CASTOR TRANSPORT AND STORAGE CASKS FOR VVER AND RBMK FUEL ASSEMBLIES

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ABSTRACT

CASTOR casks have been successfully developed, manufactured and delivered for Russian type reactor fuel assemblies. These casks fulfill both the requirements for type B packages according to IAEA regulations and the requirements covering different accident situations to be assumed at the storage site. In the following, the CASTOR casks CASTOR 440/84, CASTOR RBMK and CASTOR VVER 1000 are described, the nuclear content is characterized and an overview about the status of licensing, manufacturing and delivery is given.

CASTOR 440/84

Description

The CASTOR 440/84 is designed for transport and long-term storage of up to 84 fuel assemblies type VVER 440 or VVER 70. The CASTOR 440/84 cask basically consists of a cask body with an inner cavity which accomodates a basket with 84 positions to hold and fix fuel elements from pressurised-water reactors.

The inner cavity of the cask is closed by a primary lid and by a secondary lid. The lids are fastened to the base body of the cask using 48 socket-head cap screws M 48 (primary lid) and 48 socket-head cap screws M 36 (secondary lid).

The closed body of the cask is fitted with one shock absorber on the lid end and one shock absorber on the opposite (bottom) end for transport purposes.

Four trunnions bolted on the circumference of the cask body are used when the cask is handled by crane. In this respect, two trunnions on the lid end allow vertical handling and all four trunnnions allow horizontal handling. In addition to horizontal handling, the bottom pair of trunnions is also used to fix the cask in a transport frame.

The package has a total weight of approx. 131 t (transport configuration) and the weight of the packaging (package without radioactive contents and water) is approx. 112 t.

The base body of the cask consists of a large casting which is produced in one manufacturing process, is made of ductile cast iron (DCI) and exhibits a cylindrical cross-section on both the inside and the outside. On the outside wall of the cask, 60 radial cooling fins are machined in at a height of 60 mm in the area of the cavity.

The main dimensions on the outside of the cask (without shock absorbers) are:

Length (height):	4,080 mm
Diameter:	2,540 mm (fin base)
	2,660 mm (fin tip)

The effective dimensions on the inside of the cavity to accommodate the fuel elements are:

Length (heigth):	3,260 mm
Diameter:	1,800 mm

The cylindrical wall of the cask body has a thickness of 370 mm.

In order to improve the neutron moderation, 76 axial boreholes (diameter: 65 mm) are distributed around a semi-circle of the wall (∅ = 2,180 mm) and contain moderator rods made of polyethylene.

As protection against corrosion, the inside surface of the cask and the sealing surfaces are provided with a nickel coating. The outside surface is protected by a coat of paint on an epoxy-resin basis.

For the purpose of handling the packaging in vertical and horizontal positions, two trunnions made of stainless steel are bolted onto the cask body using 16 bolts M 30 each at the top (lid end) and at the bottom (base end).

On the bottom side, the trunnions are used to secure the load of the cask on the support frame. On the lid side, the cask shell is supported on a prism of the support frame.

The primary lid (weight: 7,680 kg) is a disc-shaped body made of stainless steel with a displaced diameter (thickness: 315 mm and diameter: 2,047 mm). On the inside of the lid flange, there are two continuous grooves to accommodate the axial sealing rings.

The primary lid is fastened to the cask body using 48 socket-head cap screws M 48.

For lid handling, eight blind-hole threaded boreholes are incorporated in the centre of the lid on a semi-circle diameter of 320 mm in order to fasten the lifting equipment.

In order to carry out the necessary handling steps during loading and unloading and during the leak test, the lid has the following attachment and testing possibilities:

One handling attachment, consisting of:

- one draining/drying borehole which is closed using a blind plug during transport,
- one borehole to evacuate inert gas from the inner cavity of the cask and to fill inert gas into it; this borehole is closed using a quick connection,

- one bolted closure lid above the handling attachment with a metal and elastomer sealing ring; the tightness of the closure lid may be tested using a test borehole which leads into the seal clearance.

The secondary lid is arranged above the primary lid and, together with the cask body, forms an alternative leak-tight containment.

The secondary lid is a disc-shaped body made of stainless steel (thickness: 120 mm, diameter: 2,245 mm and weight: 3,720 kg). On the inside of the secondary-lid flange, there are two continuous grooves to accommodate the axial sealing rings.

The secondary lid is fastened to the cask body using 48 socket-head cap screws M 36.

In order to handle the secondary lid, four blind-hole threaded boreholes M 20 are incorporated in the centre of the lid on a semi-circle diameter of 320 mm.

The following components are embedded or provided in the secondary lid:
- one bolted blind flange with a metal sealing ring in order to close and seal the space provided to accommodate a pressure-monitoring device or a pressure switch with a metal sealing ring which may be used an an alternative,
- one quick-closure coupling, bolted into a full penetration borehole and closed by a protective cap which is arranged above it and is equipped with a metal sealing ring.

