Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2007
October 21-26, 2007, Miami, Florida, USA

STATE OF THE ON-SITE STORAGE OF SPENT FUEL ASSEMBLIES AT GERMAN NUCLEAR POWER PLANTS AND FIRST EXPERIENCE WITH THE OPERATION

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ABSTRACT

In 2002 an amendment of the German Atomic Energy Act fixed – beside a limitation of a certain amount of electricity generation – the stop of the transport of spent fuel assemblies to the reprocessing plants after July 1st 2005 and the storage of spent fuel assemblies at the NPP sites.

To comply with these legal requirements, at twelve sites German utilities chose a cask storage method. For the time being, the fuel assemblies are stored in casks type CASTOR® fabricated by GNS, but also casks types of TNI and MHI are foreseen in future. In 2007 all on-site interim storages at all twelve plant sites were put into operation and in total 163 casks of CASTOR® V type have been loaded and stored in Germany.

INTRODUCTION

In Germany, 17 nuclear power plants are currently in operation supplying 30 % of national electricity. Most of the units are large reactors of more than 1,000 MWe capacity. The latest NPP (Neckarwestheim 2) was commissioned in 1989

German reactors achieved an excellent operating performance. The NPP Isar 2 is world leader in generating electricity. Other reactors like Grohnde, Brokdorf and Phillipsburg 2 were world leaders in previous years.

In 2001, the anti-nuclear German Federal Government (Social Democrats / The Greens) and the German utilities signed an Agreement to limit the residual lifetime of the existing nuclear power plants. On the other hand, undisturbed operation of the NPP but also the disposal of nuclear waste should be ensured.

This Agreement also stopped the transport of spent fuel for reprocessing after July 1st 2005 and stated that the utilities had to build interim storage facilities at reactor sites to store spent fuel.

In 2002, a law was passed the German Parliament amending the German Atomic Energy Act in view of phasing out nuclear power in Germany. According to this amendment a certain amount of electricity generation is allowed to each existing NPP. This electricity volume is calculated on the basis of an operating time of about 32 years.

Table 1 shows the possible year of shutdown of nuclear power plants currently in operation in Germany that result from limited electricity generation. According to the Atomic Energy Act there is, however, an option to transfer an amount of electricity generation amongst the nuclear power plants, even though each individual case has to be approved by the German Government.

During the estimated lifetime of the nuclear power plants of 32 years of full power operation, a total of approx. 17,250 t of heavy metal in form of spent fuel assemblies will be generated. Up to the point when transports were stopped, approx. 6,150 t of this amount had been transported to the reprocessing plants located in France and UK. For the remaining 11,100 t, interim storages had to be provided until a corresponding final repository, to be erected by the Federal Government, will be available. Assuming a capacity of 10.5 t per cask, storage capacities of approx. 1,060 storage casks have to be provided in total at the twelve plant sites. In total, a storage capacity of 1,440 casks was realised (see table 1) so that flexibility for a transfer of electricity amounts between nuclear power plants is maintained.

To comply with these legal requirements, German utilities chose a dry cask storage concept. This technical concept was already realised in two central cask storage facilities in Germany, so that it could be implemented for on-site storage facilities in a short time with a calculable expenditure in comparison to other storage concepts, such as wet storage or vault storage concepts. There are also only minor operational interfaces between the storage facility and NPP at the site, so that there will be no problem to operate the storage facility after shutdown of the NPP.

DESIGN CONCEPTS OF THE ON-SITE STORAGE FACILITIES

The following technical reasons were the basis for the utilities' decision to pursue the cask technology:

- The fuel assemblies are stored in tight, accident-proof casks.
- The casks ensure safe enclosure of the inventory, radiation shielding, heat removal and nuclear criticality safety.
- Together with the storage building, the casks ensure that dose rates are kept in accordance to the radiation protection code.

This was implemented variably, following two concepts of buildings construction for the on-site interim storage of casks:

- According to the first concept designed by STEAG encotec GmbH, the building was designed as a monolithic concrete structure with a wall thickness of 1.2 m and a roof thickness of 1.3 m. The casks will be placed in a uniform grid. Heat removal is effected by natural convection via vents at the sidewalls and the opposing roof area. For this concept, the wall thicknesses and armouring ensure protection against penetration in case of an airplane crash
- The other concept, designed by the company of consulting engineers WTI (Wissenschaftlich-Technische Ingenieurberatung GmbH), planned a two-hall-construction made of cast-in-place concrete and pre-fabricated segments.
  Wall thickness is down to 0.85 m, the pre-fabricated segments for the roof slabs are 0.55 m thick.
  The base plate is either designed as a plate with a thickness of 0.40 m, which is decoupled from the side walls, or as a solid plate of 1.50 m thickness, joined with the side walls. The casks are placed in a two-row-grid with broadened corridors. Heat removal is effected by natural convection via vents at the sidewalls and in the centre of the roof area. Protection against external impact (airplane crash) is provided by the solid cask structure.

