

MAINTENANCE OF PACKAGE DESIGN SAFETY REPORT EFFECTIVENESS OF SNF and HLW DUAL PURPOSE CASKS

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ABSTRACT

For interim storage of spent fuel or HLW in many countries transport casks are used. The design of these “dual purpose casks” has to be assessed and approved to transport regulations (based on IAEA SSR-6), and to be assessed within the storage facility licensing procedure. Although the transport cask design differs from the storage cask design, e.g. by use of impact limiters, the majority of cask components is identical for both. Differences occur also in the acceptance criteria; these are for the transport case defined in IAEA SSR-6, and have to be developed for the storage case based on the storage conditions. Considering transport after several decades of storage requires the implementation of ageing behavior into the transport safety case. Additionally the transport package design safety case has to be maintained in an up-to-date state, considering potential regulatory changes and development of scientific and technical knowledge. The review of a transport package design safety case has to be done periodically, implemented in periodic re-assessment for extension of the package design approval certificate. The review process (as a kind of “intellectual periodic inspection”) should be part of the approved applicant’s management system.

From experience we have seen that stability of regulatory requirements for Type B(U) packages was not a major problem, but consideration of ageing and developments regarding the state-of-the-art technology can cause necessary adjustments of specific technical evaluation, with the result of confirmation of package safety, or with the development of appropriate compensatory measures to reach the required level of safety. This paper will draw some examples from the past to explain the problems in periodic transport safety case reviews.

INTRODUCTION AND BACKGROUND OF SNF AND HLW STORAGE IN GERMANY

Decommissioning of spent nuclear fuel (SNF) requires several decades of storage before direct disposal. In case of reprocessing the fission products are transferred to vitrified high level waste (HLW) which has to be stored also over several decades before it can be disposed off in a repository. In Germany most of the spent fuel produced until 2005 went to reprocessing in La Hague, France and Sellafield, UK. Since July 2005 German utilities are forced by law to store spent fuel in storage facilities located at the NPP sites. Before that decision, the old decommissioning policy was based on two central storage facilities in Ahaus and Gorleben. Since 1979 it was decided in Germany to store SNF and HLW under dry

conditions in transport casks. This concept of Dual Purpose Casks (DPC) was at the first time developed with the types of CASTOR[®] casks by GNS (Gesellschaft fuer Nuklear-Service GmbH, Essen, Germany). The central transport cask storage facility Ahaus was mainly used for the storage of 305 CASTOR[®] THTR/AVR casks with the complete inventory of the Thorium-High-Temperature-Reactor (THTR) after its decommissioning in 1994. The central transport cask storage facility Gorleben was mainly used to store 108 casks (CASTOR[®] HAW 20/28 CG, TS 28 V, TN 85, CASTOR[®] HAW 28 M) with vitrified HLW received back from France. Besides 12 transport cask storage sites at NPPs (there were stored 273 CASTOR[®] V/19 and V/52 SNF casks at the end of December 2010), there are additionally two storage sites at Research Centre Jülich (for 152 CASTOR[®] THTR/AVR casks with the complete inventory of the research reactor AVR) and in Lubmin the ZLN storage site at the decommissioned former GDR NPPs with 65 CASTOR[®] 440/84 casks. All these several hundred SNF and HLW transport and storage casks have to be transported in future after a storage period which in currently per license limited to 40 years, but which is expected to be some decades longer due to outstanding evaluation, selection and licensing of a high active waste repository.

Responsibility for future generations requires from the beginning that there will be a safe transfer of the existing DPC to their currently unknown destination. All institutions (vendors, transport and storage operators, authorities, regulators, technical experts) involved in that process need to follow a strict course of keeping the foundation for transport safety, the transport package safety report (or safety case) effective through the entire lifetime of these objects.

