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Quality Assurance in Fabrication and Operation of Dual Purpose Casks for Spent Nuclear Fuel in Germany

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Abstract

In Germany spent nuclear fuel is stored under dry conditions in dual purpose casks (DPCs). Until a final repository will be available, the casks are kept in central and on-site interim storage facilities. In addition, the transportability of the DPCs at any time is required. Therefore, quality assurance in design, fabrication and operation of the DPCs is of particular importance. The system of quality assurance measures applied in Germany is presented.

For the legal scope of transport the approval certificate holder is responsible for the determination of quality assurance measures, whereas for legal scope of storage the storage license holder is responsible. Hence, for almost the same technical object, two independent regular frameworks have to be applied. The measures can be categorised as system-related and design-related and are independently approved and monitored by the competent authority BAM and its authorised inspection experts. The qualification of the applicant is reviewed in the context of the design approval procedure. The qualification of manufacturer and producers is checked and documents are pre-assessed before the start of manufacture. Manufacturing inspections are carried out according the pre-assessed documents. The manufacturing inspections are completed by the inspection before commissioning. Periodic inspections during operation ensure that the properties specified in the approval certificate are preserved over package life time. The type and the time interval of periodic inspections depend on the use of the package. For transport after interim storage a system of specific tests and inspections is prescribed.

How transportability can be retained over 20 years of interim storage is exemplified by the package CASTOR® THTR/AVR with SNF inventory of decommissioned gas cooled high temperature research reactor in Jülich, Germany. The 20 years storage license ended in 2013, therefore a transport has to be taken into consideration. The transport preparation includes repair and testing of trunnions, examination of bolting torque of lid bolts and leak-tightness tests of lid systems. A large part of the transport preparation has completed. It will be reported on lessons learned in inspections before transport and on the current status of transport preparation.

Introduction

The paper is restricted to quality assurance of package types which require an approval by a competent authority. In Germany spent nuclear fuel and high active waste is packed in casks for transport and storage. The inspections on these dual purpose casks are integrated in a system of further quality assurance measures. The objective of the quality assurance measures is that series samples of the packaging are conform to the approved package design.

Legal Basis, Regulations, Guidelines

The requirements on dual purpose casks are mainly from the field of traffic law. Figure 1 illustrates the system of regulations.

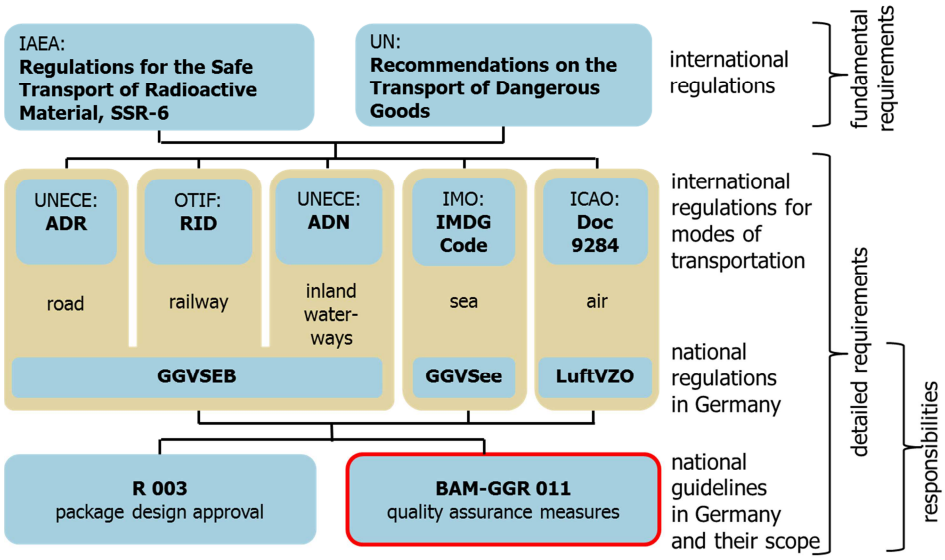

Fig. 1 Regulations

The fundamental requirements are defined in the well-known international regulations [1, 2, 3]. In Germany the international regulations for the different modes of transportation are implemented through the three national regulations GGVSEB [4], GGVSee and LuftVZO. In these national regulations responsibilities for tasks as design approval, quality assurance and quality monitoring are defined. In Germany the national regulations are explained and concretized in domestic guidelines.

