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GERMAN APPROACH AND EXPERIENCE FEEDBACK OF TRANSPORT ABILITY OF SNF PACKAGES AFTER INTERIM STORAGE

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ABSTRACT

In Germany the concept of dry interim storage of spent fuel in dual purpose metal casks is implemented, currently for periods of up to 40 years.
The casks being used have an approved package design in accordance with the international transport regulations. The license for dry storage is granted on the German Atomic Energy Act with respect to the recently revised “Guidelines for dry interim storage of irradiated fuel assemblies and heat-generating radioactive waste in casks” by the German Waste management Commission (ESK).
For transport on public routes between or after long term interim storage periods, it has to be ensured that the transport and storage casks fulfil the specifications of the transport approval or other sufficient properties which satisfy the proofs for the compliance of the safety objectives at that time.
In recent years the validation period of transport approval certificates for manufactured, loaded and stored packages were discussed among authorities and applicants. A case dependant system of 3, 5 and 10 years was established. There are consequences for the safety cases in the Package Design Safety Report including evaluation of long term behavior of components and specific operating procedures of the package.
Present research and knowledge concerning the long term behavior of transport and storage cask components have to be consulted as well as experiences from interim cask storage operations. Challenges in the safety assessment are e.g. the behavior of aged metal and elastomeric gaskets under IAEA test conditions to ensure that the results of drop tests can be transferred to the compliance of the safety objectives at the time of transport after the interim storage period.

Assessment methods for the material compatibility, the behavior of fuel assemblies and the aging behavior of shielding parts are issues as well.
This paper describes the state-of-the-art technology in Germany, explains recent experience on transport preparation after interim storage and points out arising prospective challenges.

INTRODUCTION

The use of metallic transport casks for dry interim storage of spent nuclear fuel (SNF) can be designated as a German invention. In 1978 the company GNS started the approved application for the first CASTOR® cask (CASTOR® Ia) with a monolithic cask body made of ductile cast iron (DCI), closed with a double lid system with metallic gaskets. A first CASTOR® Ic-Diorit cask was loaded and put to interim storage in Switzerland in 1983; in 1986 spent fuel storage in CASTOR® V/21 casks began in Surry, VA, USA. After first construction of two central storage facilities (Gorleben, Ahaus), since 2000 the German decommissioning policy switched over to spent fuel storage in CASTOR® V casks on at-reactor storage sites.
The paper describes the German approval procedure for transport licensing. Details about safety case requirements based on international and national regulations are given. Furthermore the licensing for interim storage is explained. The BAM activities concerning long term behavior of components and materials are explained and references are given.

APPROVAL OF TRANSPORT PACKAGE DESIGN

In Germany casks for interim storage are dual purpose casks. Every storage cask has to have a transport approval certificate at time of storage placement and over the storage time as well. Usually a Type B(U) approval (accident resistance package according to IAEA transport regulations SSR-6 [1]) is necessary. In accordance to German guideline R003 [2] the package design assessment and the approval procedure are conducted by the Federal Office for Radiation Protection (BfS) and the Federal Institute for Materials Research and Testing (BAM). The assessment has to base on a Safety Analysis Report, provided by the applicant.

REQUIREMENTS ON APPLICATION DOCUMENTS

The application documents must include at least the information required by the applicable paragraphs of SSR-6 [1]. Compliance with all applicable requirements for the requested design approval shall be demonstrated by providing a Safety Analysis Report.
The safety demonstration showing plausibly that the design meets all the requirements of the applicable regulations. The demonstration has to cover in particular:

- demonstration of mechanical stability for routine, normal and accident conditions of transport for the components of the containment system, the components of the shielding, the components of the confinement system for ensuring subcriticality and the attachments for lifting by crane and for transport on public traffic routes [9],
- demonstration of thermal behavior for routine, normal and accident conditions of transport including an evaluation of thermal stresses and the thermal behavior of the components of the containment system, the components of shielding and the components for ensuring subcriticality,
- demonstration that the limits for the release of radioactive material for normal and accident conditions of transport are met [10],
- demonstration that for the maximum radioactive contents the dose rate limits for normal and accident conditions of transport are met,

- for fissile material, demonstration of subcriticality for routine, normal and accident conditions of transport;

The quality assurance and monitoring program is necessary for design, manufacturing, documentation, and operation including all instructions necessary for maintenance and re-inspection as well as for operations during transport and in-transit storage. The experiences and involvement of the competent authority in this field in Germany are described by Wille [10].
All specifications must be considered by the user of the package to ensure the loading, the transport, the operation and the periodic inspections according to regulatory requirements. Up to now the design assessment was determined by the evaluation of the materials used with regard to their properties and compatibilities for short periods (transport periods). This suitability evaluation is supplemented by the specification of a system of periodic inspections (after 15 transports but not later than 3 years, after 60 transports but not later than 6 years, before one-time transport after interim storage), which should guarantee that the package complies the specifications before transport on public routes [10].
The safety demonstration of a design can be accomplished by using the results of tests performed with prototypes or models of appropriate scale, by reference to previous satisfactory demonstrations of a sufficiently similar nature, by calculation, when the calculation procedures are generally agreed to be suitable and conservative or by a combination of these test methods.
Reference to test results of designs similar to the design for which approval is requested is permissible if the similarity can be demonstrated sufficiently by justification and validation.

