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Quivers For Special Fuel Rods – Disposal Of Special Fuel Rods In CASTOR® V Casks

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1. INTRODUCTION

In Germany today, B(U)F-package transport and storage casks of the CASTOR® family engineered and delivered by GNS are exclusively used for the transport and dry storage of spent nuclear fuel assemblies from the German NPP. More than 420 of these casks have already been loaded and are stored in interim dry storage facilities all over Germany.

While GNS casks of the CASTOR® family are a suitable means to transfer fuel assemblies (FA) from the NPP to an interim dry storage site, Germanys phase-out of nuclear energy has triggered the demand for an additional solution to dispose of special fuel rods (SFR), normally remaining in the fuel pond until the final shut-down of the NPP.

SFR are fuel rods that had to be removed from fuel assemblies mainly due to their special condition, e. g. damages in the cladding of the fuel rods which may have occurred during reactor operations. SFR are usually stored in the spent fuel pond after they are removed from the FA.

To this day there are few reports on how to deal with damaged fuel rods in dry storage. An overview article on the management of damaged spent nuclear fuel can be found in [1], summarizing the approaches chosen in various countries.

In order to establish a disposal concept suitable for the needs of the German utilities, GNS developed a first of its kind solution.

In our presentation we describe our combined approach to prepare and package damaged fuel rods prior to dispatch and to its transport to the interim dry storage facility. For this purpose GNS designed two types of quivers for special fuel rods.

For licensing purposes, a robust design and versatile disposal concept with large safety margins in safety analysis was selected for both, the type B(U)F-package transport and storage cask CASTOR® V as well as the quiver for special fuel rods.

In addition, the design criteria of the transport and storage casks CASTOR® V/19 (for PWR-FA) and CASTOR® V/52 (for BWR-FA) were met. Effective measures were designed to cope with critical parameters such as pressure build-up, uncontrolled fuel dispersal and corrosion inside the type B(U)F-package.

Our approach represents an essential milestone to start the decommissioning and dismantling of German NPPs. It represents a quantum leap in achieving the status “free from nuclear fuel” in NPPs.

2. SCOPE OF WORK

The tasks of GNS comprised the following:

- Development of two quiver types for special fuel rods to be used in CASTOR® V/19 and CASTOR® V/52,
- Obtaining the transport licenses for the casks including the quivers,
- Preparation of the safety report in order to obtain the storage licenses for the interim storage sites,
- Production of the quivers and the CASTOR® V casks,
- Development, production and test of delivery, handling and dispatch equipment for both quiver types,
- Preparation of the application documents in order to obtain the permit to use the equipment in NPPs and
- Dispatch of quivers for special fuel rods in NPPs as well as dispatch of CASTOR® V casks loaded with quivers for special fuel rods.

3. DESCRIPTION OF THE INVENTORY OF THE QUIVER FOR SPECIAL FUEL RODS

The quiver for special fuel rods was developed by GNS in order to accommodate a large variety of different SFR types, such as

- Irradiated or unirradiated spent nuclear fuel in the form of fuel rods or fuel rod sections,
- Leak-tight and dry fuel rods with potential damages, e.g. reduced cladding thickness or deformed fuel rods,
- Leaking fuel rods, starting with pin hole defects and hairline cracks up to exposed nuclear fuel, e.g. fragments, loose pellets, broken fuel rods or debris (cf. Fig. 1),
- Fuel rods in capsules or cartridges,
- Test rods from irradiation experiments,
- Irradiated rods, such as dummy rods or control rod fingers (which may also be used for filling any existing free slots of the quiver for special fuel rods).

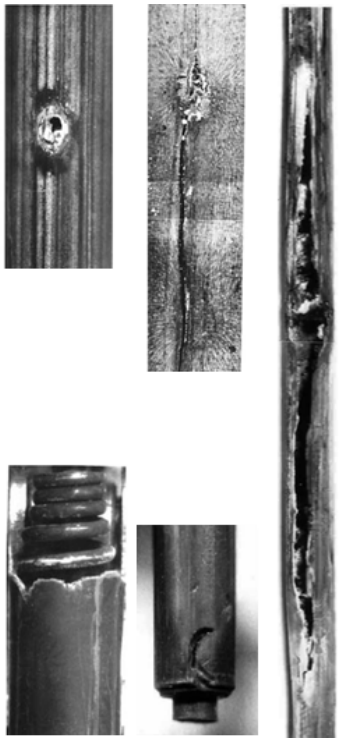

Fig. 1: Examples of damaged leaking SFRs, images extracted from [2].

Given the large variety of SFRs, special attention has to be attributed to leaking fuel rods. In such a case, it has to be assumed that a water leakage into the enveloping structure has occurred during reactor operations or during wet storage. This may result in a significant amount of water per SFR, which may be released during transport or storage, causing pressure build up and corrosion.

SFR can either consist of uranium or mixed oxide fuel with very high burn-up. Different fuel types may be mixed within the quiver, such as fuel e.g. from boiling water (BWR) and pressurized water reactor (PWR) units, as well as uranium and mixed oxide fuel.