The guideline R 003 [5] regulates the procedure of design approval. For design approval the BfE (Bundesamt für kerntechnische Entsorgungsicherheit, Federal Office for the Safety of Nuclear Waste Management) is responsible. The BfE is the successor of the BfS (Bundesamt für Strahlenschutz, Federal Office for Radiation Protection) in the field of nuclear waste management.

The guideline BAM-GGR 011 [6] describes the necessary quality assurance measures for package designs requiring competent authority approval. This guideline is the basis for the inspections of dual purpose casks.

Responsibilities and Competencies

According BAM-GGR 011 guideline the applicant respectively the approval certificate holder is responsible for the determination of quality assurance measures. The BAM (Bundesanstalt für Materialforschung und –prüfung, Federal Institute for Material Research and Testing) is the competent authority for approval and monitoring of quality assurance measures.

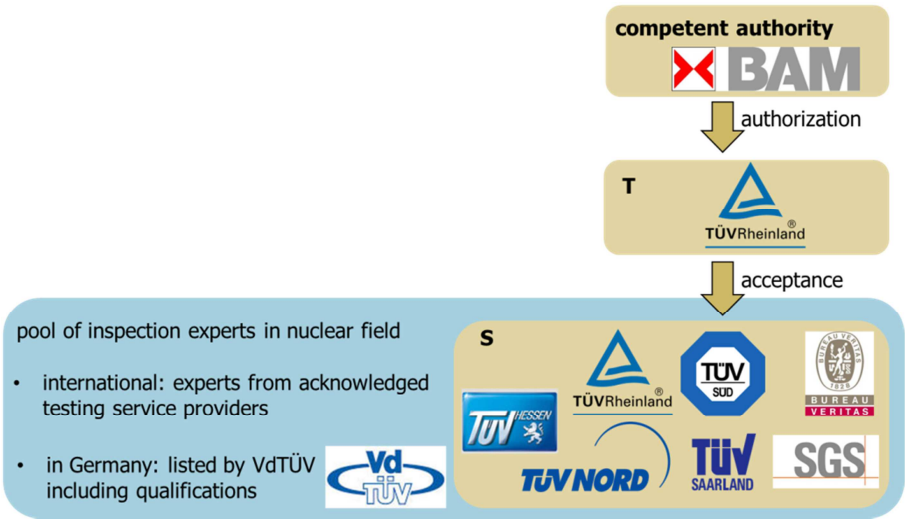

Fig. 2 Responsibilities

BAM authorizes inspection experts for subtasks, they are referred to as T. Currently this group comprises 15 persons.

A large portion of test steps during fabrication are carried out by accepted local inspection experts, called S. In Germany the VdTÜV, a joint body of testing service providers, lists inspection experts in the nuclear field with their qualifications. Most of the local inspection experts S are from this group. Currently about 180 persons are listed as accepted local inspection experts S.

Classification of Package Components

The extent of the necessary quality assurance measures depends on the safety relevance of a package component. The guideline BAM-GGR 011 defines three grades.