DESIGN ASSESSMENT

BfS and BAM carry out the comprehensive safety assessment of the design (design assessment). They assess the safety demonstration of a design with respect to compliance with the regulations. In detail, BAM carries out the safety assessment with respect to the mechanical and thermal design, the release of radioactive material and quality assurance [9]. Required tests with prototypes, models or single components are performed by BAM.
BfS carries out the safety assessment with respect to shielding, criticality safety and compliance with the activity limits concerning the radiological properties.
BfS summarizes the results of the complete procedure and issues the design approval certificate.

DESIGN APPROVAL

Design approval is granted if the design assessment has been concluded with positive results. The approval certificate is generally issued for a validity period of three (1985 Edition of the regulations) and five years (1996 Edition of the regulations). The competent authority may consider a deviation from this validity period if the applicant requests any other validity period and substantiates such request. In Germany it is possible for package designs which are compliant to the current regulations [1] (1996 Edition of the regulations) to get a 10 year approval certificate. The hereby associated requirement is an exclusion of a further manufacturing of the particular package design. For example, this procedure can be used for package designs whose loaded casks are stored in an interim storage site and a new manufacturing is not planned or impossible. Depending on the cask design, particular time intervals of maintenance and updating of the Safety Analysis Report are determined.
The validity of the approval certificate will be extended upon application if the legal regulations have not changed materially and safety related objections against an extension of the validity period can not be raised, either. Such application shall include documents to show that all applicable requirements continue to be met. This includes, e.g., an assessment of the influence of

advanced technical standards on the design as well as the practical experience feedback from using the design, particularly concerning the quality assurance and monitoring program.
Subject to other required approvals (e.g., shipment approval), any package may be transported if at the time of transport the following documents are available: a valid design approval certificate, a certificate of the inspections carried out before commencement of operation (certificate of acceptance) and the certificates of re-testing/reinspection as required.

LICENSING FOR DRY STORAGE

Spent fuel and vitrified high active wastes from reprocessing are stored in interim storage facilities which are licensed on the basis of § 6 of the German Atomic Energy Act [7] and taking into consideration the Safety Guidelines for Dry Interim Storage of Irradiated Fuel Assemblies in Storage Casks of the German Reactor Safety Commission [8]. The storage facility contains all technical and security infrastructure for operation, casks with the radioactive contents under dry and inert conditions and a building containing the casks and all handling, maintenance and monitoring equipment. Interim storage sites have been licensed as centralized facilities like Ahaus or Gorleben at first in the 1980's and later on – mainly after 2001 – due to changes of the German Atomic Energy Act as at-site facilities at all German NPP locations. The storage period was generally limited to 40 years for administrative reasons because it was expected to have a final repository available after that time. In the meantime Germany has passed a law to establish a completely new site selection procedure for a repository for spent nuclear fuel and high-level waste. This procedure and the subsequent siting and exploration procedure will take at least three decades and therefore extended interim storage periods are inevitable in the future.
More details on the licensing procedure and background are explained by Wolff [3].

LONG TERM BEHAVIOR OF COMPONENTS AND MATERIALS

During long term interim storage the main driving forces of aging effects are gamma radiation, neutron radiation, decay heat, outer corrosion effects (e. g. moisture, and air pollution), relaxation, creeping, corrosion of bolted and sealed lid systems, basket, and fuel rods.
Degradation effects strongly depend on the type of material. All main cask components responsible for the safe enclosure are usually made of metal like cask body, lids, main seals, and bolts. Additionally, polymer components are used for supplementary neutron shielding components, auxiliary seals and decontamination coatings. In general, damaging effects of radiation depend on dose rates, type of radiation and material structure. Metals are generally more resistant than polymers. Degradation effects may result in quantitative changes of specific material properties or modifications in material structure which may decrease the effectiveness of cask components.
Current investigations performed by BAM focus on the long term behavior of metal seals as the essential component for the safe enclosure, on the long term behavior of polymer materials as components for neutron shielding and on the aging mechanisms and low temperature behavior of elastomeric auxiliary seals. These investigations shall generate a better data base for understanding and quantification of aging effects and have been summarized by Wolff [3]. More details with respect to aging management fundamentals and the investigation programs performed by BAM were published by Erhard [4], and Jaunich [6]. Latest results from the BAM metal seal investigation program are published by Völzke [5]. These include extrapolation of seal pressure force decrease and decrease of elastic seal recovery depending on the temperature level and with respect to seal performance evaluation under normal operation and accident conditions during and after long term storage.