- In addition, at one site, a two-tunnel-system in a quarry with an entry building for cross transports was erected. The tunnel walls are lined with reinforced concrete with a thickness of 0.70 m, the ceilings with an 80-cm-layer. The ground plate has a thickness of 0.70 to 1.50 m. The entry area is designed with walls and ceilings of 1.50 m thickness. The casks will be placed in three rows lengthwise in each tunnel. The cask heat will be discharged via a vent stack. Protection against external impact such as an airplane crash is provided by the solid rock structure above the tunnel system.

At all twelve sites, on-site interim storages were built with a different number of storage positions depending on the estimated lifetime of the NPP at the site (see table 1). Start of construction was between September 2000 and June 2004. In April 2007, the last storage building has been commissioned.

Including all mandatory public discussions, it took almost four years to close the licensing process with all licenses, which were finally granted until end of 2003.

Among other things, the issue of the licenses was delayed by the September 11 attacks. The licensing authority ordered extensive scrutinies concerning a forced airplane crash. The mechanical consequences of an impact of a large airplane and its components as well as the thermal consequences of a kerosene fire have been evaluated. The investigations revealed that the safety functions of the casks will not be affected in principle and that the radiological consequences for the environment will be far below the reference values for initiation of emergency measures. The hall structure of the STEAG concept offers protection against possible penetration of airplane components. Mechanical protection according to the WTI concept is provided by the casks' structure.

With the construction of twelve on-site interim storages, until mid of 2007 the operators of German nuclear power plants have fulfilled the corresponding political requirements. The overall contract price for construction of twelve on-site interim storages amounts to approx. 490 Mio €.

CASK TYPES

For the time being, the fuel assemblies are stored in the casks type CASTOR®, designed and fabricated by the German manufacturer GNS mbH. In version CASTOR® V/19 for pressurized water reactors, up to 19 spent fuel assemblies can be stored; in version CASTOR® V/52 for boiling water reactors, up to 52 spent fuel assemblies are possible. The CASTOR® -casks are made of cast-iron with a borated steel basket. The most important cask data are listed in table 2.

To achieve diversity and flexibility the development and licensing of different cask types as alternatives to the CASTOR casks were pursued. Those are the Type TN™ 24 E made by the French manufacturer AREVA TN International (TNI) for 21 PWR fuel assemblies, and the type MSF-57BG made by the Japanese manufacturer Mitsubishi Heavy Industries (MHI) for 57 BWR fuel assemblies. Instead of cast iron as used for the CASTOR type, these casks are made of forged steel with borated aluminium baskets.

FIRST OPERATION EXPERIENCE

At the beginning of 1996, the first CASTOR® V cask was loaded and stored in a central storage facility; the first on-site interim storage facility was taken into operation in 2002. In the meantime, all on-site interim storages at all twelve plant sites were put into operation.

For loading processes, the casks are loaded, completely handled and checked inside the power plant: After the loading with spent fuel, the casks are drained and dried and finally equipped with the necessary pressure monitoring equipment and a protection plate.

Depending on site conditions, the casks are transported by rail or road vehicle to the on-site interim storage facility. After erection in the reception area, the casks can be transferred into a maintenance station in order to effect repair work of the coating, if necessary. After positioning in the storage area, a connection to the cask monitoring system is carried out; monitoring the cask lid interspace between the primary and secondary lid ensures leak tightness of the casks during the whole storage period.

The time needed for one cask loading takes five to seven days in 3-shift-operation, including the time for storing it inside the on-site interim storage facility of only a few hours. In the hand-ling and loading process, approx. 12 persons per shift are involved (mechanics, radiation protection and decontamination personnel). The average gamma-dose rate of these persons will amount to approx. 2.6 mSv.

Between 1996 and September 30th 2007, in total 163 casks of CASTOR® V type have been loaded and stored in Germany (see figure 1). In the years to come, 50 to 60 casks will be loaded and stored each year.