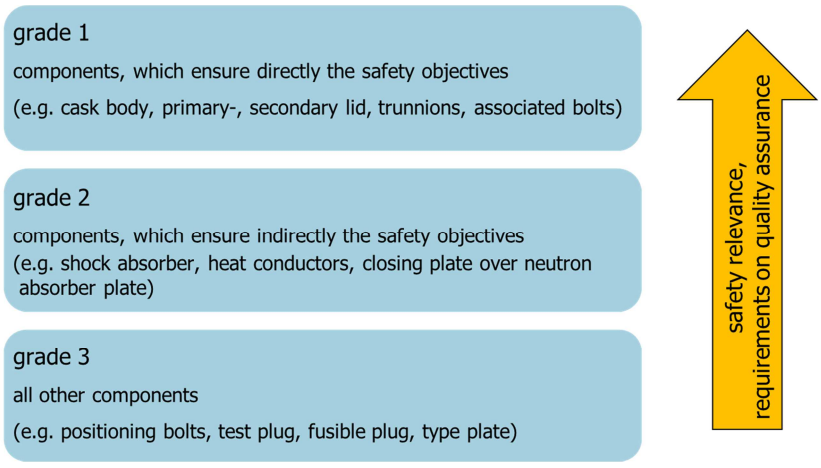

Fig. 3 Component Classification

In grade 1 are classified those components which ensure directly the safety objectives (shielding, containment of radioactive content, integrity, prevention of criticality). Grade 1 also includes load attachment points of the package. Components of grade 2 ensure indirectly the safety objectives. All other components are of grade 3. This classification can be restricted on sections, features or manufacturing phases of a component, but the highest safety relevance of a component is decisive for the component classification. The classification grade of each component is defined in the parts list of the package. The quality assurance effort increases with safety relevance.

Quality Assurance Measures

The following figure illustrates the system of quality assurance measures. The elements of the system are chronologically arranged. The quality assurance measures can be classified in system-related and design-related measures.

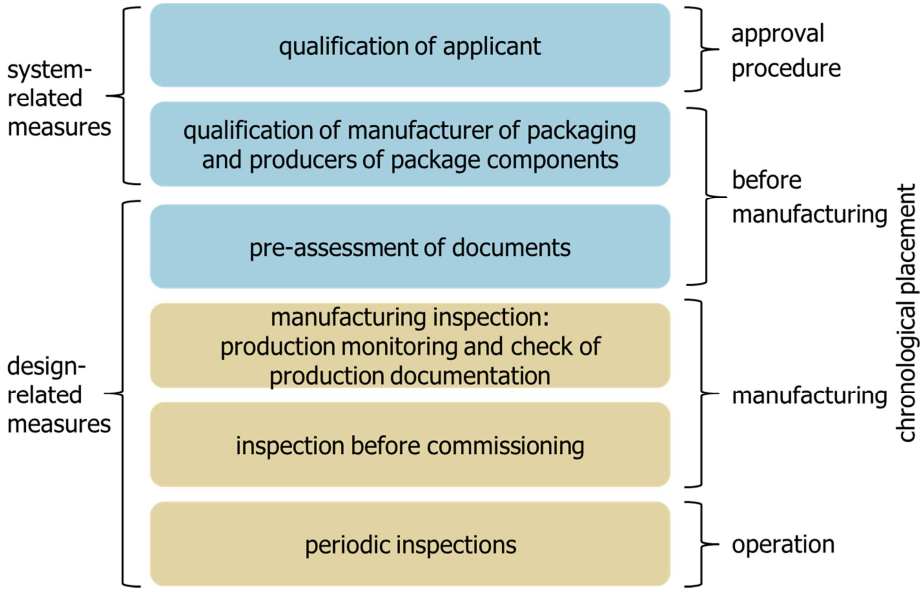

Fig. 4 Quality Assurance Measures

The qualification of the applicant is reviewed in the context of the design approval procedure. Before manufacturing starts the qualification of the manufacturer of packaging and the producers of package components is checked and documents are pre-assessed. Manufacturing inspections are carried out according the pre-assessed documents. The manufacturing inspections are completed by the inspection before commissioning. Periodic inspections during operation ensure that the properties specified in the approval certificate are preserved over package life time.

Below the elements of the system of quality assurance measures are described in detail.

Qualification of Applicant

The applicant must have an established and implemented quality management system in order to ensure the placed requirements for design, construction, manufacturing, operation and maintenance

of RAM packages. The QMS is reviewed by BAM as part of the design approval procedure. Subsequently the QMS is reviewed in three year cycles or after justified occasion. Typically the check is in form of quality audits.

Qualification of Manufacturer and Producers

The manufacturer of the packaging and the producers of grade 1 and grade 2 components must have an appropriate QMS to guaranty the required product quality. In particular sufficient human resources and an adequate infrastructure must be available. The qualification of manufacturer and producers is checked by BAM or T prior to manufacturing and is reassessed in three year cycles. In recertification quality audits findings from production monitoring are considered if necessary.