TESTS AND INSPECTIONS FOR TRANSPORT ABILITY AFTER STORAGE

In principle, it has to be ensured before transport that the package complies with the specifications of the approval certificate. This also applies, if the transport should be performed after interim storage. Until now, the evaluation of the long term behavior (stability) was not an explicit part of the design assessment while approval procedure according to the transport regulations.

The transport regulations assume casks which are only for transport. In this case the whole package is completely accessible before loading, whereas the subsequent transport period cannot be compared with the storage period. After transport and unloading of the cask a periodic inspection should be provided for all essential components and sections, if 3 respectively 6 years or 15 respectively 60 transports are exceeded.

During and after the interim storage the packaging is not assessable for periodic inspection (in sense of the approval certificate) which accesses all sections of the packaging. The existing specifications in the plan for the periodic inspections should cover the sections accessible from the outside, ensure the leak-tightness according to the specifications and where appropriate provide measurements which allow to conclude to the inaccessible sections indirectly.

Examples are:

- Accessible Sections
  Visual inspection of surfaces (e.g. decontamination coatings), visual but also surface crack inspection, load testing of the attachment system, if necessary, replacement of components
- Compliance of the containment system with specification
  Check of the documentation of the pressure monitoring system and inspection of tightening torques of the lid screws, performance of leak-tightness (e.g. leakage rate measurements)
- Measurements (conclusion to inaccessible sections)
  Verification of the shielding effectiveness, e.g. regarding the effectiveness of the shielding material in the shell of the packaging, the bottom of the packaging or between the lids

Following the described measures in accordance with the current approach and the derived questions it appears to be reasonable to expand the considerations with respect to long term behavior as part of the approval procedure for transport and storage casks.

RECENT EXPERIENCE ON TRANSPORT PREPARATION AFTER INTERIM STORAGE

Experience will be shown on the example of transport- and storage cask of type CASTOR® THTR/AVR. 152 of these casks are used for the interim storage of fuel elements of the decommissioned gas cooled high temperature research reactor in Jülich. They have been loaded between 1993 and 2009 and stored in an air-conditioned hall on the research center area. The packagings are currently in preparation for a transport to the interim storage facility in Ahaus. A possible transport to the United States is currently under discussion.

The CASTOR® THTR/AVR is a monolithic cask made of ductile cast iron with a double-lid system and metallic seals, an upper and lower pair of trunnions and separate transport impact limiters. The maximum transport mass is about 32 metric tons.

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 don´t induce appreciable decay heat to the cask.

In the storage facility in Jülich the leak-tightness of the casks is permanently observed by pressure monitoring in between the primary and secondary lid.

In order to ensure the compliance of the condition of the casks with the design approval certificate a test and inspection plan was issued by the stakeholder and approved by BAM. Details and requirements of all inspection steps are described in test specifications and work instructions. They are also approved by BAM and the main inspection steps are kept under surveillance of the designated expert of BAM.

For the helium leak-tightness tests a program was agreed to reduce the exposure dose of the inspection personal as well as the effort:

On leastwise the first 16 casks the secondary lids will be disassembled to check the primary lid seals. After positive results the leak-tightness test of the primary lids can be omitted. For the next 16 casks the same procedure will be performed for the secondary lids. At least, after no tests failed, no more leak tests are required.

Furthermore, due to the different conditions within in the storage facilities in Jülich and Ahaus modifications at the load attachment points have to be performed. Unlike Jülich, the storage facility in Ahaus is not air conditioned. To achieve resistance against moisture the trunnions made from ferritic steel are to be disassembled, checked, coated by chromalizing, reassembled and finally the load attachment points will have to be qualified by loading tests.

Instead of the foreseen surface crack testing of the disassembled bolts the operator of the casks decided to renew all bolts.