PACKAGE DESIGN SAFETY REPORT AND PACKAGE DESIGN APPROVAL

The safety case or the Package Design Safety Report (PDSR) is a collection of scientific and technical arguments, including safety assessment and package design, manufacturing and operation specifications required to demonstrate compliance with the applicable transport regulations. The “European Association of Competent Authorities for the Safe Transport of Radioactive Materials” issued the “Technical Guide – Package Design Safety Report for the Transport of Radioactive Materials” [1]. This “European PDSR Guide” is a useful guidance for structure and safety assessment details of a package design safety report. Based upon the same structure an IAEA working group developed the document “Guidance for preparation of a safety case for a dual purpose cask containing spent fuel” [2]. Figure 1 shows the structure of a Dual Purpose Cask Safety Case (DPCSC). Important for the long-term safety preservation of dual purpose casks are the requirements for ageing considerations in the safety case, ageing management during storage and inspection programs before transport after storage. The DPCSC document also addresses problems of adjusting the differences between licensing types of storage and transport package design approval. A storage license is issued for a storage period of several decades. A transport package design approval is normally issued for a period of a few to several (between 3 and 10) years. Before the end of the approval period the certificate needs to be extended for the next period by a demonstration of compliance with the current transport regulations.

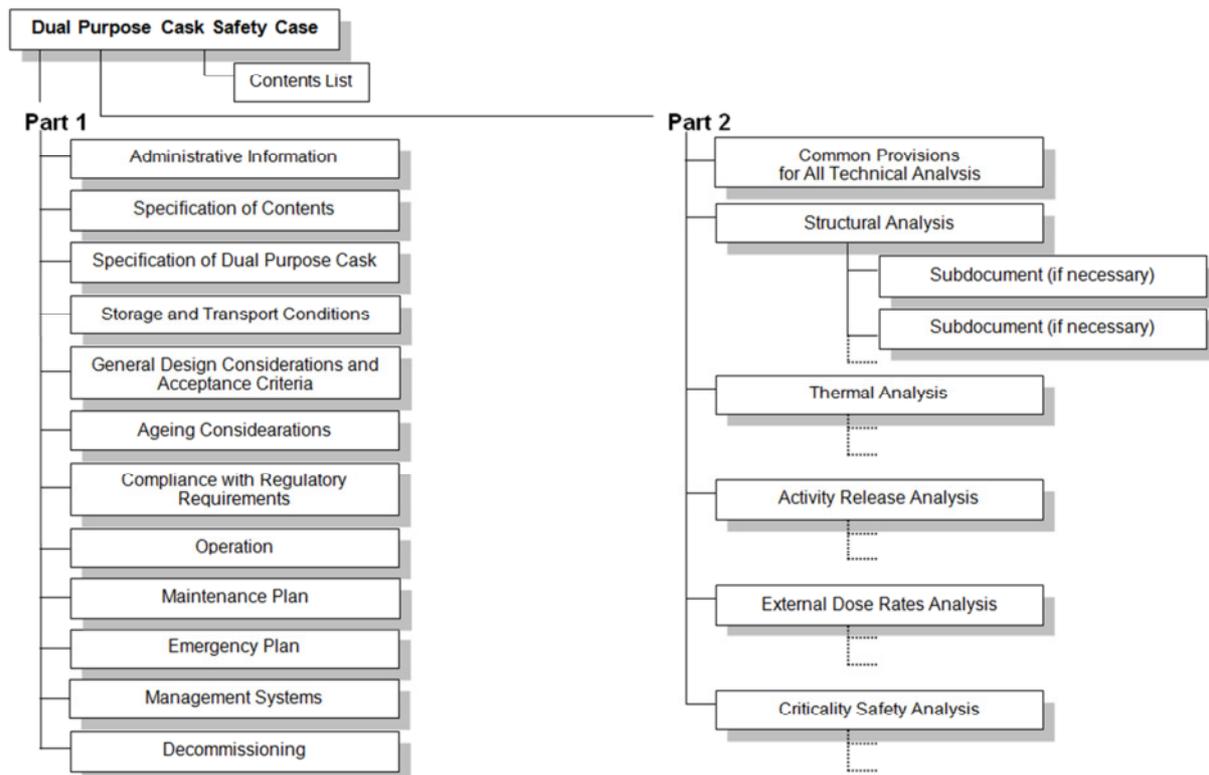


Figure 1. Structure of a PDSR; here for a SNF Dual Purpose Cask [2]

AGEING CONSIDERATIONS

For DPCs the assessment of ageing mechanisms on storage safety has to be assessed quite extensively [3]. Table 1 gives an overview on most important design DPC considerations against ageing deterioration.