The leak test for the metal sealing ring of this lid is carried out using a test borehole which leads into the space between the two sealing rings of the secondary lid.

In order to accommodate max. 84 fuel elements from pressurised-water reactors or absorber and/or shielding elements, the basket is installed in the cask cavity.

The basket basically consists of 84 hexagonal tubes made of borated steel with aluminium heat-conducting sheets arranged between them, external aluminium profiles, binding bands and a bottom plate with bases.

Nuclear Content

Max. 84 hexagonal fuel elements from pressurised-water reactors (type: VVER 440 and VVER 70) - leak-tight or not leak-tight to gas are to be transported and stored inside the CASTOR 440/84.

General fuel data of the fuel elements from pressurised-water reactors are:

Chemical form:	UO_2
Physical form:	solid
Density:	10.2 - 10.8 g/cm^3
U-235 enrichment:	max. 3.6 %
Cooling time:	min. 5 years

Values per Fuel Element:
Max. cross-section dimensions:
- hexagonal width 145 mm (144.2 + 1.5)
- hexagonal width 146.5 mm in the head area

Weight of heavy metal:	approx. 120 kg
Total weight:	approx. 220 kg
Active rod length:	approx. 2,420 mm
Max. length of fresh fuel element at room temperature:	approx. 3,225 mm

Values per Cask:

Average burn-up:	max. 36 GWd/MTU
Max. thermal output:	21 kW
Max. total activity:	$2.42 \cdot 10^{17}$ Bq

Besides, absorber elements from the ractor types VVER 440 or VVER 70 and shielding elements from reactor type VVER 440 can be loaded.

Licensing and Delivery

CASTOR 440/84 is licensed as a type B (U)-package containing fissile material in Germany and validated in Hungary, Czech Republic and Slovakia. A license for interim dry storage on the site of Nuclear Power Plant Dukovany, Czech Republic is valid. More than 20 casks have been delivered and loaded up to now to fulfill the existing delivery contract of about 60 casks in total. Within this contract SKODA Jaderné Strojírenství, s.r.o. performs machinery, assembling and quality control under supervision of GNB.

CASTOR RBMK

Description

The CASTOR RBMK cask is designed for the long-term storage of 102 RBMK half fuel assemblies, which are positioned in an existing basket. The cask is designed on the basis of the given specifications /1/, taking into account load situations from normal operations, incidents and accidents. Beside this the requirements for a transport cask /2/ have been observed in layout, design and manufacturing of CASTOR RBMK. The general design is similar to CASTOR 440/84.

The CASTOR RBMK cask body is made of ductile cast iron (DCI), cast in one piece. The cask has two lids made of corrosion protected carbon steel. The first lid (cask lid) is provided with a double-barrier sealing system to secure leak tightness. The second lid (guard plate) minimises radiation exposures and ensures the weather and additional corrosion protection of the containment barriers.

The existing basket which is placed in the cask cavity provides fuel assembly support. The cask is filled with inert gas, which ensures corrosion protection and improves the passive heat

removal. The ductile cast iron cask body together with the cask lid and its seals constitutes the confinement system. This configuration also provides the gamma and neutron shielding.

For handling operations, four trunnions, two each at the top and bottom ends are fixed with screws on the outer surface.

The main design criteria for the storage cask are:

Cask Features	**Design Criteria**
Structural Design - general Basic Design taking into account	As described in Technical Specification /1/ IAEA-Requirements /2/
Containment - general	double metal seal for each penetration of containment
- the standard leak rate of each seal	≤ 1 E-7 Pa · m^3/s (at 1 bar, 293 K)
- cavity atmosphere pressure	helium, 0.8 bar
Shielding Design* - maximum total dose rate at surface	1000 µSv/h
Thermal Design* - peak temperature of the hottest rod	< 300 °C
Criticality - general - multiplication factor (k_{eff})	fresh fuel, optimal reflection < 0.95

* under consideration of peaking results from the specific orientation of the 1/2-F/A inside the existing basket

The design characteristics are the following:

Cask overall length	4,330 mm
Cask outer diameter	2,072 mm
Cask cavity diameter	1,483 mm
Cask cavity length (effective length)	3,810 mm
Side wall thickness, min.	290 mm
Lid thickness - cask lid - guard plate	 250 mm 70 mm

Bottom thickness	255 mm
Capacity for half fuel assemblies	102
Cask cavity atmosphere	helium
Design temperature for mechanic strength of all components	100 °C

Nuclear Content

The full-size RBMK-assembly consists of two half-assemblies (so-called bundles) which are separated after discharge from reactor.

The bottom fuel bundle is turned upside down while loading the bundles inside the existing basket design for storage of the spent fuel.

