Transport and Storage Casks for Long Cooled Spent Fuel Elements

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INTRODUCTION

In the past, transport and storage casks such as the TN 1300 /1/ and TN 900 casks, which were suitable for the fuel assembly storage pond with low capacities of the older nuclear power plants, were developed in the Federal Republic of Germany.

These casks are capable of housing irradiated fuel elements after a cooling time of 1.3 to 2.5 years.

Upon the additional construction and operation of new nuclear power plants in the Federal Republic of Germany, it became necessary to design transport and storage casks which would be optimally suitable for the in many respects modified requirements.

These changed boundary conditions include among others

- the use of fuel elements with a higher enrichment of U-235
- use of mixed oxide fuel elements
- increase of burn-up
- increase of fuel element cooling times due to the larger storage pond capacities available at the reactor site.

The statements made above apply in Germany both to pressurized water reactors (PWR) and to boiling water reactors (BWR).

DESIGN CRITERIA

An investigation has been made, within the framework of a study, to establish which advanced casks can be realized on the basis of the following requirements.

General Requirements

The cask must fulfil the requirements arising from

- the regulations for the safe transport of radioactive materials /2/, and
- the boundary conditions which derive from the storage of the spent fuel elements in an intermediate storage facility in Germany /3/.

Cask Specification

Design selection has been performed on the basis of the following specifications:

- standard PWR or BWR fuel element
- enrichment 4.0 w/o U-235 or equivalent Pu fiss content
- burn up range between 45,000 and 55,000 MWd/tHM (PWR)
- burn up range between 35,000 and 45,000 MWd/tHM (BWR)
- fuel element cooling time greater than 4.8 years
- weight limit less than 120 t without shock absorbers
- cask capacity as large as possible with MOX-fuel elements occupying approx. 1/3 of the capacity
- cask material either nodular cast iron or forged steel.

PARAMETRIC STUDIES

The present section demonstrates which parametric studies were performed for the compilation of a cask concept.

Source Terms

Both the source terms for neutron and gamma source strength were calculated and decay heat determined using the computer code ORIGIEN 2.

The calculations confirm the known effects, even in the higher burn up range, such as:

- gamma source strength is practically identical for uranium and mixed oxide fuels
- neutron source strength is greater by approximately a factor of 10 in the case of the mixed oxide fuel elements, than the source strength for the uranium fuel elements
- decay heat for the mixed oxide fuel elements is greater than that of uranium fuel elements by a factor of approximately 2.

The shielding and thermal calculations were performed based on the parametric figures.

Shielding Calculations

The necessary shielding thickness for the materials selected were determined using the well known computer codes for gammas and neutrons.

Heat Transfer Evaluation

Computation methods acknowledged in the Federal Republic of Germany like HEATING 6 were used for calculation of heat transfer behaviour of the cask.

The calculation of cask surface temperature, on the other hand, was performed on the basis of the heat transfer coefficient, determined in the thermal load test on the TN 24 cask /4/.

Cask Material

The calculations performed demonstrated that both the materials, nodular cast iron, and forged steel, offer certain advantages. In the case of nodular cast iron, the neutron moderator can be optimally configured, rendering certain weight savings as compared to the necessarily externally located neutron moderator in the case of forged steel.

On the other hand, forged steel possesses the advantage that either smaller overall cask dimensions can be used, due to the higher density of the material, or that lower fuel element cooling times apply if the weight limit is exploited.

From a mechanical point of view, there is an advantage that forged steel, as a material, can be stressed under accident conditions up to the yield strength. In the case of nodular cast iron, total stresses in the material are restricted to 50 % of the yield strength (material concept for nodular cast iron in the Federal Republic of Germany).

A decision in favour of one or the other cask material requires precise analysis and coordination with the requirements of a specific plant on an individual, case-to-case basis. A universally applicable statement is not possible.

Basket Design

In both the PWR and the BWR basket design cases, borated stainless steel containing approx. 1 % natural boron was selected as basket structural material.

The PWR basket was investigated for criticality in two differing basket configurations:

- a basket configuration of 17 fuel elements in rectangular arrangement,
- a basket configuration of 19 fuel elements in radial arrangement.

The analyses for proof of criticality safety indicated that, despite the higher fissile material content, the radial arrangement produces a lower sub-critical multiplication factor.

For this reason, the basket for 19 fuel elements has been selected for the further investigations.

In the case of the BWR basket, parametric criticality calculations have been performed. Here, it became apparent that as from a U-235 enrichment level greater than 3.5 w/o (or equivalent Pu fiss content), reactivity suppressing elements (e.g., water gaps) must be inserted. Only in this way the necessary sub-criticality of the basket can be ensured.

The calculations demonstrated that a basket for accommodation of 61 BWR fuel elements represents an optimum from the multitude of boundary conditions requiring integration.

In figure 1 (see appendix), there is shown an overview of the different basket designs for PWR and BWR.

REFERENCE CASK

The parametric investigations described have led to the following reference concepts for a standard PWR and a standard BWR transport and storage cask as shown in figure 2 (see appendix).

Both concepts, the nodular cast iron cask and the forged steel cask use the common design features:

- double sealing lid system,
- smooth container surface,
- polyethylene as neutron moderator material,
- the specified weight limits for the respective plants are met.

With the designs discussed, the loading schemes shown in table 1 for the PWR fuel elements and BWR fuel elements can be achieved.

	PWR				BWR	
Type of fuel	U+ MOX	U+ MOX	MOX	U	U+ MOX	U
decay time (y)	5	6	5	5	6	5
capacity U	14	11	-	19	47	61
capacity MOX	4	8	12	-	14	-
total capacity	18	19	12	19	61	61

Table 1: Loading schemes

ASSESSMENT

It can be noted, as a result of the study, that, at least in the Federal Republic of Germany, it is possible to develop casks, which meet the requirements specified above.