Pre-assessment of Documents

All documents which ensure the relevant package properties in the context of manufacturing are verified and approved by BAM respectively T before start of production. The fabrication and test sequence plans are the essential documents. They are required for manufacturing of packages, components of grade 1 and 2 and for possible repair measures. The participation of inspection experts T and S is specified in the plans. The pre-assessment of documents is of particular importance because the course of production monitoring and inspections is set.

Manufacturing Inspection

Manufacturing and inspection are carried out in compliance with the pre-assessed documents. Production and testing follow the approved fabrication and test sequence plans. The plans must be filled out timely. For deviations in manufacturing a procedure is defined. Deviations on grade 1 and grade 2 components must be reported to BAM. Measures on grade 1 and grade 2 components require the acceptance of BAM before the measures are carried out. Whenever criticality safety or shielding may be influenced a BfE statement is required. After the completion of a component the filled out fabrication and test sequence plan and associated documents are checked.

Inspection before Commissioning

To guarantee the compliance with the design specification the assembled package is tested before commissioning. The lid system is tested for leak-tightness and the load attachment points are load tested. Finally the manufacturing documents of the package are checked for completeness and accurateness. After the successful final check of package and documentation the package type plate is stamped with the stamp of the authorized inspection expert and the date of next periodic inspection. The authorized inspection expert confirms the result of inspection before commissioning by a certificate. The certificate is send to the BAM and the approval certificate holder.

Periodic Inspections

Objective of periodic inspections is that the properties specified in the approval certificate are preserved during operation. The test plan for periodic inspections is assessed by BAM within the design approval procedure.

The type and the time interval of periodic inspections depend on the use of the package. If the cask is used for transport only it is completely accessible after unloading. In this case the periodic inspection after 3 respectively 6 years or 15 respectively 60 transports covers all essential components and sections. If the cask is used for interim storage it is not completely accessible. The periodic inspections during interim storage and before transport cover the sections accessible from the outside, ensure the leak-tightness according to the specifications and where appropriate provide measurements which allow drawing conclusions about the state of inaccessible sections indirectly.

Deviations found in the context of maintenance or periodic inspections are treated in the same manner as deviations found in the context of manufacturing. The authorized inspection expert confirms the result of a periodic inspection by a certificate.

Summary of Quality Assurance Measures

The applicant respectively the approval certificate holder is responsible for the determination of the quality assurance measures. The measures are independently approved and monitored by the competent authority BAM and its authorized inspection experts T. The inspection and the production monitoring of safety relevant package components is performed by independent experts. During operation the package properties are verified by means of periodic inspections.

Experience on Transportability after Long-term Interim storage

Experience is reported using the example of the transport and storage cask of type CASTOR® THTR/AVR.

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Fig. 5: THTR/AVR Fuel and CASTOR® THTR/AVR casks at FZJ

Cask, Content and History

The package type belongs to the CASTOR® family. The cask has a monolithic ductile cast iron body. A double lid closure system with metallic seals and permanent pressure monitoring in storage

configuration provide two independent tightness barriers. For handling two pairs of trunnions are mounted to the body by bolts. Steel sheeted, wood filled impact limiters at bottom and lid side of cask protect the cask in transport configuration. The maximum transport mass is about 32 metric tons.

The CASTOR® THTR/AVR is used for long-term interim storage of fuel from two decommissioned German gas cooled high temperature pebble-bed reactors. The inventory consists of 2 stainless steel cans, each filled with up to 2110 sphere shaped fuel elements of 60 mm diameter. The fuel elements contain Uranium und Thorium fuel compounds and are coated by a graphite shell. They do not induce appreciable decay heat to the cask.

305 casks containing fuel assemblies from the thorium high temperature reactor THTR-300 at Hamm-Uentrop are stored in the storage facility located at Ahaus (TBL-A). 152 casks have been loaded with fuel elements from the research reactor AVR at Jülich between 1993 and 2009. These casks are stored actually in an air-conditioned hall on the area of the research centre Jülich (FZJ). The leak-tightness of the casks is permanently observed by pressure monitoring of the space between the primary and secondary lid. The 10 year transport approval certificate is valid until January 2017. The extension of the approval is in progress.