The main fuel data are the following:

General

• Length of a Fuel Half-Assembly	3,640 mm
• Active Length of Fuel Rods	3,410 mm
• Grid Distance	16.05 mm
• Diameter of a Fuel Assembly	79.00 mm
• Total Number of Fuel Rods	18

Rod arrangement

• Inner Circle (∅ = 32 mm)	6 rods
• Outer Circle (∅ = 62 mm)	12 rods

Fuel

• Chemical form	UO_2
• U-235 enrichment	2.0 wt-%
(conservatively taken for criticality analyses)	2.4 wt-%
• Max. Fuel mass (UO_2)	64.7 kg
• U-235 mass (maximum)	1.369 kg
• Average burn-up	20 GWd/MTU
• UO_2-density (rod-averaged) for criticality analyses	10,116 g/cm^3

Licensing and Delivery

The cask was designed for dry long term storage of nuclear fuel from the Lithuanian Nuclear Power Plant Ignalina (INPP).

GNB performed development and wrote the safety analysis report according to the plant specific boundary conditions /1/ and the safety standards for transport casks /2/. This led to approval for cask manufacturing in 1996 granted by the Lithuanian competent authority VATESI. In addition, GNB delivered cask-specific software for safety reports concerning

plant handling and for the at-reactor storage site. The covering approval for cask loading is scheduled for end of 1997.

The fabrication and delivery of 20 CASTOR RBMK casks within the existing delivery contract for 60 casks and cask-specific handling equipment under QA-supervision of independent QA-organizations, the customer INPP and the customer's authority is completed by the end of 1997.

CASTOR VVER 1000

Description

The CASTOR VVER 1000 is designed for transport and long-term storage of up to 12 fuel assemblies from VVER 1000 reactors.

The general design features are similar to those of CASTOR 440/84 already described.

The dimensional differences result from the specific properties of the nuclear content. Main features are the following:

Outer diameter:	2,253 mm
Total height:	5,505 mm
Cavity diameter:	1,293 mm
Cavity height:	4,730 mm
Mass, empty:	91.2 t
Mass, transport configuration:	110 t
Mass, storage configuration:	100 t

Nuclear Content

Max. 12 hexagonal fuel elements from pressurized-water reactors type VVER 1000.

General fuel data of the fuel elements are:

Chemical form:	UO_2
Physical form:	solid
U-235 enrichment:	max. 4.4 %
Cooling time:	min. 3 years
Burn-up:	max. 50 GWd/MTU
Fuel masss per assemblies:	max. 500 kg

Licensing and Delivery

The CASTOR VVER 1000 was designed and produced in accordance with the transport regulations. The safety report and the cask construction were evaluated positively by the German Federal Institute for Material Research and -Testing (BAM) in /3/. It was stated that the design is in accordance with the existing licensing requirements.

The cask was produced under QA-supervision of BAM and loaded at the customer's site, the Nuclear Power Plant Novo Voronezh in May, 1984.

For future use of the CASTOR VVER 1000, GNB has developed a basket design with an extended capacity up to 18 fuel assemblies which is ready to be licensed and manufactured in case of need of Nuclear Power Plants with VVER 1000 reactors.

REFERENCES

/1/ Technical Specifications. Appendices of: Frame Agreement between IGNALINA NPP and GNB. December, 1993.

/2/ Regulations for the Safe Transport of Radioactive Material. 1985 Edition (as amended 1990). Safety Series No. 6, Vienna 1990. IAEA.

/3/ Verkehrsrechtliche Prüfung der Behälterbauart "CASTOR WWER 1000" als Typ B(U)-Versandstückmuster, BAM-Antragsnummer 1.02/2435. Berlin. Federal Institute for Material Research and -Testing (BAM).

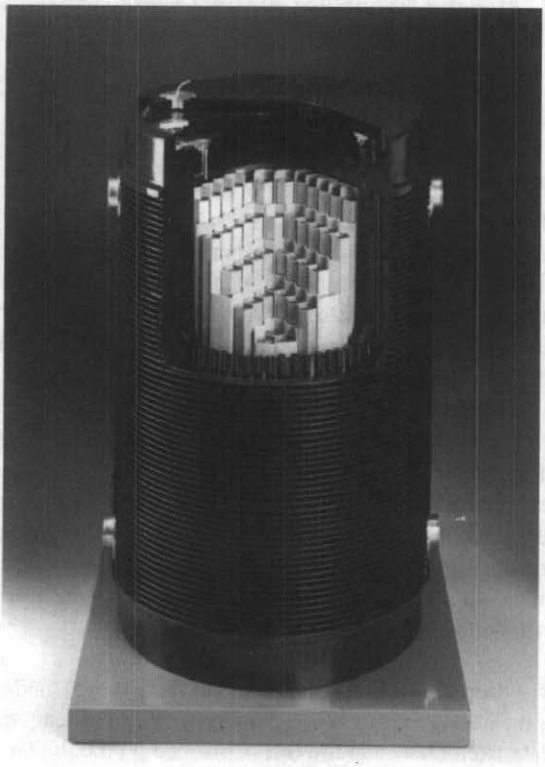

Fig. 1 CASTOR 440/84