Table 1 Status of the German on-site storage facilities

Nuclear Power Plant		**Storage Concept**	**Storage Positions**
Biblis A	KWB A	WTI	135
Biblis B	KWB B		
Neckarwestheim I	GKN I	Tunnel	151
Neckarwestheim II	GKN II		
Brunsbüttel	KKB	STEAG	80
Isar 1	KKI 1	WTI	152
Isar 2	KKI 2		
Unterweser	KKU	STEAG	80
Philippsburg 1	KKP I	WTI	152
Philippsburg 2	KKP II		
Grafenrheinfeld	KKG	WTI	88
Krümmel	KKK	STEAG	80
Grohnde	KWG	STEAG	100
Gundremmingen B	KRB B	WTI	192
Gundremmingen C	KRB C		
Brokdorf	KBR	STEAG	100
Emsland	KKE	STEAG	130
Total			**1440**

Table 2 Existing and expected casks for the German market

	Casks for PWR		Casks for BWR	
	CASTOR® V/19	**TN™24 E**	**CASTOR® V/52**	**MSF- 57 BG**
Package approval	approved	expected 2008	approved	expected 2008
Number of FA	19	21	52	57
Loading options	19 UO_2 15 UO_2+4 MOX or +4 Special FA	21 UO_2 13 UO_2+8 MOX 4 UO_2+17 MOX 17 MOX	52 UO_2 36 UO_2+16 MOX or +16 Special FA	57 UO_2
Max. average burn-up per FA [MWd/t_{HM}]	55,000 Special FA: 65,000	65,000	55,000 Special FA: 65,000	63,000
Max. initial enrichment	4,45% (U235) 4,75% (Pu_{fiss})	4,65% (U235) 4,75% (Pu_{fiss})	4,20% (U235) 4,90% (Pu_{fiss})	5,00%
Total max. heat load [kW]	39	39	40	45

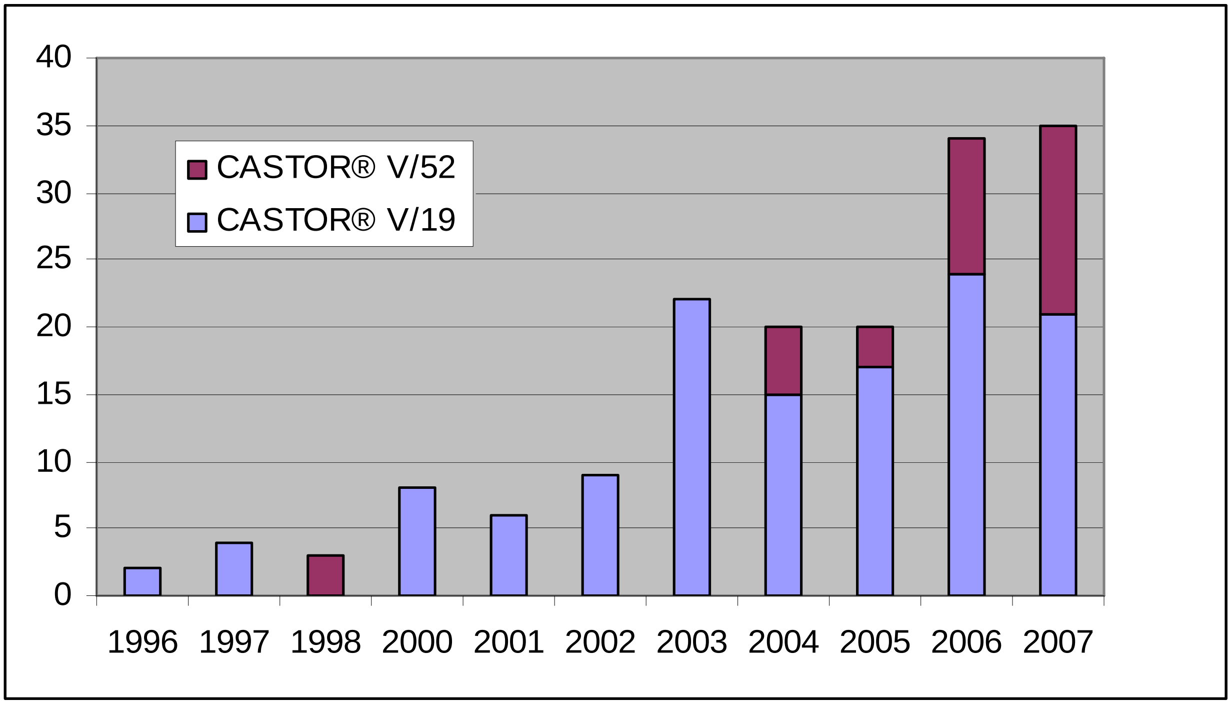

Figure 1 Loaded and stored CASTOR® V in Germany (state 30.09.2007)