The reason from the beginning was, that for longer storage periods (like 40 years in Germany) the time accumulation of effects, like metal corrosion, radiation degradation of polymere components (neutron moderators, elastomere seals, coatings), creep of bolts and metal seals had been assessed carefully under storage conditions. But storage safety related acceptance criteria are different from transport safety acceptance criteria. For a safe transport after storage the influence of ageing mechanisms onto the transport package components has to be limited to a level that ensures the compliance of an “aged” DPC with the relevant transport safety regulations. Therefore the transport package safety case has to be provided with consideration of ageing effects on the design criteria, and package safety has to be justified for the transport of an aged package. The PDSR and the approval certificate owners management system have to consider ageing effects and appropriate measures for ageing management.

Table 1. Examples of design considerations against ageing deterioration of DPC components (from [2], modified)

Components	Material	Degradation factors	Design consideration
neutron shielding	resin, polyethylene	thermal, radiation	Establishment of weight loss rate of neutron shield material in shielding analysis, thermal expansion limitation
basket	aluminum alloy, boron-aluminum alloy, neutron absorbers	thermal, radiation	Establishment of allowable stress, considering ageing deterioration in structural and compositional analysis für criticality control.
metal seal	coating: aluminum, silver spring: nickel alloys, stainless steel	chemical, thermal, creep	Moisture control and establishment of temperature limit of the metal seal.
elastomeric O-ring	EPDM, FKM	chemical, radiation, thermal	Material selection
cask body, lids	steel, ductile cast iron or coating	chemical	Moisture control; Inspection and necessary maintenance
trunnions	polymer sealants	chemical	Material selection; Inspection and necessary maintenance

PERIODIC REVIEW, GAP ANALYSIS

General

Not only DPC components are subject to ageing, this is also the case for regulations, standards, technical and scientific knowledge. Their ageing mechanism is the change. Therefore, it is essential, for keeping a PDSR up-to-date for periodic package design approval renewal, to evaluate in a periodic review the impacts of these changes onto package safety. The method for that is a gap analyses. In [2] gap analysis is defined: “A gap analysis for a DPCSC is an assessment of the state of technical knowledge, standards, and regulations regarding safety functions of structures, systems and components. Gap analysis consists of

- i) listing of characteristic factors, such as the state of technical knowledge, regulations, and standards of the safety case,
- ii) evaluation of the effect of changes of technical knowledge, and standards on the safety of the DPC package, and then
- iii) high-lighting the gaps that exist and need to be filled.”

Periodic safety reviews and gaps analyses are to be performed to keep DPCSC updated. Those periodical reviews are an important part of knowledge management, and force DPC designers, storage operators and regulators to keep knowledge on DPC safety present to all relevant institutions during the several decades lasting operation periods. Periodic reviews are the only

method which allows the tracking of safety knowledge, independently from institutional and personal changes too.

PDSR Review during Interim Storage Period

Nitsche et al [4] and Wille et al [5] describe the German regulatory concept of transport package design approval for DPCs during interim storage period in detail. If manufacturing including the loading of the casks are completed, and no transports are planned BfS issues package design certificate with a validity period of 10 years.

A step wise procedure of evaluation of documents of the PDSR over the validity period is defined. This procedure includes the evaluation of consequences at enactment of new regulations over the entire validity period of the certificate. Beyond that after 5 years the certificate holder has to provide an evaluation that all safety related technical standards and codes, and safety demonstrations of the PDSR are valid.

After 10 years an extension of the package design certificate is necessary. The complete evaluation regarding state-of-the art technology of all parts of the PDSR has to be done. The consequence could be that e. g. new analysis methods for safety demonstration have to be applied. The advantage of this substantial work is the reflection of the knowledge about the package design and the concept of safety demonstration. We understand this procedure as the aging management concerning knowledge of the PDSR and the safety concept behind.

CONSEQUENCES FROM THE REVIEW PROCESS

Documents regarding Package Description and Manufacturing

The main reason for a revision of documents is the feedback and experience out of manufacturing and operation of the packaging and the package. As long as the manufacturing of the packaging is running, improvements of specifications, drawings, and parts list occur. The revision process is necessary to reflect document status and practical experience. Sometimes tolerances and dimensions of components have to be adapted, just to improve the assembling of the packaging.

Revisions of material or component specifications could be appear due to change of the manufacturer or adaptation of state-of-the-art technology.