The inspections started in September 2012 and the casks investigated until now cover nearly the entire loading period. At the end of July 2013, after preparation of 45 casks, the main test results are:

- Check of the documentation of the pressure monitoring system: No indications.
- Visual check of all surfaces of the cask and its components including the sealing surfaces of disassembled lids: No indications
- Measurement of block-position of all lids: No deviations.
- Examination of bolting torque of the bolts of 30 primary lids: No deviations
- Leak-tightness tests of the lid systems: 30 primary lid seals were tested and fulfilled the requirements. All seals of the 45 reassembled secondary lid systems have been renewed and tested on leak-tightness with positive results.
- Check of bolts and threaded holes with gauges: One threaded hole was repaired by helicoil.
- Check and coating of trunnions: 431 trunnions refurbished and assembled, 45 loading tests successfully finished. 28 trunnions scrapped due to surface damage, replaced by stainless steel ones.

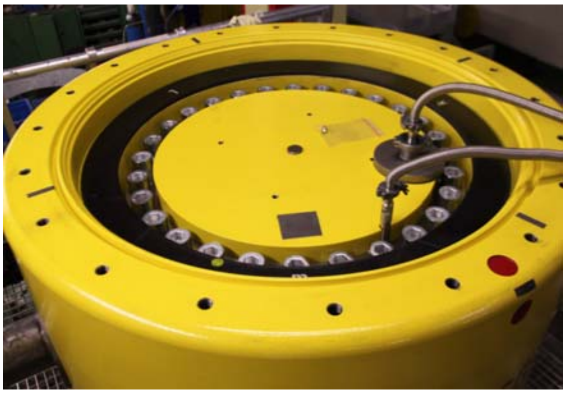

FIG. 1 LEAK-TIGHTNESS TEST AT A PRIMARY LID

FIG. 2 TEST OF TRANSPORT PREPARATION

The intermediate results of the examinations show, that there is no relevant influence of up to 20 years storage time on the cask condition.

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 in between the lids for the storage time and induce a high underground level in the helium leak-tightness tests, even after preparation by vacuum pumping of several days. Nevertheless, it is an important result that the test sensitivities were sufficient to demonstrate the clear fulfillment of the transport requirements for each investigated cask.

The “convenient” storage conditions, meaning no relevant temperature generation by the spent fuel and an air conditioned facility, have to be considered in this results evaluation.

QUO VADIS – CHALLENGES AND PROSPECTIVE WORK

WORK ON CHARACTERISTICS OF LONG TERM BEHAVIOR OF MATERIALS AND COMPONENTS

Until now the plans for periodical inspection contain restrictive determinations of inspection steps for a one-time transport after 40 years. According to the understanding of the state-of-the-art of technology there are steps such as a load test of the complete load attachment system and the complete inspection of the tightening torque of the bolts as a part of the containment system implemented. However, these determinations do not cover all questions concerning the properties of components respectively material after interim storage of many years. Various questions on long term behavior of components and materials resulting from the particular operation state (storage) of the transport package arise.

In the following several points relating long term behavior and the fulfillment of IAEA requirements (e.g. test conditions) are named for future discussion.

- behavior of aged metallic and elastomeric seals as a part of the containment system
- transferability of drop test results (e.g. leakage rate, mechanical material behavior, deformations) regarding the compliance of the safety objectives before a transport after interim storage (aged package)
- transport of defect spent fuel assemblies/rods – warranty of leak-tightness of enclosures such as quivers for defect spent fuel rods under accident conditions of transport
- behavior of aged spent fuel assemblies/rods
- change of material properties of shielding components (e.g. influence of radiation)

Basically it is to ensure that while and after the end of interim storage the package fulfills the requirements of the IAEA transport regulations, means the package has to meet the specifications of the approval certificate. It could also mean the package has to have sufficient properties to fulfill the appropriate safety cases.

REGULATORY WORK

Since many countries operate interim spent fuel storage in dual-purpose casks, the integrated safety assessment and a harmonized approved/licensing approach became evident at an international level, organized by IAEA in joint WASSC/TRANSSC (Waste Safety Standards Committee/Transport Safety Standards Committee) activities. In April 2011 a first meeting of a "Joint Working Group on Guidance for an Integrated Transport and Storage Safety Case for Dual-Purpose Casks for Spent Nuclear Fuel" took place. A First draft of a "Dual Purpose Cask Safety Case" as an IAEA-TECDOC was developed on basis of the European Guide for Package Design Safety Analysis Report [11]. This TECDOC shall be finished until end of 2013, and shall contain guidance in dual purpose cask safety assessment criteria and methods for pre-storage transport, interim storage and post-storage transport.

CONCLUSIONS

Safety assessment of spent nuclear fuel transport casks, as well as of dual-purpose casks for spent nuclear fuel storage is based on well established methods. For future applications a better harmonization of both licensing (transport and storage) areas could be recommended. In any case specific considerations of transport safety aspects after interim storage should be followed. For that purpose research on aging mechanisms, incorporation of storage related property changes into the transport safety case, and regulatory developments are necessary.

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