4. DESCRIPTION OF THE DISPOSAL CONCEPT WITH THE CASTOR® V CASK

The transport and storage cask CASTOR® V, licensed and mostly used in Germany, essentially consists of a thick-walled, cylindrical cask body with radial fins made of ductile cast iron and an in-line double lid system (cf. Fig. 2 and Fig. 3). In the case of CASTOR® V/19 for FA from PWR, a basket with 19 positions is used. In case of CASTOR® V/52 for FA from BWR, a basket with 52 positions is used. During transport, the cask is additionally equipped with two shock absorbers.

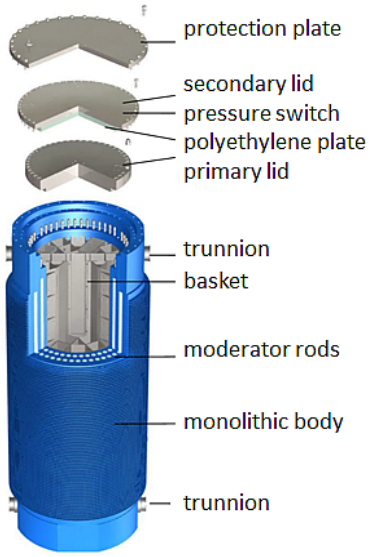

Fig. 2: Type B(U)F-package CASTOR® V/19 for transport and dry storage of PWR-FA (in storage configuration).

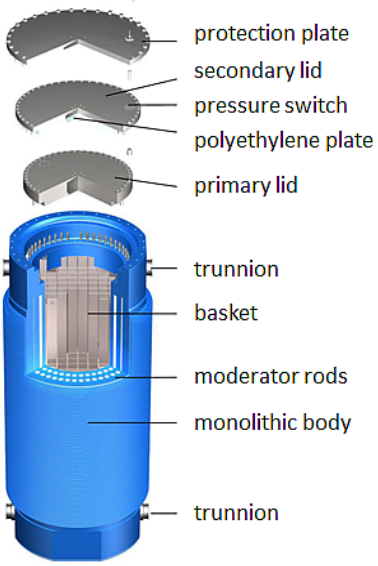

Fig. 3: Type B(U)F-package CASTOR® V/52 for transport and dry storage of BWR-FA (in storage configuration).

4.1 REQUIREMENTS FOR THE TRANSPORT AND STORAGE CASK CASTOR® V FOR LOADING WITH QUIVERS FOR SPECIAL FUEL RODS

For the CASTOR® V cask and its inventories, GNS has shown that the requirements specified by the safety objectives as well as the parameters specified in approval and license are complied with, which is in accordance with applicable regulations from transport regulations and nuclear law for dry storage in Germany. This had also to be verified for casks loaded with quivers for special fuel rods.

Thus, the overall concept for the packaging and the quiver for special fuel rods was developed on the basis

of these requirements. Furthermore, GNS verified all safety objectives such as criticality safety, shielding, heat dissipation and activity release.

Our design takes into account, that all requirements resulting from inventory characteristics such as e.g. heavy metal mass, enrichment, burn-up, thermal power, releasable quantity of fission gas and the residual amount of water are met. In addition, the limits for the mass and the geometry of the quiver for special fuel rods arising from the acceptance criteria of the cask and the basket geometry are met.

In order to exclude a large variety of interactions between the SFRs and the cask, the quiver for special fuel rods is designed to be gas-tight under routine, normal and accident conditions of transport.

4.2 DESIGN OF THE QUIVER FOR SPECIAL FUEL RODS

The base of the quiver for special fuel rods consists of a monolithic body, an internal basket, a lid as well as a head and a foot piece (cf. Fig. 4). The components of the quiver for special fuel rods are manufactured according to the highest quality standards.

The quiver for special fuel rods has been designed to be accommodated by the basket of the CASTOR® V/19 or CASTOR® V/52 using the same space as a standard FA. The overall length of the base body of the quiver for special fuel rods including head and foot pieces corresponds to the maximum approved total length of a PWR or BWR-FA.

The base body of the quiver for special fuel rods is made by forging. This proves great advantage compared to a welded construction, since high mechanic loads must be coped with during accident conditions of transport as well as thermal stresses in the welds must be expected and assessed. Recesses are cut into the outer profile of the base body, in a way that creates length and cross webs contact surfaces.

The internal basket accommodates the SFRs. Based on the evaluation of the inventory data, various different diameters for slot tubes have been defined. As a matter of principle, other configurations of the internal basket are possible, too.

The internal basket can be easily modified according to customer specifications and adopted to the required geometries and the amount of the SFR available in the NPP. Thus, an optimization in terms of loading capacity is provided. If necessary, the internal basket can be removed.

The base body of the quiver for special fuel rods and the lid protect the internal basket with the inserted SFRs against all mechanical influences and ensure the gas-tightness of the quiver for special fuel rods. The lid is fixed by screws and then welded, providing the leak-tightness of the quiver. This has significant advantages compared to screwed connections in conjunction with gaskets, since relaxation effects in a screwed connection may be observed during dry storage, compromising the leak-tightness of the quiver for special fuel rods over time. Since additional monitoring is not necessary, there are no significant follow-up costs.