Over 10 years ago BfS and BAM developed a procedure to allow a simple revision of approval certificates and bring older and improved parts list together in one certificate. A design type list was established. Boerst explained in [6] details of this modification process of the approval certificate.

Example: The impact limiters for DPCs play a secondary role. Over the entire storage time DPCs stand upright without any impact limiter inside the storage facility. Often these impact limiters are not manufactured. But for a future transport, e.g. after interim storage period, impact limiters for packages are needed. Then they have to be manufactured according current state-of-the-art technology. Probably specifications and parts list have to be adapted. Important is that these “up-to-date” components have to fit to previously manufactured packages. For such cases the concept of design type list offers a simple revision of approval certificate in future.

Documents regarding Package Operation

If we have a look to the operational documents, we noticed here most of the document revision need.

The most important document here is the operation and maintenance manual of the package. The user can find all relevant information on safe handling and periodic maintenance of the package. Due to operation of the package feedback is generated. The experience lead in most cases to a need of adaptation and improvement of these documents. At least references to new codes and standards have to be revised.

Examples:

- Experience feedback and changing requirements. Operating procedure for inspection of the package before dispatch from on-site storage facility to another nuclear facility via public routes
- Standards are changing periodically. Test procedure for surface crack test of trunnions during re-inspections might be revised.
- Standards are changing periodically. Test procedure for loading test of trunnions and of lids might be updated.
- Standards are changing periodically. Test procedure for contamination control in transport configuration might be modified.
- Experience feedback. Test procedure for leak tightness test might be revised.
- How transports are performed is changing over the time. Operating procedure for stowage of the flask on the transport vehicle might be revised.
- Equipment is changed. What kind of canopy is used for a future transport? Provide appropriate analysis to show compliance to PDSR.

Safety Analysis of Package Design

Over recent decades the transport regulations are stable regarding requirements for such kind of DPCs. Up to now test conditions for Type B(U) packages didn't change in principle. The experience shows former compliance to the regulations is still valid. However the methods, especially computational approaches, to demonstrate safety have changed over the years. For example the Finite Element Analysis (FEA) was developed and has found a way in technical design work (Fig. 2).

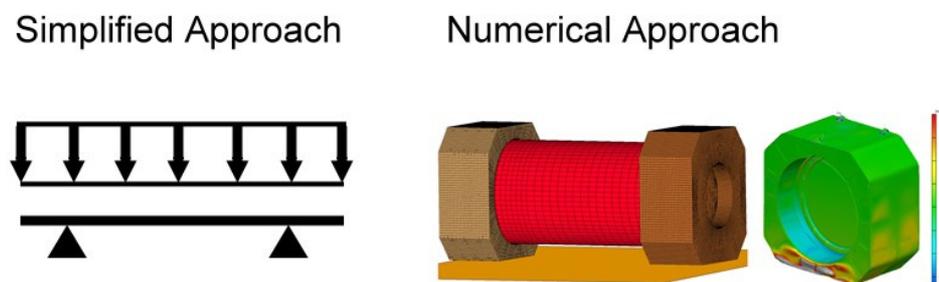


Figure 2. Former and current analysis approaches

In dependence of existing package design safety margins former safety cases might to be revised and adapted to new approaches.

In accordance to IAEA regulations national standards and codes have to be applied for package design evaluation. Normally these standards will be revised periodically. The state-of-the-art technology can be found there. In case of PDSR review process (e.g. approval certificate extension) the standards applicable have to be checked for up-to-dateness.

As an example, BAM developed a guideline for design requirements of load attachment points and closure systems of transport packages [7]. Former PDSR approaches regarding demonstration of design safety have to be transformed to these requirements [8]. The evidence that safety margins are still included when applying the new approach has to be shown by the applicant.

In particular we considered the behavior of lid and trunnion pre-tensioned bolts more in detail as in the past. The safety analysis has to be performed with lower and upper friction coefficients, just to obtain lowest and highest stresses in the bolt structure under high pre-tensioning. The evaluation has to show pre-stressing of the bolts under the loads of transport conditions is sufficiently met, the containment works well and fulfills the requirements of activity release restrictions.

For existing packages the applicant started investigation programs to get appropriate friction coefficients if values out of literature couldn't be derived. The results of the experimental investigations were implemented in the safety analysis. The assessment was done during the procedure of extension of approval certificate of these existing package designs.

