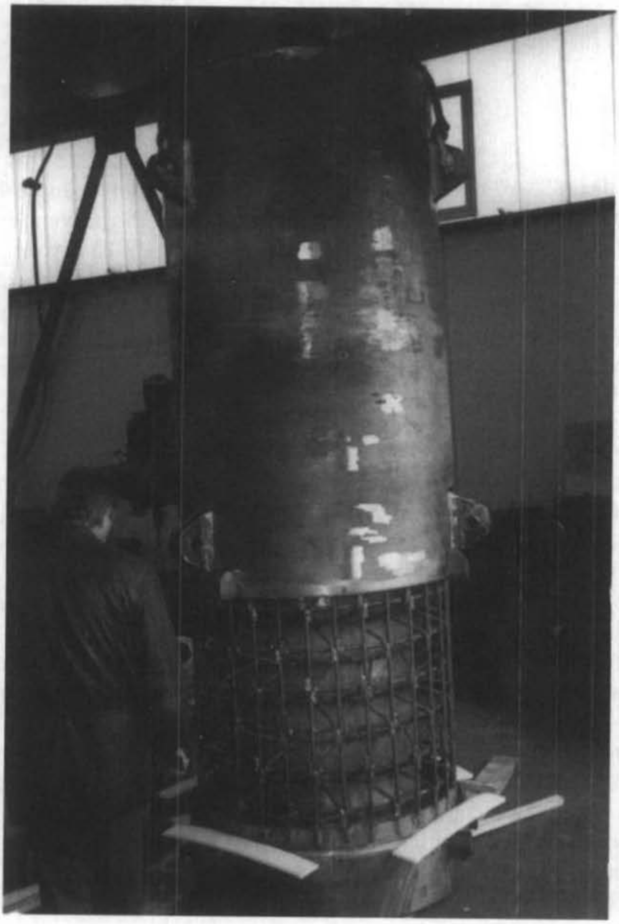

Fig. 4 CONSTOR RBMK cask model manufacturing