If required, the weld can be opened, allowing the retrievability of the SFR. A head and a foot piece are bolted to the base body providing an interface to the basket of the cask.

Fig. 4: Quiver for special fuel rods with the lid mounted to the base body and its web-like outer profile (schematic illustration).

4.3 HANDLING AND DISPATCH CONCEPT FOR THE QUIVER FOR SPECIAL FUEL RODS IN THE NPP

The loading of the quiver for special fuel rods with SFRs takes place in the storage pond. Before loading into the quiver, the SFRs are prepared, if necessary, e.g. SFRs that are not intact for handling are placed into handling sleeves. The SFRs are removed from the storage position by means of specially adapted pliers and placed into the quiver for special fuel rods.

Upon completion of loading, the quiver for special fuel rods is inserted into a specially designed shielding basket (primary shielding). Next, this assembly is moved to a station for dewatering, drying and welding and positioned into a shielding block (secondary shielding) outside the storage pond on the reactor floor (cf. Fig. 5). These shielding measures help to significantly reduce the dose rate and to minimize individual dose.

The processing outside of the storage pond on the reactor floor offers great advantages in various technological aspects and with regard to drying. In order to be able to dry leaking SFRs efficiently, the SFR will be heated to support vacuum drying. Drying is required in order to minimize the amount of residual water and to cope with effects such as pressure build-up

or corrosion during interim dry storage. After drying, the quiver for special fuel rods is filled up with inert gas, the lid is bolted and afterwards welded to the base body of the quiver by means of a qualified welding procedure.

Almost all processes for the dispatch of the quiver for special fuel rods are performed by remote handling within a gas box, filled with protective inert gas and are monitored by video surveillance (cf. Fig. 6).

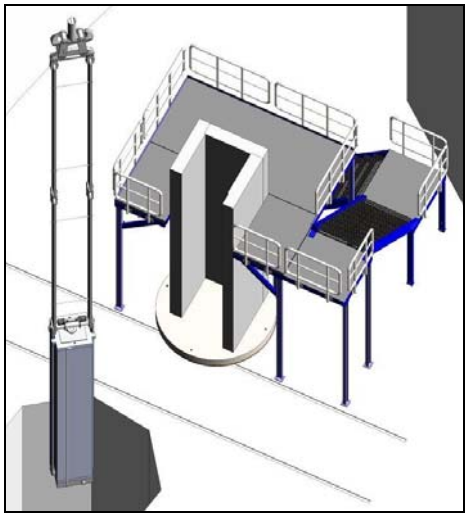

Fig. 5: Transfer of the loaded quiver for special fuel rods into the drying and handling station (schematic illustration).
The assembly of primary shielding and quiver for special fuel rods is attached to a lifting yoke and suspended over the pond. In the upper part of the image, the secondary shielding and a working platform are shown.

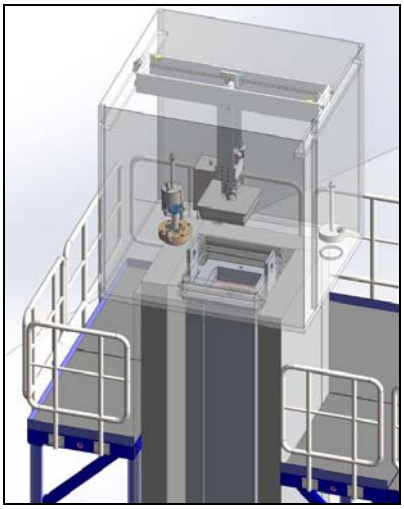

Fig. 6: Drying and handling station with gas box (schematic illustration). One can see the gas box (semi-opaque) mounted on top of the secondary shielding.

Next, the dispatched quiver for special fuel rods is placed back into the storage pond. The loading and dispatch procedure of the transport and storage cask CASTOR® V/19 or CASTOR® V/52 is essentially performed in analogy to a loading with fuel assemblies. Depending on the total heat output of the loading, special measures for drying of the inner cavity of the cask may become necessary.

5 SUMMARY AND OUTLOOK

The quiver for special fuel rods features a robust yet simple design, with a high mechanical stability, a reliable leak-tightness and large safety margins for future requirements on safety analysis. The quiver for special fuel rods can be easily adapted to a large variety of different damaged fuel rods and tailored to the specific need of the customer.

The quiver for special fuel rods is adaptable e.g. in length and diameter for use in other types of transport and storage casks and is applicable in other countries as well.

The overall concept presented here is a first of its kind solution for the disposal of SFRs via CASTOR® V-casks. This provides an important precondition in achieving the status “free from nuclear fuel” of the shut down German NPPs.

Applications for use in the type B(U)F-package transport and storage cask CASTOR® V/19 and CASTOR® V/52 have been submitted in Germany in accordance with transport regulations and nuclear law for interim dry storage. The examination and accompanying tests as well as the necessary qualification procedures are currently ongoing. The production of the quiver for special fuel rods has started.

ACKNOWLEDGEMENTS

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[2] No. NF-T-2.1, Review of Fuel Failures in Water Cooled Reactors, IAEA Nuclear Energy Series (2010)