But what happens if new approaches and new investigations show the existing safety margins of the analysis are not sufficiently high enough? The consequences are enormous. Loaded packages could not be transported without compensating measures. In most storage facilities unpacking is not a solution, due to missing hot cells or wet storage pools.

Consequently the safety of the transport package design has to be enhanced. One opportunity is to strengthen the impact limiters in order to reduce loads onto the containment system under mechanical impacts and fire scenarios of regulatory testing. The improved impact limiter design could be tested additionally just as component of the improved package design. The acceleration and deformation results will be implemented in the PDSR structural analysis. The safety of existing loaded packages is enhanced without a change of the containment system and the loaded cask itself, but with a way of increasing package safety for future transports with manageable efforts.

In general the extension of an approval certificate is possible if new standards and guidelines are fulfilled, covered, or compensatory measures to reach an appropriate level of safety are defined.

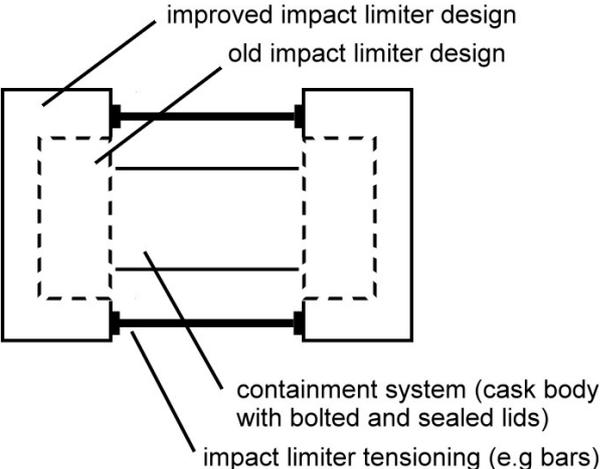


Figure 3. Impact limiter improvement

SUMMARY

Dual purpose casks are designed to fulfill transport and storage requirements. During the storage period the knowledge of the transport design has to be kept in mind. In Germany a concept is established, that during storage period the package design approval certificate has to be valid over the storage period. The concept allows a transport at any time during the storage period as well as after the defined storage period.

The transport package design safety case has to be maintained in an up-to-date state, considering potential regulatory changes and development of scientific and technical knowledge. The review of a transport package design safety case has to be done periodically, implemented in periodic re-assessment for extension of the package design approval certificate. The review process should be part of the approved applicant's management system.

The stability of regulatory requirements for Type B(U) packages was not a major problem up to now, but consideration of ageing and developments regarding the state-of-the-art technology can cause necessary adjustments of specific technical evaluation.

The main reason for a revision of documents is the feedback and experience from manufacturing and operation of the packaging and the package. As long as the manufacturing of the packaging is ongoing, improvements of specifications, drawings, and parts list occur. The revision process is necessary to reflect document status and practical experience.

A very important document is the operation and maintenance manual of the package. The user can find all relevant information on safe handling and periodic maintenance of the package. The experience feedback leads in most cases to a need of adaptation and improvement of these documents. At least references to new codes and standards have to be revised.

Methods, especially computational approaches, to demonstrate safety have changed over the years. For example the Finite Element Analysis (FEA) was developed and has found a way in technical design work. In dependence of safety margins former safety cases might to be revised and adapted to new approaches.

In accordance to IAEA regulations national standards and codes have to be applied for package design evaluation. Normally these standards will be revised periodically. The state-of-the-art technology can be found there. In case of PDSR review process (e.g. approval certificate extension) the standards applicable has to be check for up-to-dateness.

The extension of an approval certificate is possible if new standards and guidelines are fulfilled, covered, or compensatory measures are defined.

CONCLUSIONS

If spent nuclear fuel is stored over periods of several decades, and has to be transported after that storage, don't forget the first law of loss prevention:

“Those who ignore the past are condemned to repeat it”.

Translated to our case this means that we, as currently acting persons and institutions, have to ensure with high reliability and high margins of safety the appropriate safety of SNF/HLW dual purpose cask operations to be performed in future, perhaps by a future generation, and future institutions. Considering those possible institutional and personal changes in future, the periodic review and update of the safety case and the package design approval is an important element of knowledge management.

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