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Fig. 6: Cask with Impact limiters on Transport Frame

The interim storage facility at FZJ was operated based on a storage license under §6 of AtG [7] awarded by BfS in June 17, 1993. The license was limited to June 30, 2013. Actually an order of the atomic energy authority in the German federal state Nordrhein-Westfalen (MWEIMH) is the legal basis of the storage. In the context of this order the MWEIMH demanded the evacuation of the storage facility on July 2, 2014. At present three approaches are pursued: (1) continuation of storage in Jülich, (2) transport in the USA or (3) transport to the storage facility at Ahaus (TBL-A). For the first option a storage license is required. In the licensing procedure a geological survey considering earthquake must be completed. The second option appears possible because the fuel originates from the USA and the draft of an environmental assessment of the U.S. Department of Energy [11] from January 2016 comes to positive results. However the required transport license and export license was not requested until now [10]. Regarding the third option can be stated that the BfS awarded a storage license for the 152 casks in the storage facility TBL-A on July 21, 2016, but a transport

license is pending.
Independently from the finally chosen option the transportability of the casks shall be ensured.

Transport Preparation

A successful inspection before transport is the prerequisite for the relocation of the 152 casks.
The inspection is carried out on the basis of an inspection plan, test specifications and work instructions. The documents are approved by BAM and the main inspection steps are kept under surveillance of the authorized expert of BAM.
As a preparation for the relocation of the casks modifications at the load attachment points were performed. The trunnions were disassembled, checked, chromate coated to achieve resistance against moisture or replaced by new stainless steel trunnions. Instead of the foreseen surface crack testing of the disassembled trunnion bolts the operator of the casks decided to renew all bolts. The reassembled load attachment points were checked by a load test under 1,5-fold operating load. The work and the tests on the 608 load attachment points started in July 2012 and were successfully finished in March 2015.

Fig. 7: Leak-tightness Test and Testing of Trunnions

For the helium leak-tightness tests a program was agreed to reduce the exposure dose of the inspection personal as well as the inspection effort: On a minimum of 31 casks (20% of the 152 casks) all metallic gaskets of the tightness barrier chosen for the transport must be leak-tightness tested without deviation. For the leak-tightness tests of the large metallic seals of the primary and secondary lid a minimum sample size of 16 casks (10% of the 152 casks) is defined. Nevertheless all small gaskets of the tightness barrier chosen for the transport must be leak-tightness tested.
In the period from January 2012 to December 2013 leak-tightness tests were carried out. Overall 33 primary lid systems were completely tested and 22 primary lids systems were simplified tested. All 55 corresponding secondary lid systems were reassembled with new seals and checked. On the basis of the number of successful leak-tightness tests the remaining casks may be tested simplified.
Regrettably there is no comparability between the results of the leak-tightness tests of the primary lid seals after loading with the results after interim storage. The outer elastomeric seals have been

exposed to 6 bar helium in the monitored volume between the lids for the storage time. This induces a high background level in the helium leak-tightness tests, even after preparation by vacuum pumping for several days. Nevertheless, it is an important result that the test sensitivity was sufficient to demonstrate the clear fulfillment of the transport requirements for each investigated cask.

Moreover all surfaces of the cask and its components including the sealing surfaces of the disassembled lids were visually checked, the block position of the lids was measured and the bolting torque of the bolts of the disassembled 33 primary lids was examined. No deviations were detected in the tests. Bolts and threaded holes were checked with gauges. One threaded hole had to be repaired by helicoil.

The pressure monitoring system did not record any event until now.

Status

The intermediate results of the examinations show, that there is no relevant influence of up to 20 years storage time on the cask condition. On the basis of the positive inspection results, the good condition of the casks and the optimal storage conditions the BAM agreed to an extension of the expiration date of inspection test steps: The validity of test steps at the lid system and at the trunnions and trunnion bolts was adjusted to the validity of the trunnion load test to consistently 6 years.

Currently the transport preparation is suspended. It will be continued after the upgrade of a crane system which is required for the handling of the casks.

Conclusion

Experience in inspections of various cask types shows that the properties specified in the approval certificate are met with high reliability at commissioning and during operation.

Using the example of CASTOR® THTR/AVR with AVR inventory it was demonstrated that the transportability was retained after 20 years of interim storage.

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