Freedom exists, too, in selection of cask material. The decision in favour of nodular cast iron or in favour of forged steel is dependent in the final analysis on the respective wishes and requirements of the nuclear power plants.

REFERENCES

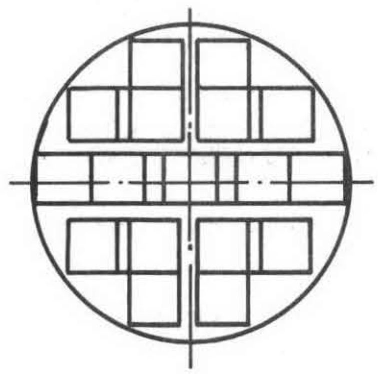
/1/ H. Keese et al., "The TN 1300 Transport/Storage Cask System", Proceedings of the 7th International Symposium on Packaging and Transportation of Radioactive Materials, Vol. 1, 1983, pp. 242 - 247

/2/ Regulations for the Safe Transport of Radioactive Materials, 1985 Edition, International Atomic Energy Agency (IAEA), Vienna 1985

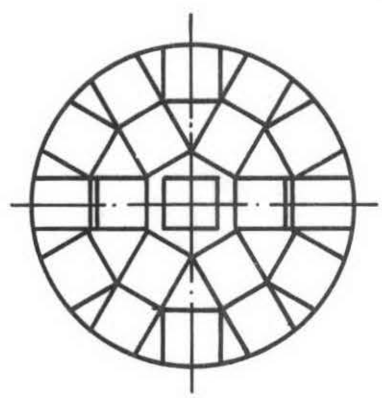
/3/ Technische Annahmebedingungen für ein Brennelement-Zwischenlager

/4/ Cagnon, R. and Mason, M.E., "Design and Demonstration of the TN 24 Spent Fuel Cask for Dry Storage and Transport", Proceedings of the 8th International Symposium on Packaging and Transportation of Radioactive Materials, Vol. 2, 1986, pp. 181 - 189

PWR - basket with 17 Lodgements



PWR - basket with 19 Lodgements



BWR - basket with 61 Lodgements

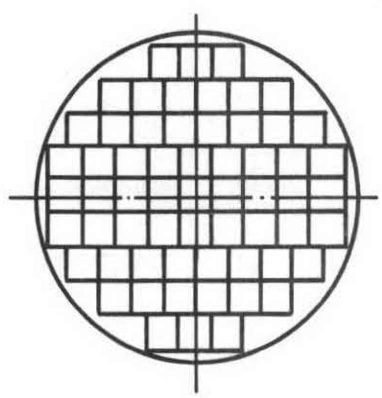


Figure 1: PWR and BWR basket design

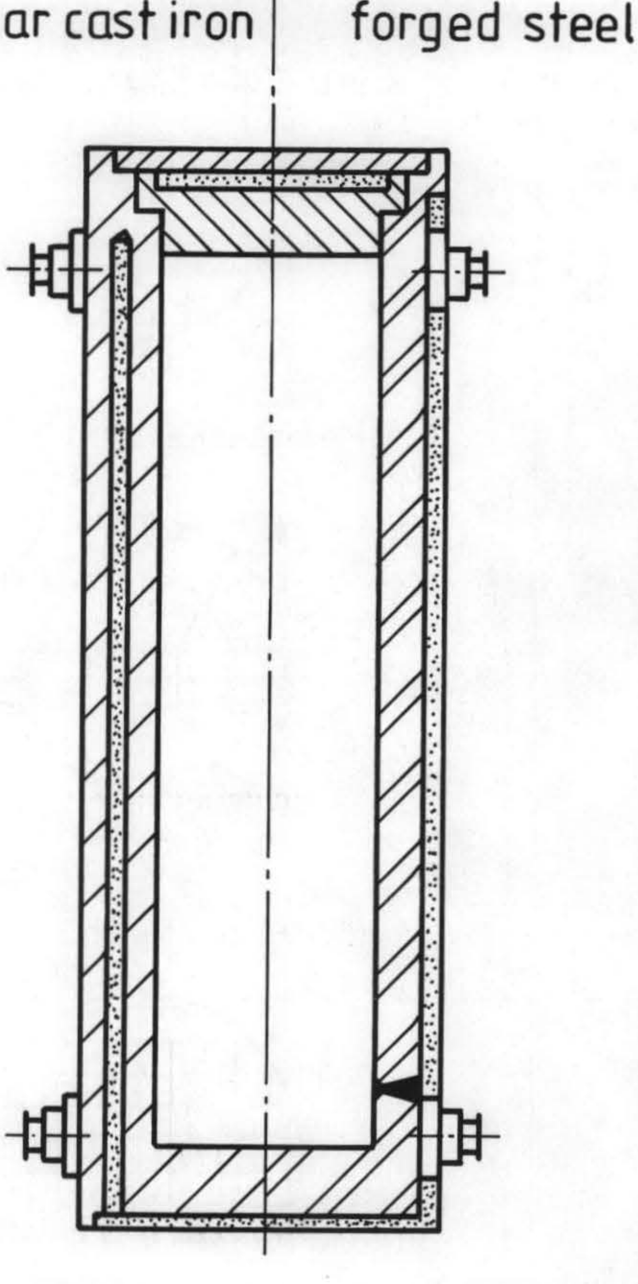


Figure 2 : Reference Cask Concepts
(schematic figure)